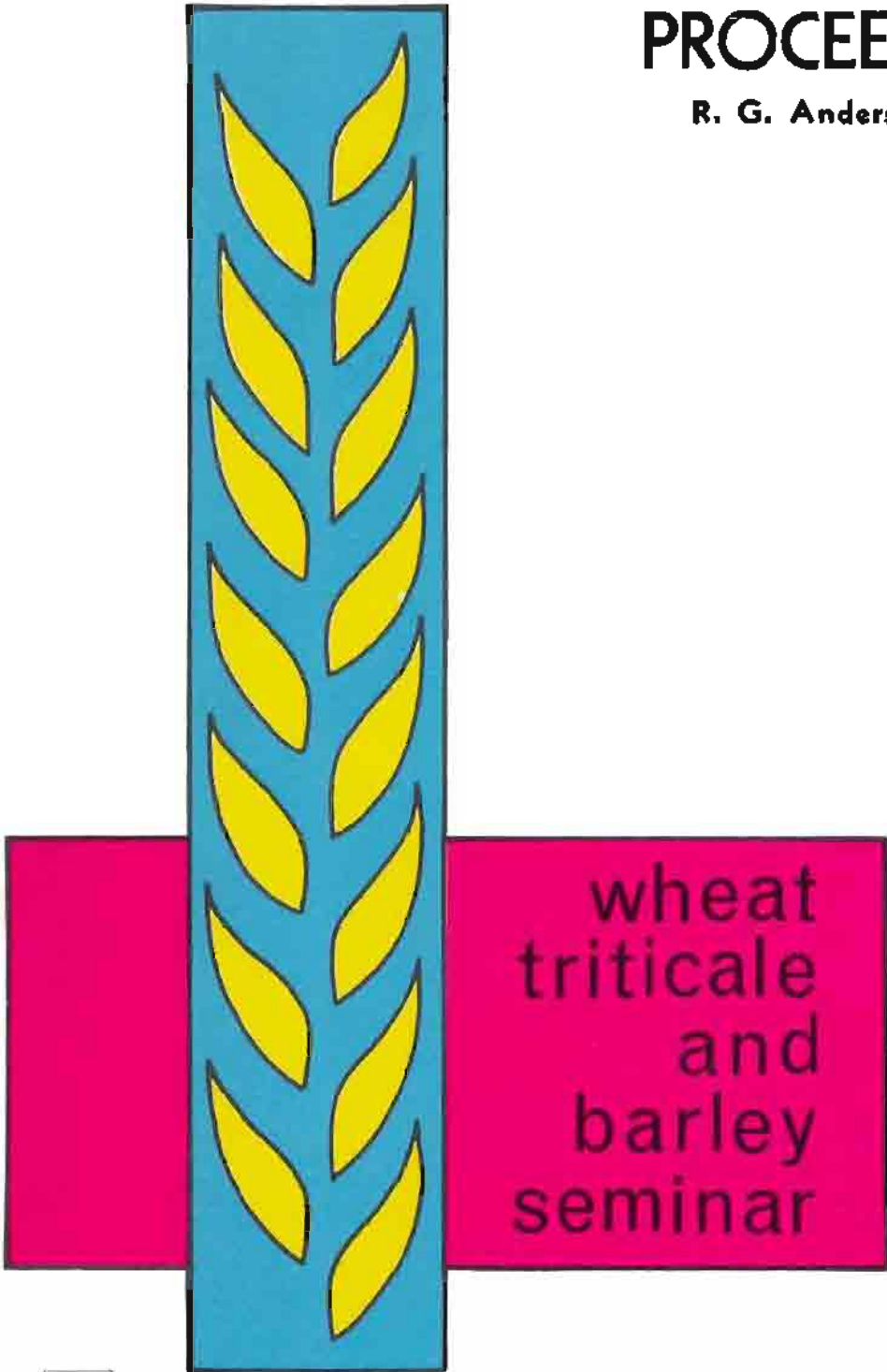
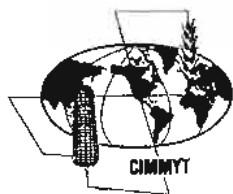


PROCEEDINGS

R. G. Anderson, Editor



wheat
triticale
and
barley
seminar



International Maize and Wheat Improvement Center

january 22 – 26, 1973

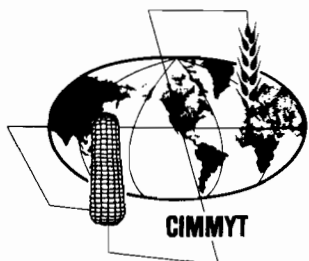
El Batán, Mexico

C O N T E N T S

	Page
Welcome of the Director General. <i>Haldore Hanson</i>	1
Official Opening of the Conference. <i>Oscar Brauer</i>	3
The Background of International Collaboration in Cereal Research and Production Programs. <i>J. George Harrar</i>	4
Changing World Needs for Grains in the 1970's. <i>Donald Paarlberg</i>	6
The Role of Genetic, Agronomic and Plant Protection Research in Increasing Yield, Nutritional Value and Production in Cereals. <i>M. S. Swaminathan</i>	24
The Alternatives before us in Agricultural Development: An Economist's View. <i>Theodore W. Schultz</i>	64
CIMMYT's Past Role, Present Position and Future Challenges. <i>Norman E. Borlaug</i>	89
Genetic Improvement of Spring and Winter Bread Wheats and Durum Wheats. <i>R. Glenn Anderson</i>	99
Breeding for Yield Potential, Stability, and Adaptation. <i>Arthur Klatt</i>	104
Quality: Industrial and Nutritional. <i>Arnoldo Amaya</i>	114
Potential and Prospects of Dwarf Durums. <i>George Varughese</i>	122
Durum Wheat Yield Per unit area, Stability, Climatic Adaptation and Fit to Cropping Rotations. <i>Marco A. Quiñones</i>	125
The Disease Problems of Durum Wheats. <i>J. M. Prescott</i>	128
Durum Wheat Quality. <i>Arnoldo Amaya</i>	134
Barley, an Introduction. <i>W. L. McCuiston</i>	143
Present Status of the Barley Crop in Morocco. <i>Aristeo Acosta</i>	147
Barley Protection. <i>Enrique Rodríguez</i>	152
Quality in Barley. <i>Evangelina Villegas</i>	155
Agronomic Research. <i>Richard Bradfield, Chairman</i>	159
Moisture Utilization and Conservation in a Fallow-Wheat Rotation. <i>W. L. Nelson</i>	162
Cultural Practices to Maximize Yields under Rainfed and Irrigated Conditions. <i>Bill C. Wright</i>	175
Wheat in Rotation with Legumes. <i>John Doolette</i>	179
Tillage and other Agronomic Practices in the Wheat-Fallow Cropping System. <i>Floyd E. Bolton</i>	184
The Role of Insecticides, Rodenticides and Pesticides in Maximizing Yields and Protecting the Crop in the Field and the Grain in Storage. <i>Gonzalo Granados</i>	203
Opening Remarks about Triticale. <i>L. H. Shebeski, Chairman</i>	212
Highlights of the CIMMYT Triticale Program (1965-72). <i>F. J. Zillinsky</i>	213
A Look at Yield Trends in Triticale. <i>E. N. Larter</i>	215
Diseases of Triticale. <i>Santiago Fuentes Fuentes</i>	221
Quality in Triticales. <i>Evangelina Villegas</i>	227
Improved Seed- an Essential Input for Increasing Production. <i>Ahmet Demircakmak</i>	235
Developing Programs and Training Personnel for Seed Multiplication and Distribution. <i>Johnson E. Douglas</i>	240
Technological Aspects of Cereal Production Change. <i>Ignacio Narvaez M.</i>	267
The Role of Cereals in Multiple Cropping. <i>D. M. Leeuwrik</i>	271
Economic Aspects of Cereal Production Change. <i>Don Winkelmann</i>	277
Managing The Production Program. <i>Robert D. Havener</i>	280
Distribution of Genetic Materials: Segregating Populations and Uniform International Yield and Screening Nurseries and the Reporting of Data. <i>Armando Campos</i>	288
Regional Evaluation of Germplasm. <i>Gerbrand Kingma</i>	291
Regional Disease and Insect Surveillance. <i>E. E. Saari</i>	298
Regional Seminars. <i>Abdul Hafiz</i>	301
Collection of Germplasm. <i>K. W. Finlay</i>	305
Physiologic Research as a Tool in Improving Yield Potential. <i>R. A. Fischer</i>	314
Practical Training for Junior Scientists and the Identification of Scientists for Graduate Training. <i>John. H. Lindt, Jr.</i>	324
Opportunities for Senior Scientists of National Programs to Participate in the CIMMYT Core Research Program, Brief Orientation Visits of Educators and Research and Government Administrators to CIMMYT and Opportunities for Postdoctoral Training Fellowships. <i>Ernest W. Sprague</i>	329
Visual Aids for Training. <i>Claire Tailier</i>	334
Report of Drafting Committee. <i>Haldore Hanson</i>	335
Summation of some of the Issues Raised in the Symposium and CIMMYT's Present View of its Capabilities. <i>R. G. Anderson</i>	353
List of Participants	375

wheat triticale and barley seminar

Editor: R. G. Anderson, Associate Director,
International Wheat Program



**Centro Internacional de Mejoramiento de Maíz y Trigo
International Maize and Wheat Improvement Center**

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WELCOME OF THE DIRECTOR GENERAL

Haldore Hanson

I am very pleased to welcome you to this Symposium at El Batan; the Mexicans have given us a beautiful winter blue sky and the surrounding blue hills. These we enjoy every day for nearly 5 months in the winter. The radio this morning reported that the low temperature last night was 40 degrees and the high this afternoon will be 70. This is fairly typical of what we enjoy here at CIMMYT.

I will say for the benefit of one of our speakers in the back row, Dr. Wellhausen, that after a year and a half in this building at CIMMYT headquarters our staff are still extremely pleased with the functional nature of these buildings and we think we have as excellent a set working conditions here as any of the international centers. For those who are here for the first time, we hope that you will take advantage of this week to tour our laboratories and other buildings. If you need any help, our staff members are ready to escort you.

This conference was planned to serve two separate functions. One was to bring together a group of wheat and other cereal researches and most of the program from now until Thursday noon has been designed to serve this purpose. A second purpose is to review what is CIMMYT's present role and what will it be through the 1970s. To discuss the second purpose we are holding a small committee meeting on Thursday afternoon. Members of the committee are being asked to develop at least an outline and perhaps a partial draft of the report on this second topic on what should be the role of CIMMYT in the 1970s. We don't expect to complete a document this week. We expect the CIMMYT staff to have the responsibility of reviewing what you people feel in this conference are the remaining problems of the 1970s, and on that basis the staff will have the responsibility to issue a report which all of you will receive later.

Before we proceed with our business, I wish to call on a representative of the President of Mexico to officially open this conference. Oscar Brauer is an old friend of many CIMMYT staff members, and is one of that generation of young Mexicans --maybe 200 or 300 of them-- who went abroad to get their advanced training in agriculture after World War II and who, after coming back, have advanced in the service of the Government of Mexico. Dr. Brauer took his doctorate in Germany in Agriculture. He has served as the National Director of Research of Mexico and comes to us this morning as the Under Secretary of Agriculture, or as many of your countries would say, the Vice-Minister of Agriculture, Dr. Brauer.

OFFICIAL OPENING OF THE CONFERENCE

Oscar Brauer

It is a pleasure for me to give all of you a most cordial welcome to Mexico on behalf of the Secretary of Agriculture, Manuel Bernardo Aguirre, and the Government of Mexico.

Sometimes in the world press and other times in technical conferences or on visits to other countries, we have heard mentioned the "Mexican wheats" and it is a true cause for great satisfaction for Mexico that such varieties had been developed in Mexico and were the consequence of cooperative work between Mexican and foreign scientists.

During the last 30 years we have seen the national average yield of wheat increased from about 700 kg/ha to more than 3,000 kg/ha. Maize yields increased from 700 kg/ha to more than 1,100 kg/ha. Both increases in production have a great significance because they refer to a very extensive area and, therefore, represent a great increase in the total production.

There is another benefit, perhaps more important, that has increased at the same time--highly qualified technical and scientific personnel. More than 200 professionals went abroad to study agricultural science and take advantage of cooperative international programs. These scientists returned to our country with Ph.D. and M. S. degrees to be in charge, in large part, of the national agricultural research and in this way they have influenced improved production techniques and obtained production increases in many other crops.

Also, much of the personnel trained abroad now impart their knowledge in the higher level training centers and, thus, the research topics and the thesis topics solve the technical problems of Mexican agriculture at the same time.

The results of the research in the last 30 years have given great benefits in the irrigated areas and in the regions with good rainfall and good soils. Still, there are many areas without irrigation and with poor soil and poor farmers who are waiting for the present and future benefits of the research.

Knowing that you have come here to discuss the future and not the past, Mexican officials and researchers are awaiting the results of your efforts in order to take advantage of the benefits that you may be able to provide.

Again, welcome to Mexico and thanks for coming and for your contribution to this symposium.

THE BACKGROUND OF INTERNATIONAL COLLABORATION IN CEREAL RESEARCH AND PRODUCTION PROGRAMS

J. George Harrar

(Dr. Harrar's paper was given orally. The following outline was developed from notes taken during his delivery.)

Dr. Harrar paid tribute to the three original scientists --Drs. Stakman, Bradfield and Mangelsdorf-- who were commissioned by the Rockefeller Foundation to investigate the feasibility of assisting the Mexican Government in its agricultural research program. They were assisted greatly in their work by the then Minister and Sub Secretary of Agriculture, Ing. Marte R. Gomez and Ing. Alfonso Gonzalez Gallardo, respectively.

As a result of these investigations, the Government of Mexico and the Rockefeller Foundation undertook a joint program of agricultural research in the Republic. Drs. Stakman, Vallejo, Wellhausen and Harrar were appointed as expatriate scientists to assist from the Rockefeller Foundation. Dr. Borlaug and other scientists came in succession to become involved in various aspects of the program. Dr. Leonel Robles and Ignacio Ortega were among the early Mexican scientists.

In the beginning, the decision was taken to work on maize and wheat. The philosophy adopted by the group from the very beginning, was that they would take all the assistance they could obtain from whatever source, and the resulting materials would be made available to anyone asking for them. Dr. Harrar was happy to say that this philosophy continued to be held throughout the days of the Oficina de Estudios Especiales and is held by its successor, the present CIMMYT.

Through help received from colleagues in the United States Department of Agriculture and elsewhere, the germ plasm available was rapidly expanded. The wheat variety Supremo was subsequently released and marked the beginning of a long succession of varieties in wheat and hybrids in maize. The whole idea of boundaries on science was scrubbed and the concept of responding to the needs of people was made the watchword.

It was soon found that if the Mexican farmer was to be persuaded that he could better himself, the scientist not only needed to develop varieties but had to become involved in all aspects of improvement. Pests, soil problems and many other aspects had to be solved through interdependent research if output was to rise. In other words, the idea of team effort to achieve a better pattern of production became

well established early in the program.

In those early days it was found that Mexico had a great shortage of trained scientists. Again this became a major thrust of the new program, and through the years a very able team of dedicated Mexican scientists was trained and assembled. This sharing of knowledge and development of national competence in agricultural research through the medium of training spread to other countries of Latin America and then to the worldwide concept. This activity has populated many of the countries with people of prestige who are dedicated to extending ideas and efforts leading to agricultural improvement.

In the past few years the dramatic developments of the Green Revolution have shown on a small scale what can be accomplished by this approach. This worldwide interest slowly removes the national boundaries to research. It can only be achieved by highly motivated scientists within the national programs. Agricultural research is meaningless until it is translated into action programs. It is through the development of international confidence that improvements can be made.

The whole concept of the crop-oriented interdisciplinary team approach gradually grew and now pervades much of the world's research. This in turn led to the idea of the International Institute as a method of extending the benefits of the team approach to all countries desirous of cooperating. This movement built up momentum and financial assistance was forthcoming to build up critical masses of scientists addressing themselves to problems of specific crops. These Institutes are viewed as instruments of change for the future.

There must continue to be extensive training programs to reinforce the national programs. Sometimes countries must take calculated risks to instigate change. Problems must be monitored and production protected. There are now six centres devoted to this thrust into the future. In the Rockefeller Foundation we refer to these centers and similar programs as the "Conquest of Hunger". The world has the opportunities, and must continue to find new ways, to solve this age-old problem.

CHANGING WORLD NEEDS FOR GRAINS IN THE 1970's

Donald Paarlberg

Last year, the Soviet Union experienced a severe shortfall in its wheat crop and subsequently made unusually large grain purchases on the world wheat market, especially from the United States. In India, late and insufficient monsoon rains caused a sharp decline in grain production. In much of Southeast Asia the rice harvest was reduced by adverse weather. Drought also cut Australian wheat output.

This situation, with accompanying high prices and distorted trade patterns, has resulted, I think, from unusually poor weather. We don't know enough about the weather to engage in long-run predictions with any accuracy. It appears that weather is not a random variable. Good years show some tendency to cluster, and so do bad years. When the weather is better than average in one area it appears likely to be better than average in other areas; the same thing appears to be true when weather is bad. The recent past is not likely to be the new normal. Much work needs to be done in studying weather as related to crop yields.

I say all this in order to counter a new and growing belief that there has been a fundamental deterioration in the world food situation. Disappointing crops and high food prices are headline grabbers. For example, in the December 11 Washington Post we read "Specter of Famine Looms Over India". The same issue proclaimed "Indonesia Facing Crisis Because of Rice Shortage". There are plenty of such headlines but relatively few that call attention to the very real strides made in recent years in establishing a solid base for long-run increases in productivity in agriculture in many countries.

Some critics seem to believe that these recent events prove the Green Revolution has failed. Moreover, many are indicting technology itself, the very basis of the Green Revolution. Some ecologists, sociologists and economists say that the most important effect of improved technology is to make us worse off by accelerating imbalances in our economic structure, our social patterns, and our relationships with nature. Fortunately, people of this kind were not calling the shots during the Industrial Revolution or, more recently, the Agricultural Revolution in North America. If they had been, the world food situation would be more precarious than it is now.

World agricultural production declined slightly in 1972. Although world grain output was down from 1971, the 1972 crop was still the second largest on record. And we can expect efforts to

expand grain production in 1973 as farmers and governments respond to high prices. Of course, weather and other crop conditions will be major factors in determining the success of these efforts.

Great variations in food availabilities bring about problems and real hardships, but the record indicates that there is a lot of stability in the long-run trends in food and grain production. For the world as a whole, and even for the poor countries as a group the production of food per capita has shown a rising trend, according to USDA indices dating back to 1954, which is when our series began.

Over the period 1954-1972, there was an upward trend in the per capita production of food throughout most of the world. Africa is the exception. Food production per capita in developed regions increased about 1-1/2 percent annually, while the less developed regions experienced a much slower rate: less than 1/2 of 1 percent. But the difference was less a function of food production than of the very rapid pace of population growth in the less developed world.

Our food production indices indicate an overall, long-run improvement in the world food situation. Admittedly, for the less developed countries, this improvement is from a very low level.

But these indices do not tell us all we would like to know about nutrition levels around the world. For individual countries, only the annual changes in the output of edible products are measured. The indices cannot tell us whether the products were consumed in the producing country or exported or fed to livestock or eaten by rats and mice.

Even if we had current statistics on the available supplies of food, those statistics would not tell us how many hungry people there are. For many reasons, including poverty, inadequate distribution facilities, persistence of traditional habits, tastes and taboos, some people have inadequate diets, even in a rich country with abundant food. Our indices are averages and do not pinpoint many special problems. As has been pointed out, one would not be comfortable with a hand on a hot stove and a foot in the icebox. Yet, statistically speaking, the temperature might be fine, on the average. Despite their limitations, I think these indices do point to the general direction in which we are headed, a course of improvement in diets around the world.

Most of the world's population relies upon high carbohydrate foods - cereals, sugar, roots, tubers and plantains - for a major share of its diet. Cereals are the most important food staple group, directly accounting for almost two-thirds of the average per capita calorie intake in the Far East and nearly half of the calorie value of the diet in the Soviet Union and Eastern Europe. Rice and

wheat are consumed in the largest quantities, but corn is the principal cereal in much of Africa and Latin America.

Cereals are also the major protein source. Even in areas where animal products are relatively plentiful, cereals still furnish a large part of the total protein supply. In less developed areas, dependence on cereals for protein is especially important.

Cereals, however, are more than foodstuffs. Less than half of the cereals produced (outside Communist Asia) are used for directly consumed food. According to FAO food balances for 1964-66, 48 percent of the cereals was used for food, 38 percent for animal feed, and 14 percent for seed, starch, liquor and other uses.

We can expect the direct food use of cereals to rise as population grows. But the relative importance of the direct food use of cereals will decline. We have comparable statistics for the OECD countries for the 1954-56 and 1964-66 average periods. The total quantity of cereals used for food went up slightly but per capita use fell 10 percent. However, non-food use of cereals per capita went up 24 percent in the decade.

When we look at the total production of grain over the last two decades, we see a great difference in the performance of the developed and the less developed regions. Developed countries increased their total production of grains more than 60 percent with hardly any increase in the total area planted to grains; thus all the increases came from higher yields. On the other hand, the less developed countries, while increasing their production by about three-fourths, expanded their total area in grains by about one-third. Over this period the average yield per hectare of grains in the developed countries increased twice as fast as the average yields in the less developed countries. Current overall average grain yields in the less developed regions are only about 60 percent of those in the developed countries.

Wheat and rice yields have increased dramatically in particular less developed areas and even in particular countries, largely as a result of the pioneering work done at this institution. Average yields are increasing in the less developed countries as a group. But there is as yet little evidence of revolutionary change on a broad basis. While astonishing progress has been made in developing new grain technology, the general adaptation of these advances still has a long way to go. The upward trend in average rice yields in the less developed countries has not accelerated in recent years. Since the early 1960's average wheat yields have been increasing faster than before, but not so fast as in the developed countries.

This in no way denies the great importance of the technological changes which have been labeled the Green Revolution. The general adoption, or rather adaptation, of these improved practices

remains to be accomplished. And, of course, continued and expanded research work is needed to hold the ground that has been gained and to achieve the additional gains that are needed.

* * * * *

Recently there have been reports of a number of problems associated with the implementation of the new technology. These problems include:

1. The need for better water control systems to permit more efficient irrigation.
2. Salinity and water logging -- old problems that are being aggravated by new irrigation development and unlined canals.
3. Land fragmentation, which increases the difficulty of implementing the technology of the Green Revolution.
4. Insufficient capital to meet the increased requirements for purchased inputs.
5. Inadequate extension education to inform farmers of the best use of machinery and agrichemicals.
6. Inadequate pest control.
7. Inadequate food storage, along with rodent and vermin control.
8. Insufficient farm-to-market transport.
9. Excessive reservoir siltation due to lack of proper watershed protection.

Admittedly there are these problems. Most of them can be alleviated by additional and improved technology. But criticism of the Green Revolution comes also from another source -- from those who challenge technology itself. Undeniably, there are extremely important economic, ecological and social problems associated with technological change and economic growth. They must receive attention, more than they have had. But to stop all change and growth is not the proper solution. I agree with Rene Dubos, who said in a recent address to the American Association for the Advancement of Science: "The human use of natural resources and of technology is compatible with ecological health."

* * * * *

I know that this conference is focused on food production, not

on population growth. Nevertheless, I want to comment on the population problem. Unless the rate of growth in the world's population is checked there is no solution to the world food problem. The agronomists do not have the solution, the plant breeders do not have it, nor do the plant pathologists have it; it does not exist. Long range projections of present rates of population growth simply run off the chart and beyond the range of agricultural solutions that are either possessed or conceivable. For some decades agriculture can meet the needs of a population growing at present rates. But time will run out. By the extraordinary accomplishments of agricultural scientists both here and elsewhere, valuable time has been bought with which to check the rate of population growth. That time should be used to good advantage. There is heartening progress in certain countries.

The rapid expansion in population not only places great stress on the food supply; it also brings social unrest, political disturbance, and environmental degradation. Unchecked population growth may encounter these latter problems before the food supply becomes severely limiting. There may be limitations on population growth that are more critical than the one on which Malthus focused.

* * * * *

With rising incomes, people consume more food and particularly higher quality and more expensive foods, which require greater agricultural resources for their production. Rising demand for animal products generates a demand for grain for feed. In societies which have moved away from a subsistence orientation, prices largely determine what food is produced, how much, and to whom it is distributed. Social welfare programs to feed particularly disadvantaged groups make important contributions to the nutrition of some.

Economists have devoted considerable attention to measuring the relation of income to the demand for food. It is generally agreed that the proportion of income spent on food changes greatly as the level of income changes, but there is uncertainty as to the magnitude and rapidity of the changes. Most studies of the relations between per capita incomes and food consumption have measured food by monetary value. But this is a deceptive measure. Poor people will eat a larger amount of their accustomed diet if they can afford it. But the main way in which the value of food consumed increases is through changes in the number of different food consumed and substitution of higher unit value foods for lower value ones. Even more important in the richer countries is the increase in expenditures on the services related to marketing and processing foods as incomes increase. Clamor in the U.S. now is due to the cost of high living, not the high cost of living.

People with higher incomes generally buy more meat, dairy products, fruits, vegetables and sugar. Since most of these foods

are nutritionally desirable, an improved diet is to some extent selected by consumers as their incomes rise. For large groups of people, when diets in which animal protein is important are compared to diets based mainly on cereals and to diets consisting largely of roots and tubers, the protein content of the former tends to be greater, and the quality of the protein nutritionally better.

While increased consumption of animal protein usually provides a nutritionally improved diet, it is now recognized that combinations of fish and vegetable protein can also provide an adequate balance of amino acids. Fortunately, good nutrition can be obtained by a very wide variety of combinations of foods, with consequent great spread in cost. Pulses can be very helpful in providing a diet nutritionally adequate in protein at much lower cost than animal products. For example, protein from beef usually costs many times as much as protein from soybeans.

Fortification of foods by adding missing elements and special feeding programs for groups such as school children and pregnant women can help to overcome the income constraints to improved nutrition. Within the next decade substantial progress will be made in the breeding of staple crops with more and better protein. This can be an excellent way of improving diets in the poor countries.

* * * * *

Scientific and technological progress in agriculture must be accelerated, especially in the poor countries. Expanding needs for food and the limitations of land make it clear that technological developments to increase per-hectare crop yields are essential. Those affluent people from the advanced countries who recommend a slowdown in the rate of economic growth are acting with propriety when they advocate this for themselves. They are in a less defensible position when they recommend this for others in other countries, who are less fortunate.

Usually, until economic development gets well underway, agricultural methods change only slowly. To a large extent agricultural production increases through expansion onto additional land and by use of traditional methods. Most developing countries have been able to expand their cultivated area by putting crops on land formerly unused or occupied by pasture or forests.

However, good unused land is becoming less readily available throughout the poor countries, and especially in a number of countries in Asia, Central America, the Near East, and Northwest Africa. In much of Africa south of the Sahara and in South America, the man-land ratio is less adverse. But, to make use of much of the large reserves of land not now cultivated would require large expenditures for clearing jungles, establishing soil conservation

programs, building irrigation systems, controlling malaria and tsetse flies, and building new settlements for colonizers. For these and other reasons, the moving of large numbers of people to remote new areas is difficult and usually has not been very successful. The process takes about three generations, even in good areas.

Multiple cropping and inputs such as fertilizer, insecticides, herbicides, and improved seed are, in a real sense, substitutes for land. Although, of course, these inputs must be applied to land, they make the land so much more productive that less land is needed or the shortage of land becomes a much less restricting element on agricultural production. The increasing use of improved seed, chemicals, and machinery not only has been the main factor in increasing agricultural output in the rich countries, but has necessarily led to a greater commercialization of farming, since more and more of the inputs come from outside agriculture and require money outlays.

Substitution of machinery and especially large-scale machinery, for labor is one of the most significant characteristics of agriculture at the stage of development reached in Western Europe and the United States. However, in many of the poor countries, because of the rapid increase of population in rural areas, the farm labor force will grow at a very fast rate for a good many years. Thus, the problem will tend to be more in the direction of finding productive work on the farm or in farm-related activities rather than in supplanting farmers with machinery. For both wheat and rice, the Green Revolution seems to call for more labor per acre.

There will need to be further developments and changes in technology, the marketing situation, availability of credit, and other aspects of agriculture. Research should continue to develop still better varieties of grain and other crops.

* * * * *

The title of my talk refers to the 1970's. I am well aware of the hazards of trying to look ahead. A year ago we could not foresee today's world food situation. I have already said that the weather cannot be predicted with accuracy so far into the future. There are other important forces that cannot be predicted. One such is government policy with respect to agricultural production and trade. Another is the rate of development and spread of new technology, such as are involved in the new varieties of grain. Another is the rate of increase in the population and of income, which are the main factors on the demand side. The income effects on the demand for food grains and for livestock products (and thus for feed grains) may be greater than we had thought.

The central question is: Is the recent shortfall in world grain production simply a fluctuation around the long-run trend; or does it indicate a major change in the trend itself? Let's look at

what the experts have said about the trends and about the future for world grains. The main producers of long-run projections of world production, utilization and trading of agricultural commodities are the FAO and the Economic Research Service of the USDA. A projection is only a disciplined estimate based on known assumptions.

In 1971, FAO published a major two-volume set of agricultural commodity projections for the period 1970-1980. This study was a continuation of previous FAO studies of the outlook for agricultural commodities. The data used generally extended through 1969 or 1970. The study concludes that by 1980 the average "shortage" of food will be somewhat less than at present, but that "the absolute number of people short of food may be much the same as today". The study also concludes that the outlook for protein nutrition is better than was believed on the basis of earlier studies. In fact, "diets would become more diversified in both high income and developing countries with a continuing shift to animal products, fruit and vegetables from cereals and roots." The study also concludes that substantial world "surpluses" are likely for wheat, rice and coarse grains, as well as for other products.

I would like to add a parenthetical comment here. I think the terms "surplus" and "shortage" can be misleading when we are talking about long-run projections. In a sense, there never are "surpluses" or "shortages" of food; everything gets used up and no one is able to subsist on unproduced food. When food is abundant there is an improvement in diets. When crops are poor diets deteriorate. If crops are bad enough, people starve. Population does not outrun food supply.

In 1971 the U.S. Department of Agriculture also published projections of the agricultural commodities to 1980. These projections are being revised. I have some preliminary results. The Department also concludes that per capita nutritional levels of the LDCs are likely to improve. Their projections suggest that under normal weather conditions the world's capacity for production of cereals will increase faster than consumption and that thus there will likely be a rebuilding of wheat stocks, downward pressure on prices, and possibly programs to restrict production in the major grain exporting nations. These projections do not take into account unusual years such as the poor year 1972, or some of the exceptionally good years we have had in the past.

Looking at the separate cereal markets, the analysts still expect consumption and trade of wheat and rice to grow less rapidly than that of coarse grains. The growing need for feed for livestock and poultry improves the outlook for coarse grains.

The projections suggest that countries in the developed and in the centrally-planned parts of the world will continue to be the major producers and consumers of wheat and coarse grains. Trade will continue to flow from the five or six major developed exporters to

other developed and developing countries. The LDC s will continue to import wheat and coarse grain despite substantial increases in grain production. China will likely import wheat and export rice. The potential trade levels of the USSR and Eastern Europe remain a mystery, but these projections suggest that the USSR and Eastern Europe will be close to self-sufficiency in grains by 1980. Obviously policy decisions and trade relations could change this. Decisions regarding levels of stocks needed, and amount of animal products to be produced or a series of years with bad weather could significantly change the trade picture.

The projections suggest that consumption of wheat will grow about as fast as production in the LDC s. Per capita consumption of both wheat and coarse grains in 1980 in the LDC s will generally increase but the levels are low compared with the rest of the world. A more rapid increase in production in many of the LDC s could easily be consumed at home. On the other hand the major exporters of wheat and coarse grains will likely find domestic consumption and exports growing slower than production.

Rice trade is small relative to total consumption of rice in the major rice producing and consuming regions. The projections indicate that trade will remain small. Major increases in rice consumption in Asia will more likely come from larger domestic production than from larger trade. Appended tables give these projections.

There are many factors which could significantly change this picture of the future world grain situation. In addition to the possible changes mentioned earlier, the following factors need to be watched carefully.

1. The petroleum-producing regions of Latin America and West Asia could decide to produce or import more animal products in order to upgrade their diets. This would increase the need for feed grains.
2. The liberalization of world trade could alter production and trade patterns, especially for the developed nations.
3. Major breakthroughs or even continued steady progress in the work you all are doing could increase crop yields, change production patterns, change production costs, and boost nutritional values of cereals.

In the nineteen-sixties, when there were several bad crop years and the mood of the world food supply turned pessimistic, our analysts in the Department of Agriculture continued to project an increase in the per capita supply of food. They were right. Now, in the 'seventies, the mood has again turned pessimistic and again our analysts project improvement in dietary levels. Let us hope they are right again. Whether they are right or wrong depends in large measure on the scientists and technologists in this audience and in other research centers around the world.

Table 1--World production, consumption and net trade of grain, 1964-66 and 1969-71 with projections for 1980 1/

Commodity and Item	Developed countries 2/			Central plan countries 3/			Developing countries 4/			World		
	1964-66	1969-71	1980	1964-66	1969-71	1980	1964-66	1969-71	1980	1964-66	1969-71	1980
----- Million metric tons -----												
<u>Wheat</u>												
Production	109.1	112.2	130.8	122.8	142.7	176.3	47.2	63.0	91.1	279.1	317.9	398.2
Consumption	78.7	87.8	96.2	136.9	147.1	181.3	66.1	82.7	120.4	281.7	317.6	397.9
Net trade 5/	32.9	29.2	34.3	-14.1	-4.4	-5.0	-17.8	-21.8	-29.3	-1.0	-3.0	0
<u>Coarse grains</u>												
Production	222.2	274.4	349.0	163.1	194.5	244.8	108.0	123.5	160.1	493.3	592.4	753.9
Consumption	235.9	272.7	339.7	163.1	198.0	245.9	103.1	118.2	163.7	502.1	588.9	749.3
Net trade 5/ (Low):	-3.4	-0.9	4.8	0	-3.5	-1.1	4.9	5.9	-3.6	1.5	1.5	0.1
(High):		17.5				-10.0			-7.5			0
<u>Milled rice 6/</u>												
Production	15.0	16.7	15.9	64.4	63.8	78.2	93.0	114.5	155.4	172.4	195.0	249.5
Consumption	14.3	13.7	14.1	64.0	63.5	77.5	94.3	116.4	157.7	172.6	193.6	249.4
Net trade 5/	0.4	1.8	1.8	0.4	0.3	0.7	-1.1	-1.9	-2.3	-0.3	0.2	0.1
<u>Total grains</u>												
Production	346.3	403.3	495.7	350.3	401.0	499.3	248.2	301.0	406.6	944.8	1,105.3	1,401.6
Consumption	328.9	374.2	450.0	364.0	408.6	504.7	263.5	317.3	441.8	956.4	1,100.1	1,396.6
Net trade 5/ 1/	29.9	30.1	40.9	-13.7	-7.6	-5.4	-14.0	-17.8	-35.2	0.2	-1.3	0.1

1/ Preliminary projections, minus indicates net imports.

2/ Includes United States, Canada, Western Europe, Japan, Australia, New Zealand and South Africa.

3/ Includes Eastern Europe, USSR and the Peoples Republic of China.

4/ Includes rest of world.

5/ Some regions do not balance because of stocks.

6/ 1967-71 column is an average centered on 1969.

1/ Low net trade alternative.

DISCUSSION

Anderson

Dr. Paarlberg, would you care to comment on the growing need for protein in the context of growing populations. Do you not feel that animal proteins will become increasingly scarce?

Paarlberg

People are becoming affluent and as we observe when they do this, they want more animal protein. There are not enough agricultural resources in the world to feed people with animal protein to the extent that we in the U.S.A. rely on this source of food. There just aren't enough resources to do that. It seems to me that as populations grow and as incomes increase and, therefore, the desire for more protein increases and the capability to achieve better nutrition increases, that this is going to have to occur by enriching the protein content of our cereals. This is going to have to be accomplished by technology that will transform some of our pulses into food analogs that resemble animal products and that cost less than half as much. I do believe that for sometime, and in many parts of the world, it will be possible to provide increases in meat, milk and eggs, but over the long run and for much of the world, it seems to me that improving diets is going to have to be achieved by relying more on plant proteins, either improved plant proteins or plant proteins transformed by technology. We can provide improved diets with the somewhat limited agricultural resources that we have.

Da Silva

I am pleased to hear from Dr. Paarlberg that emphasis should be given to rural population development. There is a real need to improve the standard of living. I have been impressed with your discussions on food production and food supply. The emphasis, however, has been on the consumer. This is natural, but we agricultural scientists do not think it is correct to largely ignore the producers. As I see it, the rural population today is in a very difficult position in relation to the urban population. All the measures you speak of and the concerns are for the consumers and there is not enough attention to improving the living standard of the rural population. For instance, rural populations have less economic opportunities and the poverty is greater than in cities. Most poor people come from rural areas. Work is more difficult to obtain in the country. The general approach seems to be that even in wheat production, you emphasize that we want to produce cheap wheat for the population but there is little thought for the fact that this could mean a lower opportunity for income for the rural population. Investments in opportunity are generally large in the city sector as compared with rural areas. Health is also worse in the country. Thus, if work and justice are meaningful,

we as agricultural scientists should attempt to change this situation and press for some kind of parity on price of product, opportunities for work, investment and assistance. This would improve the distribution of income in the world.

Fischer

In the figures you (Paarlberg) gave us, I believe some 40% of world cereal production is used as feed grains. Do you make a distinction or do you think it worthwhile to make a distinction between feed grains fed to ruminants and feed grains which go to monogastric animals, especially as this influences the value which can be placed on the protein quality of feed grains.

Paarlberg

The feed grains that go to feed chickens and swine --monogastric animals-- by and large are used more efficiently in conversion into human food than the feed that goes to ruminants such as cattle. I am aware that this is taken account of in the respective prices for these animals. You can buy poultry and pork at a much lower cost per pound than you can buy beef. In an open, competitive society, those people who have the means and wish can purchase the more expensive foods and those who have less means or less desire can purchase the less expensive animal products and those who have still less income or still less taste for these costly foods will consume very little of either. Now I suppose it would be possible for some great social engineer to feed the human population on a very efficient basis just like we would feed the animals on a feeding on a feeding line and I am sure that this would result in an improvement in human nutrition on the average. I am sure it could be done at a lesser cost, but the human being resists being treated in that fashion and he has his preferences and his taboos. The distribution of food is only in part on the basis of nutritional considerations and only in part on the basis of economy. It is in large measure on the basis of human preference and on the basis of tradition and on the basis of the palate. The truth is that while the stomach is most concerned, I guess, with nutrition, it is the tongue that does most of the talking and is most persuasive in the conferences where these things are decided.

Borlaug

I would like your opinion on what the prospects for food grains are likely to be at the end of this winter on a global basis.

Paarlberg

We are pulling down our food grain reserves in the U.S.A. to meet this enormous world market that Dr. Borlaug knows was brought about when this very extraordinary demand for food grains appeared in the markets as the result of the disappointing Russian crop. The U.S.A. was really the only country in the world that had substantial

quantities of food grain and we have largely obligated these for the current year. If we ship what we have committed during the present marketing year, we should have pulled down our reserves from well in excess of a billion bushels where it was, to less than 500 million bushels. Now we can pull it down a little lower than that, but not much lower. We are, in the U.S.A., increasing our wheat acreage next year. We have removed our acreage limitations. We have eliminated the set-aside program which was intended to curtail production of wheat and we anticipate that with the good crop prospects now for our winter wheat and with additional wheat likely to be planted in the spring area, that our production next year will be substantially increased. But, Dr. Borlaug, we are now in a situation in which our reserve capacity to supply wheat to needy countries over the next 6 to 8 months is now not easy. We are not at the bottom of the barrel, but we have gone with our reserves down to a point where they are, I won't say critically low, but where we must be cautious about overcommitment. As a consequence, any additional demand made on us would be carefully reviewed.

Schultz

How can agricultural scientists influence government policies favorably toward greater food production and agricultural development?

Harrar

I have thought that in our own country (U.S.A.), the agricultural scientists for many years accomplished a great deal in the narrow sense insofar as making production possible, which leaves us in the comfortable supply position we are in today. But it seems to me the scientists in general rather prided themselves in remaining remote from the problems and difficulties around them. Probably all of us are a little short sighted. Hopefully, we have become better enlightened. When I talked about team effort, I meant this in the broadest sense in all scientific, economic and social activities. We have too long said this is the other man's responsibility. On some occasions, I am afraid we have not even assumed the obligation to communicate across the scientific, economic and political communities. To a degree, we see the beginnings of a move to correct this. We hear various groups speaking on how we must do a better job of expressing ourselves to the nation's leaders. After all, I don't know why it took us so long to learn that we had to communicate with the people who call the shots and decide where the money is to be spent. If you don't speak up and get your fair share, you are in for real disappointments. I feel that the agricultural community with the strength that it has can be a great force for communicating information and understanding. The kinds of things we have heard from Dr. Paarlberg this morning are clear-cut indicators that we cannot stand alone. This institution cannot stand alone unless we communicate with other centers and other people. We speak of exotic germ plasm; I think we need a little exotic information brought into the field as well so we can really examine what happens. We get some information but then it stops and is not followed up. How much have the land-grant colleges associated themselves in developing high-level, high-quality, judicious but influential voice with the government. After all, the government is a collection of people we put there and unless we communicate we will always be in a position of criticism, pessimism and lack of understanding. The vocalists may be better

speakers than the agriculturists but they have the media at hand. We must get into the total situation of the society and not just our own limited field. We must help to get those things done that we feel must be done.

Hafiz

In the Near East Region there is not a shortage of protein, but there is a shortage of calories which we can get from the carbohydrates. In Afghanistan and Sudan, for example, they have as much protein as in the U.S.A., but the proteins are misutilized as they are converted to provide energy and function as carbohydrates. Thus, the shortage of the latter are more important since the economics of plant and animal proteins are much different. Part should be provided by legumes and part by carbohydrates. In Egypt, for example, if you wish to provide each person one gm of protein per day, you will need 70 million pounds per year, but through cereals this would be US \$7 million. Distribution, storage and marketing of animal proteins is very difficult. If we are thinking of marketing, we need to stress production of cereal proteins of better quality rather than try to get animal protein.

Qureshi

I would like to comment on Pakistani wheat production. Pakistan's production began to increase in 1965 and this continued to 1970 and levelled off. Our country is poor and has only limited resources so it is virtually impossible for us to bring in large quantities of wheat. At present, fertilizer use is 28 to 30 pounds per acre and production is about one-half ton per acre. We can easily raise this to one ton by bringing up the fertilizer level to 75 pounds per acre. One other problem we have is an increasing gap between research and production and we need to increase our attention to production.

Wright

World trade in wheat has been dominated in the past by a small number of countries. This year with the tremendous increase in price and trade, I wonder if Dr. Paarlberg would have advice for those countries who previously were not involved in trade but are thinking of how they might enter the world market.

Paarlberg

I could answer that question much better if I knew what the weather would do in the next two years. Let me tell you a story of the U.S.A. In 1966-67 after two poor crops in the world, there was much feeling that there had been a real change in food supply and that we should crank up on production. We did. We produced an enormous quantity of food only to find that 1968 was a particularly favorable year and we had wheat stacked up on hand for several years which has only now moved. Now, if the situation in 1973-74 is one

which is likely to cause continuing need, it could well be good for all countries --large and small-- to expand their production to try and meet the need, thereby serving hungry people and also improving their own economic situation. On the other hand, if weather is good, we in the U.S.A. with our expansion considered would have great difficulty in finding sales, and a nation just breaking into the export market would have even greater difficulty. So, all I can say is each country should look at its competitive advantages over time and see whether wheat exportation is a wise move. We have looked closely at this, so have the Australians and Argentinians. Whether additional countries which have been marginal in wheat production should join the game is, I feel, very unclear.

Hanson

I should like to have some thought given to how much protein of cereals and legume protein can be increased. I would hope this might be discussed during the course of the week.

Fischer

With the rapid fluctuation in price during the past 12 months, would you care to comment on how this can affect planning in the developing countries? Secondly, would you support a revitalized international wheat agreement to remove part of this fluctuation?

Bronzi

I understood that the U.S.A. took a decision to extend cereal production by 30 million acres. Perhaps Australia and other countries also did. Is this information available and being distributed?

Paarlberg

This information is available. We put out an issue on the world food situation in December and we will update this before February. Anyone wishing this can send for it and other reports as well. The two major sources of this type of information are FAO and the U.S.A., and I believe, with proper modesty, that ours is more current.

Concerning the previous question on the International Wheat Agreement, the fluctuations in price certainly interfere with planning. I would point out that these price changes are signals that we must raise prices in our agricultural programs. It was a signal to us that we should liberalize farm policy and allow our farmers to increase production. Price, however, which is always considered the villain of the piece is not always bad. It helps to allocate resources. If through some device we held the price of wheat at present levels, there could be two serious effects.

(1) People would not be conservative minded for wheat in consuming areas and there would be no signal that this was a scarce item.

(2) In the producing countries there would be no signal that there was a shortage and more was needed. Price is a steering wheel to adjust consumption to production.

An international agreement could adjust prices some by taking peaks off here and filling in valleys there. This sounds good in planning. However, it is our experience that it does not work as well in practice. We have found that a big exporter like the U.S.A., by virtue of its vulnerability to world opinion, is required to abide by these agreements but not all the signatory governments feel this constraint and when the price declines, some of the countries can go below the floor set and dump their surplus. This takes our markets away, which we don't find helpful. When the price rises, we are held at the ceiling price while other countries sell above this.

There are these inadequacies in these agreements. They can serve to seemingly endorse and justify nationalistic and protectionist programs in some countries. As a result, our enthusiasm in the U.S.A. for international grains agreements is not without reservations.

Reddan

Is there sufficient attention being devoted to farm management systems that would utilize the abundant supplies of rural labor in order to avoid the kind of problems that could arise if we developed capital intensive agricultural systems?

Paarlberg

Let me say that we were not sufficiently wise to do this when we mechanized the cotton industry; for example, we disemployed literally millions of people in the process. We found that we could mechanize cotton production and produce it a fraction of a cent less than we could with human labor. So, we mechanized our cotton production and paid no attention to the disemployed who had not been trained for other kinds of employment. We did not produce job opportunities in the rural areas so they migrated 500 to 1,000 miles to the large urban centers. But here there were no jobs available, the kind of skills they had were not saleable, and they found themselves in an alien social climate.

We created two problems: (1) in the rural areas we depopulated so they were unable to provide the necessary social services needed, and (2) in the urban areas with all kinds of problems that we read about and see.

Out of our experience --so difficult and bitter concerning which we have pangs of conscience-- we can give some council to other people in other countries who are at the early stages of agricultural development. We can't point to what we have done with any pride. We can say we have gained some experience which may be useful to other people.

We have launched a rural development program. The purpose is to create in rural areas agriculturally related, off-farm job opportunities to permit the people to remain in the rural areas where they want to be with friends and relatives so they can earn a better living and get some of the health, education and social services they need. This will allow the building of our new increments in the rural areas. We are beginning to do this, but we should have done it 25 or more years earlier.

When I travel around the world, I see the same thing happening. In different countries there are different names like decentralization of industry, rural-urban balance, etc., but it is underway in a lot of places and it is certainly a part of the whole pattern of economic development, including agricultural development and my plea is that countries now in the very early stages of agricultural development avoid the kinds of problems we got into in the U.S.A.

Rao

I have two comments. First, on how far the advisory scientific community has an effect on government policy. I would like to say that if the scientific community had not advised the Government of India in 1966 to import 18,000 tons of wheat from Mexico, perhaps we would not have had the wheat we have in India. This is one example of where government heeded the advice of the community. In India there is a shortage of pulses and also oil seeds. The safflower and soybean are very good for cultivation and the Department has gone into these in a substantial way. However, the problems arose in marketing and the government failed to act rapidly enough for the farmers to market these crops and encourage production. They now realize that the scientists had told them this earlier. There is now indication that government is prepared to listen to scientific advice.

Secondly, I would like to comment on protein malnutrition. Actually, carbohydrate is important as has been pointed out, but we would like to produce more pulses. We need the right varieties of green, bengal or red and black grams. Production in India has fallen by 1.2 million tons. All of us know that production must be increased.

Wellhausen (Chairman's Remarks)

I think that all of us agree that during the last two decades, tremendous progress has been made in food production in certain areas of the tropics and semitropics. It is also clear that these production advances could not have occurred without a well-organized, effective agricultural research program focused on the pertinent topics. As might be expected with scarcity in manpower, credit, fertilizer and other inputs, the modern scientific package put together by the agricultural scientists moved fastest in those areas where production possibilities were most favorable and where payoff from input investments was the highest. I think this was a logical consequence.

Unfortunately, conditions vary from one area to another within and between countries. Areas ideally suited for the rapid advance of modern agriculture are limited in number and size throughout the world. The high-yielding, fertilizer-responsive, disease-resistant varieties and corresponding technologies that have worked so well in the more-favored agricultural areas become markedly less attractive in rainfed areas where moisture varies from year to year or irrigation is not available. Although much more food can be produced in the more elite agricultural areas, through further perfection of the scientific package and its wider and more complete application, it is doubtful that the food requirements of the 1990s or the social problems ahead can be met by concentrating only on these better areas.

As we continue to push production in the more favored zones, we must also make a special effort to speed up the use of modern technology in the more marginal, but economically viable regions. This will mean further strengthening research activities, the development of more elastic varieties, more precisely suited agronomic practices and, above all, new delivery systems and incentives if we are to get the technology applied. We must remember that these delivery systems are going to be location specific and vary from region to region. What works in one place may not work in another.

Aside from the food problem, there is another important point that we can not overlook. Millions of people are residing in the more marginal areas that depend on agriculture as a livelihood. Dr. Da Silva mentioned it this morning. These people, too, can benefit from technology although the profits may be less. The greater the delay in stimulating these people to change, the greater the disparity of income between them and those from more favorable areas will become. If this continues, these people are not apt to remain satisfied. These are some of the main issues and challenges for the 1970s.

THE ROLE OF GENETIC, AGRONOMIC AND PLANT PROTECTION RESEARCH IN INCREASING YIELD, NUTRITIONAL VALUE AND PRODUCTION IN CEREALS

M. S. Swaminathan*

I. Introduction

The 1960's witnessed a major jump in the productivity and production of wheat and barley. The release of the semi dwarf winter wheat variety Gaines in 1961 in the United States followed by the release in 1963 of the semi dwarf spring wheats Lerma Rojo 64-A and Sonora 64 in Mexico, all of which owed their dwarf plant stature to the Japanese Norin wheats, marked the beginning of a new era in wheat yields. Yields exceeding 10 tons per hectare were obtained with Gaines in Washington State and the Mexican semi dwarf spring wheats also helped to establish new world records in yield. The introduction of genes for relative photo insensitivity through selection in two diverse environments as well as of genes conferring resistance to a broad spectrum of pathogens and physiologic races of stem, leaf and stripe rusts through a dynamic scrambling of genetic material followed by rigorous rejection of susceptible genotypes, made the Mexican semi dwarf strains exhibit a range of adaptation not visualised as possible before. An important innovation in assessing genotype environment relationships and in generating an awareness of the yield potential of the dwarf genotypes was the initiation of the International Spring Wheat Yield Nursery by CIMMYT and the International Spring Wheat Rust Nursery by the U.S.D.A. This was followed more recently by the organization of several other international nurseries, including the International Winter Wheat Performance Nursery organized in 1968 by the Nebraska Agricultural Experiment Station in cooperation with USDA. Imaginative political and administrative decisions like the import by India of 18,000 tons of seeds of Lerma Rojo 64-A and Sonora 64 from Mexico in 1966, followed by even larger seed imports by Pakistan and Turkey helped the rapid testing and spread of high-yielding strains. Consequently, the area under dwarf wheats rose in India from about 4 hectares in 1964-65 to over 4 million hectares in 1971-72.

High yields, stability of performance resulting in low risks, good market demand and price coupled with the availability of an agronomic technology which was capable of decentralized adoption led to the new fertilizer-responsive strains finding immediate acceptance by illiterate peasantry over wide areas in countries like

* This paper was presented by Dr. M. V. Rao.

India and Pakistan. Technology was matched by appropriate political and administrative action and farmers, extension workers, scientists, administrators and political leaders functioned for the first time like members of a good symphony orchestra, leading to a doubling of wheat production in countries like India within a span of 5 years. A new confidence in the agricultural capabilities of the developing nations was thus generated.

Greater fertilizer responsiveness and yielding ability were introduced in barley during the last decade through the use of breeding concepts such as those of Finlay and Wilkinson (1963), use of induced non-lodging mutants and the exploitation of hybrid vigour. The benefits of these scientific advances have not yet accrued to the farmers of most developing nations. In India, for example, barley is an important crop but the crop is mostly grown without irrigation in soils of poor fertility or in saline-alkali soils. A scientific finding of great significance to human and animal nutrition was made in Sweden in 1968 when the Hiproly (high protein-cum-high lysine) character was identified in a strain from Ethiopia. Attempts to transfer this character to cultivars are in progress in several countries (Munck 1972).

During the 1960's, some of the major barriers to triticales becoming a cultivated cereal were removed. Thus, genotypes with a good fertility, better seed filling and non-shattering habit were identified in Canada, Mexico, Hungary and several other countries and some triticales strains were released for cultivation for feed purposes in a few countries.

II. Production and demand trends

According to FAO figures, the world wheat production and demand picture is as follows (in million metric tons):

	<u>1964-66</u> <u>(Average)</u>	<u>1970</u>	<u>1980</u>	<u>Growth rate</u> <u>(Percent per year)</u>
World Demand	276.6	312.9	377.4	1.8
World Production	276.6	304.9	395.4	2.6

Calculations by the National Commission on Agriculture of India reveal that wheat requirements of India would amount to 24.23 million tons in 1975, 30.05 million tons in 1980 and 36.66 million tons in 1985. Considering that wheat production in India during 1972 exceeded 26 million tons, the targets for 1980 and 1985 appear to be attainable with the more extended application of existing technology. However, wheat has also become a buffer crop in India, having to play the role of a gap-filler for deficiencies in millet and rice production. Therefore, the actual production of wheat, which is a winter season crop and, hence, less prone to violent undulations in yields, has to be higher, particularly in seasons when either due to drought or floods or other aberrations in weather the

monsoon-season (June-October) crops are affected. The relative stability of wheat production was evident even before the advent of the dwarf strains during the drought years 1965 and 1966 (Table 1).

Table 1. Increase in agricultural production in some states

State	Percentage increase in food grain pro- duction during 1967- 71 over 1961-64	Area under high- yielding varieties as % of total area under food grains	Average yield of food grains (kg/ha)	
			1961-62 to 1964-65	1967-68 to 1970-71
Punjab	87.2	36.1	942	1718
Haryana	64.9	13.3	770	1084
Uttar Pradesh	28.2	12.6	746	901
Gujarat	27.0	9.4	549	664
Tamil Nadu	7.5	21.6	1118	1202
Andhra Pradesh	4.7	5.3	773	770

The release of the Mexican semidwarf wheats, Lerma Rojo 64-A and Sonora 64, for general cultivation in 1966 followed by the selection from Mexican segregating or mutagen-treated material and release of high-yielding, amber grain strains like Kalyansona, Sonalika, and Sharbati Sonora in 1967 generated great enthusiasm among farmers for the new technology. In fact, dwarf wheats did to Indian agriculture during the sixties what hybrid maize did to American agriculture in the thirties and forties, namely, to introduce the concept of input use and better management. Interestingly, it is in areas like the Punjab, Haryana and Western Uttar Pradesh where the production advance in wheat was maximum, that rice production is also going up fast, thus providing another example of the value of catalysts in change. For a variety of reasons, among which difficulties in scientific water management and the incidence of pests and diseases are important, the yield potential of dwarf rice strains is yet to be realized on a large scale in small farmers' fields. Hence, in India the production advance has been relatively poor in states where the High-Yielding

Varieties Programme was primarily based on rice (Table 2).

Table 2. Percentage reduction in yield per hectare as compared to 1961-62.

State	Crop year	<u>Reduction in yield per hectare (%)</u>	
		Rice	Wheat
Madhya Pradesh	1965-66	51.4	19.3
Maharashtra	1965-66	39.1	27.9
Uttar Pradesh	1965-66	30.5	10.0
Uttar Pradesh	1965-66	43.4	4.9

On the other hand, wheat cultivation has become popular in states like West Bengal, Andhra Pradesh and Mysore, where wheat was until the advent of the dwarf strains, an insignificant crop. To cite one example, the State of West Bengal now produces over a million tons of wheat, while about five years ago this figure was only about 50,000 tons.

III. Secondary advantages of the new plant types in wheat

Apart from the primary advantage of high yields arising from the ability to respond well to fertilizer and water, the dwarf wheats have several other advantages with reference to increasing the total wheat output of a country. Because of their non-lodging habit, they can be grown as inter- or companion-crops with others. Sugarcane and wheat are becoming good companion crops in India. Secondly, the relative insensitivity to photoperiod provides resilience with regard to sowing dates. This makes late sowing possible in fields where there are problems like water stagnation. Also, multiple cropping practices like growing potatoes between September and December and wheat from late December to April have become feasible. The telescoping of duration according to growing conditions has made it possible to grow wheat in non-traditional areas and in non-traditional seasons. For example, the variety Kalyansona has given in trials yields of 30 q/ha within 100 days in Coimbatore in South India (11°N latitude), while the same variety grown in the Kashmir valley (35°N latitude) in rotation with paddy takes nearly 200 days and may yield about 50 q/ha. An idea of the extent of drop in yield that takes place with delayed sowing in the north-

western parts of India can be obtained from the data in Table 3.

Table 3. Effect of sowing date on the yield of wheat varieties
(North Western Plains Zone 1970-1971)

Date of sowing	Yield (q/ha) of variety		
	Kalyansona	Sonalika	Hira
November 9	57.6	58.6	63.7
November 29	51.0	56.5	51.4
December 19	43.1	46.3	43.4
January 8	39.5	43.8	40.9

IV. Major problems for the seventies

In my view some of our high-priority research tasks are:

- (a) to stabilize the yield of dwarf wheats under good conditions of management through reducing their genetic vulnerability to diseases and pests and developing national and regional disease surveillance and warning systems,
- (b) to increase the yield potential of unirrigated wheat,
- (c) to improve the capacity to give better returns from unit quantities of inputs of fertilizer and water and thereby help to reduce the cost of production in small farms,
- (d) to exploit the potential of dwarf durums for greater output per litre of water,
- (e) to work for the next quantum jump in yield in wheat and barley,
- (f) to improve the nutritive and end-use quality of bread and durum wheats,
- (g) to develop high-yielding-cum-high-quality varieties of food and feed barley and,

(h) to develop commercial varieties of food and feed triticale for unirrigated areas. The precise priorities from this general list will naturally vary from area to area.

(a) Stabilizing yield of irrigated wheat by controlling diseases and pests.

(i) Position in India:

Wheat in India suffers from many diseases but the most important of them are caused by fungi. The bacterial and viral diseases are comparatively less important so far in the country. Among the major diseases are the three rusts, smuts and bunts and foliar diseases like Alternaria and Helminthosporium blights. The minor diseases are either localized or their incidence is low thus far.

Considerable work on wheat rusts was done by K. C. Mehta from 1922 to 1950. He concluded that rusts cannot survive in the plains of India during the summer months but they can over-summer in the northern hills as well as in the Nilgiri and Palney Hills of South India which serve as primary sources of infection for the winter crops in the plains. Extensive surveys since 1967-68 have thrown further light on the spread of rusts. Yellow rust (Puccinia striiformis west) is essentially a problem of North and northwestern regions comprising the States of Punjab, Haryana, Himachal Pradesh, North Rajasthan and Northern regions of Uttar Pradesh and Bihar. Brown rust (Puccinia recondita Rob. ex Desm.) is an all-India problem and has two distinct foci of infection - one in the South and the other in the North which normally become active almost at the same time.

In the case of black rust, the wheat disease surveys have provided very interesting results. The bulk of the inoculum of black rust (Puccinia graminis pers. f. sp tritici Erikss & Henn) is supplied from the South and the northern hills contribute very little, if at all, to the epidemics in the plains of India. Black rust has a single focus in South India. From there the inoculum is blown to Central India, where in January and February it multiplies rapidly. Therefore, Central India, Mysore and Maharashtra are the main areas where the inoculum of black rust multiplies in the winter months and poses danger to the crops in the North and northeastern plains of the country. To minimize the threat of black rust to the northern plains it is, therefore, essential to check its establishment and spread in Central India, either by recommending resistant varieties or by chemical control.

Systematic breeding for disease resistance has been in progress since 1935 and during the last forty years several varieties possessing a high degree of field resistance, such as NP 718, NP 790,

NP 797, NP 809, Ridley, NP 836, NP 846, have been released.

In more recent years, resistant dwarf varieties like Kalyansona, Sonalika, UP 301, Safed Lerma and Choti Lerma have been recommended for different zones. Among these varieties Kalyansona and Sonalika have become very popular in the main wheat growing regions of the country and are now cultivated in large areas. Kalyansona has been in the field for more than six years on an extensive scale and it has checked the spread of yellow rust to a great extent. It has been observed that even though yellow rust is appearing normally in the foothills, it is not spreading southward as much as it did in the past. Kalyansona is probably serving as a buffer and preventing the spread from the foothills southward. However, the extensive cultivation of a single variety in such a large area is fraught with danger and attempts are being made to introduce varieties with diverse genetic composition to ward off the danger of a rust epidemic. Unfortunately, some new strains of races 10, 20 and 38 have been reported in recent years and Kalyansona has been found to be susceptible in isolated pockets. The most discouraging feature is the appearance of a few unidentified strains which attack Kalyansona and Sonalika varieties, both of which possess maximum field resistance to yellow rust in the country. Until now, these strains are restricted but they may flare up at any time. The change in the race flora has brought the problem of yellow rust to the fore front once more.

At the time of release of Kalyansona, it possessed more resistance to diseases than any other known variety. It was resistant to black and yellow rusts, loose smut of wheat and hill bunts. But the change in the race population has rendered this variety susceptible to stem rust in South India. Race 122 of black rust which was reported in 1952 and which until in 1968 remained a nonsignificant race, suddenly increased in the Nilgiri hills, then in Mysore State in 1970 and then it spread to the North, rendering Kalyansona susceptible, mainly in the southern parts. This change in the race flora has necessitated its replacement in South India.

In the past durum wheats were mainly restricted to Central and South India and in the North only bread wheats were cultivated. One of the probable reasons for lack of durum cultivation in the North could have been its high susceptibility to yellow rust. Sometimes yellow rust appeared so severely in durums that the plants were unable to reach the flag leaf stage. Even today some local or improved varieties like Kathia, Malvi local, Ekdania - 69, A.206, A.9-30-1, Narsingarh-111, NP404, Jaya, and Vijaya cultivated in Central India are highly susceptible. However, considerable improvement in the resistance of durums has been achieved and in the trials a large number of durums in the north are giving much better performance to yellow rust. Among the aestivum varieties a considerable number possess resistance to yellow rust. For instance, such popular varieties as Kalyansona and Sonalika possessed an extremely high resistance to this rust under field conditions until recently.

The success of breeding for resistance lies in developing a rapid system for replacement of varieties. Quick replacement of varieties is very closely linked with quick and better methods of screening the varieties to suit a dynamic selection programme. During the last few years, Plant Pathological Screening Nurseries have been located in different parts of India. The locations or "Hot Spots" have been selected because of their geographic location and climatic conditions which favour the development of a particular disease. For instance, Kalyani in the East has been selected for Helminthosporium diseases and Wellington in the Nilgiri Hills for black and brown rusts, powdery mildew and Septoria.

Screening varieties under field conditions needs both a national and an international approach. Recent epidemiological studies of yellow rust have indicated the possibility of introduction of yellow rust races from remote regions. It is desirable that CIMMYT should initiate international monitoring of diseases in selected regions of the world.

CHEMICAL CONTROL:

At present chemical control on a mass scale does not appear a feasible possibility. However, the discovery of systemic fungicides like Plantvax and RH-124 have opened new avenues of research which will need greater attention in the coming years. It has been shown that Plantvax can give protection to the crop by two sprays and it also gives protection for a few weeks by seed dressing. Probably use of pellets which release the chemicals slowly may help in this direction.

Chemical control of rust can only be effective if there is a disease forecasting system. At present, we have very little information on this aspect but recent investigations have shown that for black rust the source of primary inoculum is in South India and consequently there is a possibility of predicting the black rust epidemic. In the last six years a wheat disease surveillance programme has given useful information about the dates of appearance of rust and their spread in different parts of the country and this has been correlated with prevailing temperatures.

Attempts are now being made with rain samplers and satellite photography to trace the disturbances in South India and Bay of Bengal which appear to be responsible for quick dissemination of rust spores to Central India. The preliminary data clearly indicate it (Nagarajan, unpublished).

Among the major diseases, loose smut (Ustilago ruda var. tritici) comes next to wheat rusts. The survey data show that the average loss due to the loose smut in India is only 2 - 2.5 percent. The disease is more prevalent in the cooler parts of the country and it is comparatively less in the southern regions. There has been a considerable decline in the incidence of this disease during

the last few years. This decline is primarily the result of the extensive cultivation of Kalyansona, which is practically immune to loose smut under field conditions. At present, loose smut of wheat has receded in importance in the main wheat belt but the withdrawal of Kalyansona variety may once again change the position. Quite a few varieties which have been released in recent years such as Lal Bahadur, Hira, Moti, UP 301, UP 310, PKD 4 and the NI series are susceptible to loose smut. Even Sonalika and Choti Lerma are susceptible to this disease under field conditions. Therefore, the replacement of Kalyansona by any of these varieties or by another susceptible variety will once again increase loose smut incidence and anticipatory action will be needed.

From the breeders point of view, attempts should be made to transfer the Kalyansona resistance to future varieties. The breeder may also look for the utilization of morphological resistance in closed-glumed type of plants. Another hopeful approach for the future lies in the use of systemic fungicides. Fungicides like Vitavax or Benlate are extremely useful in controlling the disease by simple dressing with 0.2% chemical.

Another disease which should receive more attention in the future is Karnal Bunt (Neovossia indica (Mitra) Mundkur). Commonly known as "partial bunt of wheat", it is endemic to the Indian sub-continent. This disease was first reported in 1931 and until recently, it was presumed to have been much more widespread. It has been reported in Himachal Pradesh, Jammu and Kashmir, Punjab and also in parts of Rajasthan and West Uttar Pradesh. Even now, its incidence is extremely low, being only traces. The potential danger of the disease is not from its high prevalence, but its effect on wheat quality. Two percent infection of this disease can cause a significant deterioration in the quality of flour and the chapatti. It has been demonstrated on the basis of experimental data that at one percent or less infection, the quality is little affected but with higher levels the quality deterioration is considerable. It is, therefore, necessary that a watch is maintained on the spread and the prevalence of the disease throughout the whole wheat growing area of the country. This is all the more necessary in view of susceptibility of improved and old conventional varieties. We are, at present, unaware of the factors responsible for the spread of this disease and, therefore, more work is needed on the epidemiology of the fungus.

Other bunts (Tilletia foetida Waller Liro. and T. caries (DC) Tul.) are of minor significance in India. These are commonly known as "Hill Bunts" or "European Bunts". In India they are restricted mainly to the northern hills which account for only 2 to 3 percent of the total wheat production of India. The bunts are essentially a problem of these regions and sometimes the incidence of bunt is extremely high, ranging up to 20 percent or more. The hill bunts cause greater quality deterioration than the Karnal bunt but these can be effectively checked by seed dressing with Agrosan GN, Cerasan, New Cerasan or Panogen.

Powdery mildew of wheat (Erysiphe graminis DC. f. sp. tritici Em. Marchal) was regarded, in the past, as a disease of the hills but the position appears to be changing. In recent years, the disease has been reported from many parts of the country, such as Karnal, Ludhiana, Pantnagar and many places in Rajasthan. Some of them are quite far from the hills. At present, our knowledge of powdery mildew, particularly the mode of perpetuation of the disease, role of perithecia and dissemination of conidia is limited. The perithecial stage, which is so common in the hills, may be responsible for its perpetuation but there are no scientific data to prove this so far. Powdery mildew can be one of the serious diseases of the future as ecological conditions provided by intensive wheat cultivation are more suitable for its spread.

Other foliar diseases of wheat such as Helminthosporium sativum Pammel, King & Bakke and Alternaria trititica Prasada & Prabhu are equally important. Alternaria disease is unique to India. In symptomatology it resembles Helminthosporium.

The disease is more common in the southern and eastern parts of the country, such as Bihar and Bengal. The climatic conditions of eastern regions favour spread of these diseases. In Bengal, particularly, which is essentially a rice area, there has been a considerable increase in the wheat area in the last few years. Wheat disease problems in Bengal and other humid regions are quite different from the problems of western parts of the country.

Bacterial and viral diseases are of very little importance in India. But the bacterial and nematode complex causing Ear cockle and "Tundu Disease" is of common occurrence in the Northwest. The disease is carried by nematode galls from one place to another. Transportation of large quantities of seed from one region to another can facilitate the spread of this disease to areas where it does not occur. The disease can be controlled by removal of the galls by flotation method and this can be helpful in reducing the disease. Sharbati Sonora, E.9176 and E 4870-B are tolerant to the disease.

Apart from those mentioned above, wheat suffers from many other diseases which have been classified as minor diseases or diseases of little economic importance. Among them leaf blotch or glume blotch caused by Septoria tritici Rob. ex. Desm. and S. nodorum (Berk.) Berk. deserve mention. These diseases are quite restricted. The former is found in localized pockets in the Northwest, mainly in the foothills where the humidity is high, and the latter is prevalent in the hills of northern and southern India. Septoria is an extremely important disease in some parts of the world, such as the coastal belt of the Mediterranean Sea but in India this does not appear to be so important. Probably the climatic conditions of India with its fairly high March temperatures do not permit a rapid spread of this disease and in normal years it may remain localized. Septoria nodorum has been increasing in the hills of South India, particularly in the

summer crops, but it is very mild in winter. In the North some information of wide occurrence of S. nodorum has been obtained from the hills but its exact position is not fully known.

Downy mildew (Sclerospore maciospora Sacc.) of wheat has never been an important problem in India. It was reported by Tyagi in 1968. Since then many reports of its occurrence have been received. The disease is only prevalent in patches which are waterlogged and it could perhaps spread to wider areas in irrigated regions. However, simple precautions such as proper levelling of the field to avoid water stagnation will stop this disease from doing much damage. The disease will have to be watched in the future should it spread to new areas.

Flag smut (Urocystis tritici) of wheat is yet another minor disease. But in certain fields, where it is well established, it can take a heavy toll. The disease has been reported from many parts of the country, but so far its incidence as a whole is low. The redeeming feature of this disease is that it can be controlled by the systemic fungicide vitavax.

Molya disease caused by the nematode Heterodera avenae, occurred in certain regions of Rajasthan in the past but in recent years this disease has been reported from many parts of Rajasthan and also from Punjab and Haryana. It is more important on barley than on wheat. Large-scale screening of wheat varieties has shown that some varieties like Pb. C. 281, Pb. C. 513, NP 771, Sonora 63 are tolerant to the disease.

There have been scattered reports of Ophiobolus graminis Sacc. from M. P. (Saksena S.B.). Even though the fungus was reported by Padwick (1940) it does not appear to be of any importance so far. Similarly, root rot caused by Sclerotium rolfsii Sacc. has been reported to occur in some dryer regions in Madhya Pradesh (Agrawai and Singh 1968). However, these problems do not appear to have much significance at present. Similarly, Fusarium and Pythium seedling blight may occur in heavy soils under irrigation, particularly those areas where paddy is cultivated.

In the future, some deficiency problems are likely to arise. The excessive application of nitrogenous fertilizer is creating problems of deficiency of other elements such as zinc. Yellowing of Kalyansona, which is mainly due to an inadequate supply of nitrogenous fertilizers, is widespread in the country but other varieties like Lal Bahadur, Sonalika, R.R. 21, and UP 310 do not show this symptom.

(b) Breeding policy:

Since rusts pose the greatest threat to the wheat crop, breeding work in the past has largely been confined to developing strains

possessing vertical or race specific resistance. In this approach, the breeder should be ready for periodic varietal replacement and varietal zoning. A dynamic seed multiplication programme is vital to keep seeds of varieties with divergent sources of resistance ready.

The multilineal concept of Borlaug is yet to be tested and adopted on a large scale. In countries like India, where the flour is used for making unleavened bread and the public distribution system does not market varieties separately, this approach is feasible and is already being attempted under the All-India Coordinated Wheat Improvement Programme.

Horizontal resistance has always been of interest to breeders. It has been suggested that some of the tall varieties of India like NP 4, NP 52, C. 273, C. 591 and Type 84 possess considerable horizontal resistance (Anand et al. 1969). Miramar 63, a yellow rust-resistant variety released in Colombia has maintained its resistance for many years. Derivatives of Hope, Thatcher, Yaqui-50 and Rio-Negro are also considered to possess horizontal resistance. A useful approach could be the combination of horizontal resistance in a multiline which has several genes for vertical resistance.

The identification in Africa of maize strains possessing horizontal resistance to Puccinia polyspora has kindled much interest in a more intensive use of this method. Maize, being a cross-pollinated crop, has a natural capacity to adapt itself to a new organism. Even here, this capacity may be lost when inbred lines are used. However, a constant effort to develop resistant varieties on the one hand and a vigil over the spread of diseases on the other hand should be maintained.

Pests

Insect pests, which were not so important in the past in wheat, except in some areas, are gaining in significance with the altered ecology and micro-environment under which the dwarf wheats are cultivated. Army worms sometimes cause trouble in the latter part of the wheat season in India. The insect pests should therefore not be neglected.

(b) Achieving the next quantum jump in yield

Yield in wheat, barley, triticales and other crops depends upon their capacity to produce dry matter and its efficient partitioning between the economic and noneconomic parts. The equation given by Yoshida (1972) sums this up elegantly:

$$Yecon = K \times Y_{biol}$$

Where Yecon is economic yield, Y_{biol} is the biological yield and K is the harvest index. Therefore, in any crop improvement program,

an improvement either in biological yield or the harvest index or both would alone enhance economic yield. Improvement in harvest index is largely responsible for the enhanced yield potential of both dwarf aestivums and dwarf durums (Fig. 1, 2 and 3).

The biological yield at any given place is a function of carbon dioxide, water, nutrients and photosynthesis rate of the plant. Apparently, in rice the highest rates of photosynthesis of $55 \text{ gm/m}^2/\text{day}^{-1}$ have been obtained for brief periods (see Evans 1971). This is close to the theoretical limits. The plants which gave this rate of photosynthesis had upright leaves and a high Leaf Area Index. No such achievements have yet come to light in wheat, barley and triticales. Therefore, under intensive agriculture where water and nutrients are not limiting, the ability of plants to accumulate dry matter should play a dominant role in the improvement of these crops. There are several other connected processes which need our attention to achieve this objective. However, the first thing should be to screen for variability in photosynthesis rates in wheat, barley and triticales. Earlier workers believed that photosynthesis per unit area did not vary (Watson 1951). This does not seem to be true any more (Yoshida 1972). In Triticum and Ageilops species, the species with a low chromosome number appear to have higher photosynthesis rates (Khan and Tsunoda 1970, Donstone and Evans 1970). Some less evolved species of wheat even seem to have a rudimentary parenchyma bundle sheath, a characteristic of C_4 high photosynthesis plants. However, when hexaploid wheat cultivars from different sources were examined for relative photosynthesis rates 10 days after anthesis 200 to 300 percent differences between the lowest and highest were observed (table 4). The variety Kalyansona, which has been so successful in India, has a poorer photosynthesis rate than triple dwarfs and some other Indian wheats such as C 306, K 65 and K 68. In the studies of Khan and Tsunoda (1970) and Dunstone and Evans (1970), only a few genotypes were examined in the seedling stage. A large-scale screening for low CO_2 compensation in wheat also did not reveal the existence of high-photosynthesis wheat genotypes (Moss and Musgrave 1971). But low CO_2 compensation may not be the characteristic of all high-photosynthesis plants as is true for sunflower and Typha latifolia. Therefore, what we need are quick and simple techniques to determine photosynthesis rates in order to screen as large and diverse a germ plasm as possible. In this task we have to be conscious of the stages when we want high photosynthesis rates. In addition, one cannot lose sight of important morphological features of leaves.

Having assured a high photosynthesis potential, one can think of ways and means of further improving the harvest index. A consideration of the harvest index brings us the realization that it is nothing but the output of grains which can be traced back to the number of ovules per unit area and the 1000-grain weight. Assuming we maintain a 50 g 1000-grain weight, how would we improve the number of ovules or grains per unit area? We can:

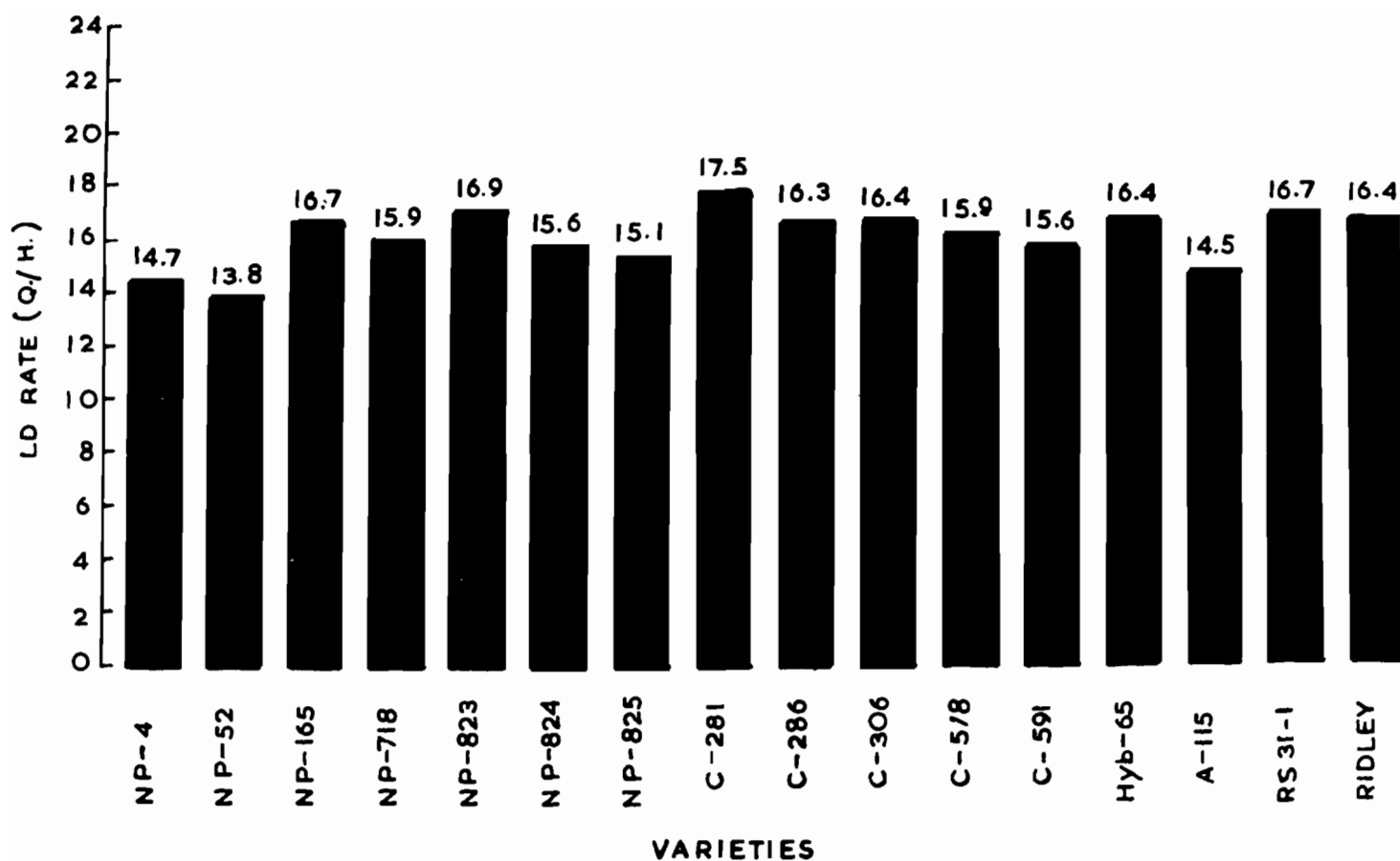


Fig. 1. Yield of tall wheat varieties in coordinated trials.

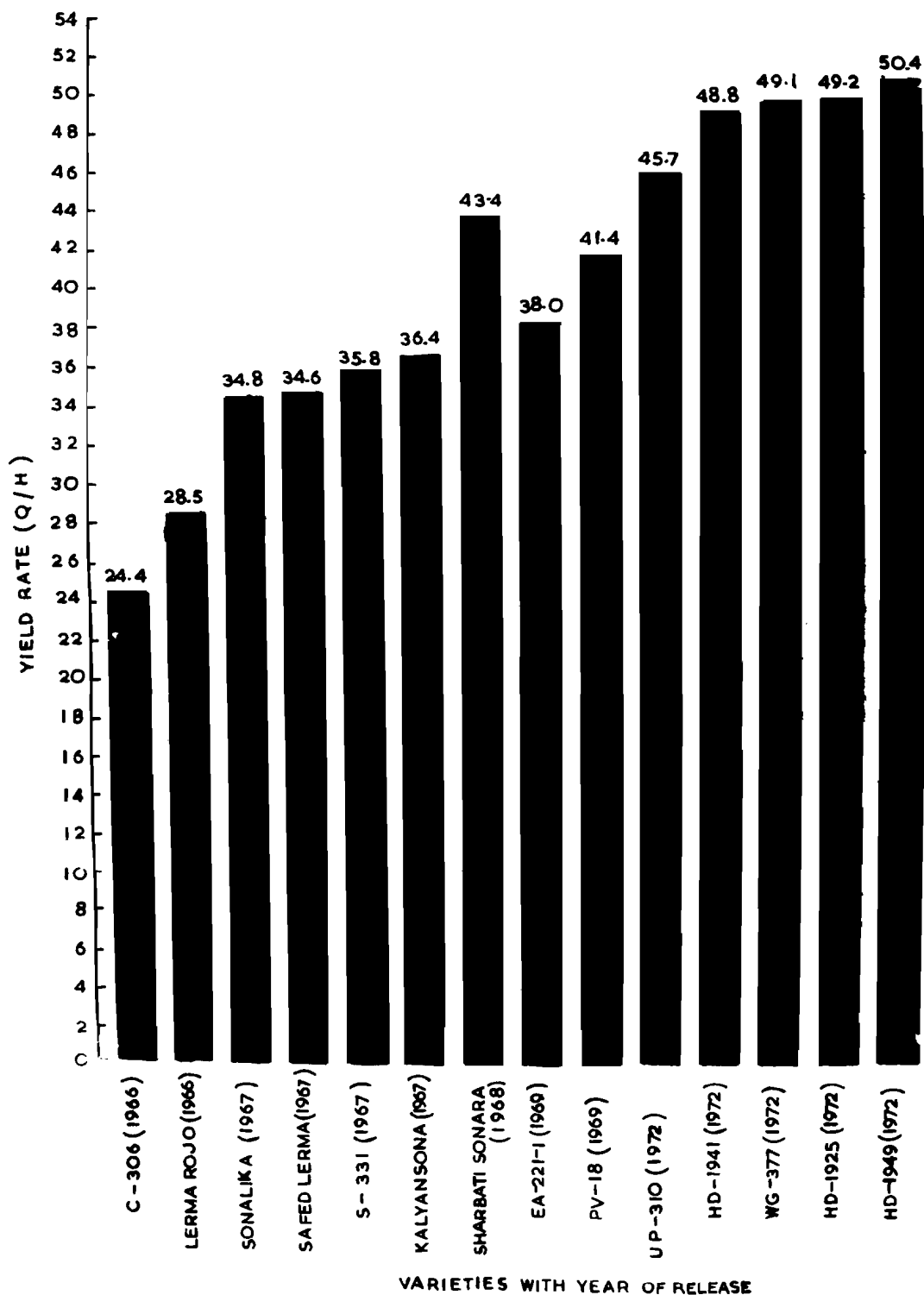


Fig. 2. Yield of recent wheat varieties in coordinated trials (C. 306, tall; rest, semidwarf and dwarf).

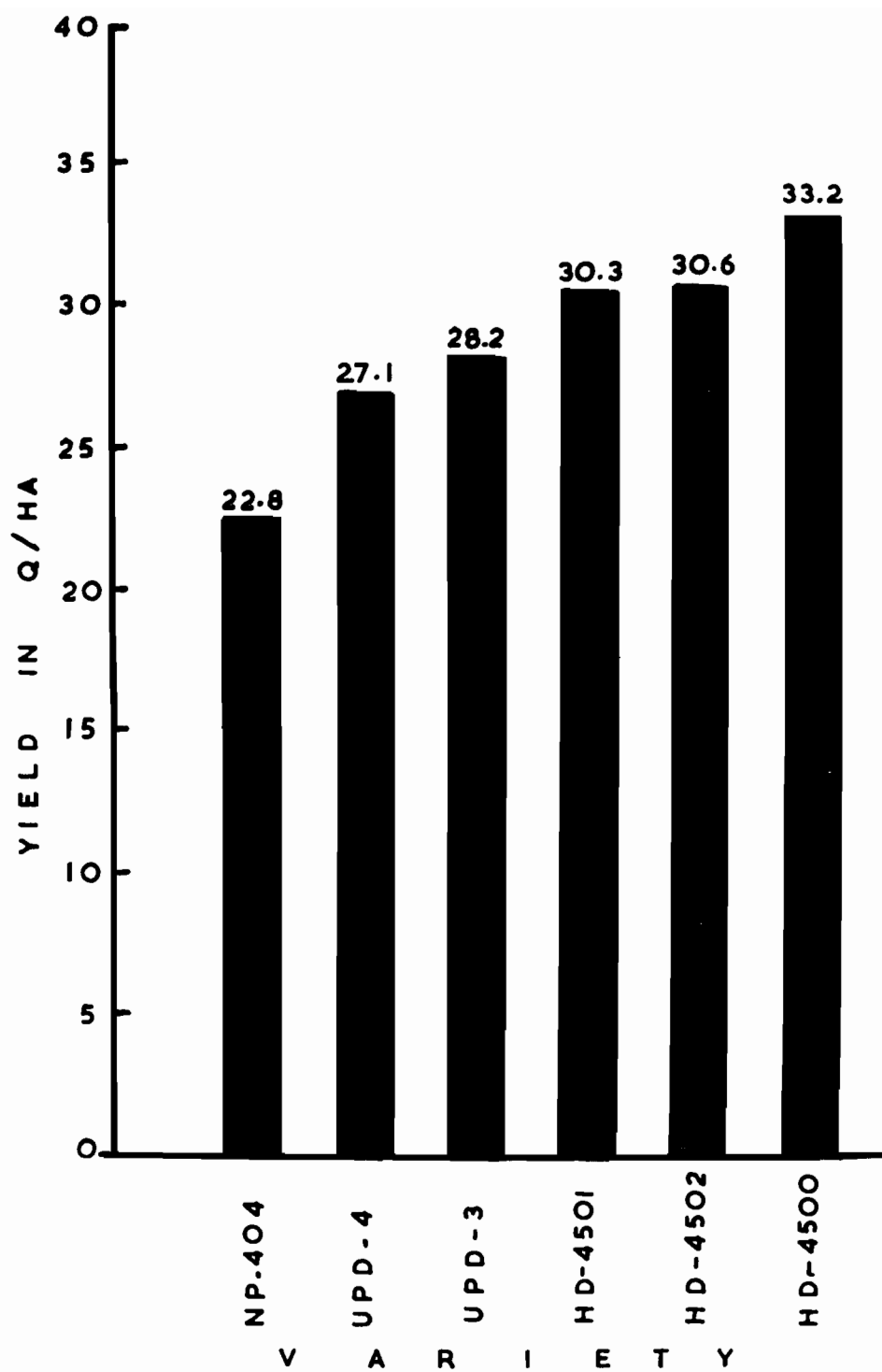


Fig. 3. Yield of tall (N. P 404) and dwarf durums in initial evaluation trial.

- a) increase grains/ovules per ear and/or
- b) increase the number of ear-bearing tillers per plant.

Donald (1968) preferred a branched ear to raise the number of grains per ear. Asana (1968) also emphasized the importance of such an ideotype for dryland conditions, because under such conditions tillering is suppressed but the main shoot is affected much less. Instability of branched ear types, sterility, their nonsynchronous tillering and lateness have so far stood in the way of development of such varieties. Further research in this field could be rewarding.

We know that in most wheat varieties the number of grains per ear is restricted by poor development of florets. Some varieties like Kalyansona have greater potentiality in this respect and can produce up to 6 grains in each middle spikelet. The size of inner grains is reduced considerably (Rawson and Ruwali 1972). The high number of grains per ear is often associated with poor tiller performance.

So far studies have been largely confined to examining the role of flag leaf, awns, leaf sheath, etc. in relation to the productivity of the ear. In a plant like wheat where the process of ear and spikelet differentiation is accomplished much before the ear comes out, the fate of the plant in terms of yield is decided much earlier. Agronomists have observed that moisture stress at the time of crown root stage in Kalyansona adversely affects the yield of this variety. Under Delhi conditions it has been observed that this variety's crown root initiation stage correlates with degree of ear differentiation when seeds are sown in the first half of November. Wheat, unlike barley and Sorghum, forms a terminal spikelet from the apical cell (Bonnett 1966). Therefore, once this spikelet has been formed the chances of further growth of the wheat ear are nil. Even if moisture availability after this stage becomes abundant, the only effect it can have is the better development of florets. Sorghum and barley can apparently resume growth of the ear after a drought, if moisture is made available. It would be useful to study the variation for this trait at the species level.

The stage when the ear is differentiated is crucial for two additional reasons:

- i) This stage is reached within a month and it is the time when tillers are differentiated.
- ii) Roots are also in their active period of development.

Since almost all cultivars of wheat respond to day length and temperature, it is likely that these events may not occur with the same precision at every place. The long-duration varieties are high tillering and they are more sensitive to long photoperiods. Could it be that tiller differentiation and development precedes ear differentiation in such varieties because they have a long ju-

venile phase? The short-duration varieties, on the other hand, might have poor tillering because in these types the juvenile phase is short. Therefore, a negative correlation between ear characters and tillering habits may have a lot to do with physiological behavior. Lupton (1970) has found that as soon as the wheat plant enters the reproductive phase, there is almost no translocation between tillers on a plant. Hence, an appropriate tillering pattern will have to be chosen for each agroecological milieu.

There is no limitation of light in the field at the time of ear and tiller differentiation since there are barely two fully expanded leaves on the plant. However, these two small leaves plus a third emerging one contribute to the developing spike, tillers and roots. Does this not cause an intense competition? In addition to supporting these organs, the leaf expansion would itself need energy. What is the effect of leaf area and photosynthesis rate at this stage on the differentiation and development of the ear? What is the optimum leaf area for ensuring the emergence of a desirable ear? How will partitioning of photosynthates between roots, tillers, ear and leaves be effected and regulated at this stage? These are questions which deserve study.

The question that occupies us in India is the efficiency of light use during winter, the growing period for wheat. We know that most wheat cultivars are saturated for light needs at about 3,000 f.c. Even after anthesis the light intensity on the 3rd and 4th leaf from the top leaf remains 2,000 f.c. or more. Can we find cultivars that would use light intensities up to 10,000 or 12,000 f.c. If this is to be achieved, it has to be at temperatures between 15 to 25 C. This, in other plants, is dependent upon the presence of a C_4 pathway (Loomis, Williams and Hall 1971). In addition to providing a high photosynthesis rate, this system is associated with higher water use efficiency and adaptability to moisture stress and higher temperature (Downton 1971 and Slayter 1971). In India the grain-filling period coincides with rising temperatures and atmospheric drought. Could the presence of a C_4 pathway help under such conditions, particularly under dryland agriculture? If it does help, we will have to think of possible genetic stocks to be used in breeding such varieties.

Selection criteria employing quick screening techniques are important in any crop improvement program. Two important criteria seem to have been developed recently; one concerns nitrate reductase as an index of total reduced nitrogen (Crog and Hageman 1970). The second is accumulation of proline in relation to drought resistance in barley (Singh, Aspinall and Paleg 1972). Since these techniques involve simple and quick determinations, it might be worthwhile to screen germ plasm using these criteria.

Table 4. Photosynthetic $^{14}\text{CO}_2$ fixation in the flag leaf of main shoot 10 days after anthesis in wheat cultivars (Data of Dr. S. K. Sinha, IARI)

Cultivar	^{14}C fixed/cm ² /10 min CPMx10 ⁻²	^{14}C fixed/leaf/10 min CPMx10 ⁻³
Gabo	580	1178
HD 1949	277	540
Kalyansona	189	500
Kalyansona P-46	189	600
Lal Bahadur	409	745
NP 790	230	553
S 331	416	857
CD at 5% P.	113	237

c) Increasing the capacity for more and better nutrient utilization

Ramamoorthy and Chandra Sekhara Rao (1972) have outlined an agrochemical approach to increasing the yield of wheat. They found that with 6 wheat varieties in the first year and 9 in the second year grown under normal pot culture conditions at Delhi as well as under partial drought at different stages of growth of the crop, the yields, pooled for both years, were significantly related to the percentage composition of the seed by the following multiple regression which has an R^2 value of 92.37% (Eq.I) :

$$Y = 54.01 - 12.485 N + 1.12 N^2 + 23.335 P - 38.48 P^2 - 38.955 K + 38.211 K^2 - 0.4126 Fe + 0.0019 Fe^2 - 0.324 Cu + 0.0257 Cu^2 + 0.364 Zn - 0.00252 Zn^2$$

.... Equation I

The regression shows a critical value of N of 5.57%, K=0.51%, Fe= 108.6 ppm and copper, 6.3 ppm when the yield would be minimum and the optimum value of P = 0.303 and zinc = 72.22 ppm when the yields would be maximum. The ranges of values encountered in the seed in this experiment for N, K, Fe and Cu are 2.18 - 5.74; 0.295 - 0.890; 53.28 - 144.15 and 7.22 - 16.66, respectively. Assuming that by breeding and agronomic practices a value within about the range of nutrients already obtained in this experiment is possible, a maximum yield potential of 54.4 gm per pot of 6 plants covering a soil surface area for 452.6 sq. cm working out to the estimated yield potential of 119.2 q/ha can be obtained when N = 2.18%; P=0.303%; K = 1.2%; Fe = 220 ppm; copper = 16 ppm and zinc = 72.2 ppm.

In another experiment involving 4 varieties of wheat with 2 different spacings and 4 levels of P under two methods of application (broadcasting and placement), the yield of wheat was also significantly correlated with the composition of seed. When the data were pooled for 2 years, the following regression, which is statistically significant, was obtained (Equation II):

$$Y = 3540 + 19260 N - 4206 N^2 - 48876 P + 51924 P^2 - 54303 K + 739429 K^2$$

.... Equation II

From this, optimum values of N = 2.29 and P = 0.316% were obtained as against 2.18 for N and for P = 0.303% for pot culture, as well as a critical value of K = 0.367 at which the yield showed a minimum. Taking the optimum value of N and P obtained in this field experiment and a value of 0.67 for K, which is the value tenable in the range of K value obtained in the field, this regression gives a yield potential of 121 q/ha, which is very close to the one already estimated from the pot culture data.

In a further field experiment at Delhi with the varieties Sharbati Sonora and Kalyansona under both normal conditions and those subject to partial drought at the crown root initiation stage but with sprays of various nutrients applied to the plant at that time, it was observed that yield is significantly related to the composition of seed by the following regression which is also statistically significant with a R^2 value of 58.4% (Eq. III):

$$Y = 82.97 + 27.42 N - 7.65 N^2 - 167.57 P + 188.06 P^2 - 183.53 K + 246.86 K^2 - 0.06242 Fe + 0.000475 Fe^2 - 1.169 Zn + 0.0342 Zn^2 + 5.711 Cu - 0.5083 Cu^2$$

... Equation III

This yielded optimum values of N and Cu of 1.79% and 5.6 ppm for maximum yield and a critical value of P, K, Fe and Zn of 0.44%; 0.37%; 67.6 ppm and 17.2 ppm, respectively, for a minimum. Even in this regression, substituting all the values that were considered

needed for obtaining 119.2 q/ha in the pot culture experiment excepting the value of K which is taken as 0.87% tenable in the field experiments, a yield estimate of 124.6 q/ha is again obtained.

From these studies, it appears that if a suitable seed composition of the type assumed above in the field experiment is achieved, it should be possible to realize a yield potential of about 120 q/ha as against the maximum of about 80-90 q/ha being obtained with Hira at present. This estimate also tallies with the one recently made by physiologists on the basis of the sink capacity of wheat.

The next problem will, therefore, be the one connected with obtaining the above-mentioned agrochemical characteristics of wheat seed composition.

The pot culture data showed the following composition for Kalyansona seed under normal conditions of moisture and fertilizer application: 2.28%; 0.316%; 0.345%; 63.3 ppm; 37.6 ppm and 8.9 ppm for N, P, K, Fe, Zn and Cu, respectively; whereas the triticale strain ARM-133 showed a composition of 3.17%; 0.416%; 0.48%; 86.6 ppm; 58.4 ppm and 12.88 ppm, respectively, for the various nutrients. This shows that Kalyansona for N and P and triticale ARM-133 for zinc are near the stipulated composition. The trace element composition of triticale and major nutrient composition of Kalyansona are more near the optimum chosen, although improvements are still needed to raise the value of K and Fe considerably and Zn to a smaller extent. Breeding programmes have, therefore, to be geared to combine these two characteristics of Kalyansona and triticale ARM-133 and supplement them by both fertilizer and micronutrient application to arrive at the desired composition.

Assuming that a Kalyansona which requires 2.17 kg N; 0.38 kg P and 2.65 kg K for production of every quintal of grain, the nutrient requirement for producing 120 q/ha would be 260 kg of N; 104 kg of P_2O_5 and 382 kg of K_2O . Assuming also that the contribution from the soil is of the order of 30%, 50% and 40% of the soil available nutrient content and the percentage utilization of the fertilizer to be 50%, 20% and 150%, including the priming effect as is the case with Kalyansona this works out to a fertilizer requirement of 400 N, 450 P_2O_5 and 170 K_2O kg/ha. This means that the cross must also be a three-gene dwarf to withstand such high amounts of fertilizers. It will also be desirable to breed genotypes with high capacity to extract nutrients from the soil and to utilize more efficiently the applied fertilizer. There are wheat varieties which can easily utilize soil nitrogen to the extent of 50% and fertilizer P to 30%. If these properties are also combined the fertilizer requirement will come out to 320, 270 and 170 of N, P_2O_5 and K_2O on a soil with average N, P and K of 200, 10 and 300 kg/ha.

To sum up, the agrochemical requirements for producing 120 q/ha of grain may possibly be obtained by combining the major composition

characteristics of Kalyansona seed and the micronutrient composition characteristics of triticale and also making the genotype a three-gene dwarf.

Exploitation of hybrid vigour and utilization of divergent sources of dwarfing could also provide avenues for improving the capacity for nutrient utilization. Borlaug's dream of Rhizobium cerealis and the introduction of the capacity for biological nitrogen fixation in wheat may also come true some day.

d) Improving the yield potential of unirrigated wheat.

Negative correlations between root growth and duration, spikelet number and duration, and moisture availability and tillering ability reduce the yield potential of unirrigated wheat. Also, the bare adequacy of moisture at the time of sowing for germination renders fertilizer application difficult, unless implements which facilitate placement are used. In India, durum wheat is grown extensively in the black soil areas of central and peninsular regions where sowing has to be done with receding moisture.

Asana (1970) suggested selection for higher spikelet number on the main spike or a branched spike and for earliness for improving the yield and stability of performance of unirrigated wheat.

I believe that the present high-yielding varieties of wheat available are incapable of making full and efficient use of the naturally available growing season in the northern wheat belt. According to present recommendations, mid-November appears to be the optimum time for sowing high-yielding wheat varieties in most parts of the country. Our present highest-yielding varieties mature in 135-145 days, even under those environmental conditions where maturity is not hastened by hot, dry weather. When planted in late December they utilize no more than 100 days. Further south and east of the main wheat belt, the life cycle of the present varieties is completed in about 100 days or less.

The following two main climatic factors limit wheat yields in India:

- (i) High temperatures during September and October prevent early sowing and hence the exploitation of otherwise ideal growing weather during the immediate post-monsoon period. The present high-yielding varieties if planted early in the season (when maximum air temperature is above 30 C) suffer poor emergence, seedling mortality and enter the reproductive phase quickly without good vegetative growth. This results in poor stand, reduced tillering, smaller earheads, and early maturity leading to low yields.
- (ii) High temperature and atmospheric drought during March and April force the crop to mature and limit the crop season. If the hot weather sets in before the grain filling is completed, severe yield reduction occurs due to grain shrivelling.

In this part of the world, a large area is available for wheat sowing in October when the soil moisture condition is better for wheat sowing. If early sowings are made possible by breeding varieties which will tolerate initial high temperature and by evolving suitable production technology, wheat yields can be considerably increased.

There is a definite need to develop varieties suitable for planting at different stages in the season since all the fields are not vacated from the kharif crop early in the season. A wheat variety suitable for late planting should not only be of short duration and early in maturity but must also possess the ability to achieve rapid germination and rapid seedling growth under low temperature conditions. If tolerance to high temperature and atmospheric drought during the grain-filling stage could also be incorporated, the average duration of the crop will increase and this will improve the production potential of a late-planted crop. There is also need and scope for developing agronomic practices making plants less vulnerable to high temperatures late in the season.

By and large, a high degree of positive correlation has been established between plant height and coleoptile length. Because of a short coleoptile, high-yielding dwarf varieties very often result in poor stands due to deeper planting or due to low moisture in the top layer of the soil if seeded at the proper depth. In order to further increase the versatility of the high-yielding dwarf varieties, it is desirable to increase their coleoptile length so that good germination and satisfactory crop stand can be easily achieved, even in those situations where pre-sowing irrigation can be given with difficulty or not at all.

Substantial yield increases have been reported in maize following increased population densities and improved agronomic practices. High plant populations are needed to utilize the full potential of soil with high infiltration rates and high moisture holding capacities. However, soils with low infiltration or moisture holding capacities require reduced plant populations for best yields. To realize the yield increase through this avenue, it is important to synthesize varieties that will tolerate increased plant density and competition without deleterious effect on production physiology. It would be desirable to pay greater attention to developing varieties that will respond favourably to high plant populations and, optimum populations for such genotypes need to be established for different production environments.

At Pantnagar, Dr. J. P. Srivastava and his colleagues have been studying the grain yield performance of pure stands of fixed lines and their mixtures under irrigated as well as rainfed conditions for several years. The lines included in the tests were disease resistant to eliminate the effect of diseases in the mixed populations. We observed that certain mixed populations outyielded other mixed populations and pure stands, although the mixtures which gave highest yields in irrigated and rainfed conditions were differ-

ent. Mixed populations are discouraged because of possible heterogeneity of the produce and consequent difficulty in grading for milling and baking purposes. However, in India where most wheat is consumed as chapati, slight heterogeneity in the produce can be tolerated. Suitable mixtures of selected genotypes can be exploited to provide better crop insurance to farmers against uncertain rainfall and temperature prevailing in rainfed cultivation.

So far in this century the production of three major grain crops (maize, sorghum and pearl millet) has been revolutionized by the exploitation of hybrid vigour. Hybrid wheat has, in the last decade, received much attention. The interest presently seems to be on the decline, probably due to the difficulties associated with the number of genes required to restore fertility under adverse environmental conditions. A great advantage of hybrid vigour in sorghum is the resilience which it confers on the plant with reference to its ability to withstand the vagaries of weather and moisture stress. Intensive studies are needed in wheat to assess whether heterosis confers any advantage under conditions of drought. If wheat behaves like sorghum in this respect, further investment in a hybrid wheat programme will be worthwhile as a part of the over-all strategy for improving the yield and stability of performance of unirrigated wheat.

e) Improving yields through better agronomic management

Recent agronomic research in India under the All-India coordinated projects has revealed considerable scope for increasing yield and income per unit quantity of inputs through better management. The data of a few experiments are summarized below.

i) Water requirement of tall and dwarf wheats

The results of irrigation experiments with new high-yielding varieties of wheat have revealed that these varieties do not require more water than the tall varieties (Table 5). They, however, need better-timed application of irrigation during their growth.

Table 5. Evapotranspiration of different wheat varieties during rabi seasons of 1966-67 and 1967-68 (Singh, N. P. and Dastane, N. G. 1970).

Year	U.S.W.B. pan evapo- ration (mm)	Evapo-transpiration (mm)					
		Sonora 64	Lerma Rojo	Kalyan- sona	Safed Lerma	Sonalika	N.P. 718
1966-67	661.7	391.1	394.4	400.2	392.2	399.6	405.9
1967-68	644.3	303.1	300.2	307.2	301.0	297.9	308.0

ii) Critical stages of aestivum wheats for irrigation

Forty-eight experiments were conducted during 1965-66 to 1971-72 at different locations under the All-India Coordinated Wheat Improvement Project to study the most sensitive stages of crop growth when moisture stress is detrimental to crop yield and to answer the question, how best to utilize water if it is scarce. The conclusions drawn from these experiments, depending on ground water table and rainfall received, are summarized in Table 6.

Table 6. Time and frequency of irrigation of wheat crop ranked in order of final yield advantage.

No. of irrigations	Stage of crop growth at application
1	Crown root initiation (CRI)
2	CRI and flowering
3	CRI, jointing and flowering
4	CRI, tillering, jointing and flowering
5	CRI, tillering, jointing, flowering and milk
6	CRI, tillering, jointing, flowering, milk & dough

iii) Relative performance of aestivum and durum wheats and triticales

An experiment was laid out during 1971-72 at the Indian Agricultural Research Institute, New Delhi, to study the response of two varieties of Triticum aestivum, Kalyansona (two-gene dwarf) and Hira (triple-gene dwarf), one-dwarf durum (HD 4502) and one of the triticales to three moisture regimes, 0.0-0.3, 0.0-0.5 and 0.0-0.8 atmospheric tension, and three levels of nitrogen applications, 60, 120 and 180 kg/ha. Phosphorus and potassium were applied at uniform rates of 60 Kg P_2O_5 and 40 kg K_2O /ha respectively. The grain yield data from this experiment as influenced by various moisture regimes are given in Table 7.

Table 7. Response of *Triticum aestivum*, *Triticum durum* and triticale to moisture regimes and nitrogen levels (Singh, S. N. and Bhardwaj, R. B. L. 1972)

Moisture regimes (atm. tension)	No. of irriga- tions	Hira	Kalyan- sona	HD 4502	Triticale
<u>Grain yield (q/ha)</u>					
0.0.-0.3	10	58.5	53.0	59.4	40.9
0.0.-0.5	6	55.7	53.0	57.8	39.1
0.0 -0.8	3	45.2	48.0	53.9	39.3
S. Em. Var. within moisture $\pm$ 1.32 q/ha C.D. 5%=3.8 q/ha					
<u>Grain yield kg/10,000 litres of water/ha</u>					
0.0.-0.3	10	9.6	8.7	9.8	6.7
0.0-0.5	6	10.2	9.7	10.5	7.1
0.0-0.8	3	11.3	12.0	13.5	9.8

The triticale strain used gave the lowest yields at all the moisture regimes. The durum wheat (HD4502) gave the highest yield (53.9 q/ha) at 0.0-0.8 atmospheric tension with only three irrigations while the aestivum varieties (Hira and Kalyansona) ranged between 45 to 48 q/ha. The variety HD4502, however, continued to show superiority over these aestivum varieties at the other two moisture regimes also, though the differences were of lower magnitude.

Table 7 further reveals that for the unit input of water (10,000 litres/ha), dwarf durum HD4502 gave the highest return at highest tension in terms of grain yield (13.5 kg) while returns from aestivum wheat Kalyansona and triticale were 12.0 and 9.8 kg, respectively.

Another experiment was conducted in Delhi with the wheat varieties Kalyansona, Hira and dwarf durum HD4502 in a field with slightly different soil characteristics to study the effect of irrigation on the yield when applied at different stages of crop growth. A uniform dressing of 150 kg N, 75 kg P₂O₅ and 60 kg K₂O/ha was given to all the treatments. The results have been summarized in Table 8.

Table 8. Yield and gross income per 10,000 litre of water per hectare of different wheat varieties (Anon. 1972)

Varieties	No irriga- tion	One irriga- tion	Two irriga- tions	Three irriga- tions	Four irriga- tions	Five irriga- tions
<u>Grain yield, kg/10,000 litre/ha</u>						
Dwarf durum HD4502	26.3	24.8	22.4	18.1	16.6	15.3
Kalyansona	22.3	23.7	21.6	21.2	17.5	15.4
Hira	16.1	22.6	21.2	21.1	19.3	17.0
<u>Gross income, Rs /10,000 litre/ha</u>						
Dwarf durum	20.0	18.9	17.1	13.7	12.4	11.6
Kalyansona	16.9	18.1	16.4	16.2	13.3	11.7
Hira	12.9	17.2	16.1	16.0	14.7	12.9

Among the durum and aestivum wheats, durum performed better under no irrigation or when one irrigation was applied (Table 8). With only a pre-sowing irrigation, dwarf durum produced 26.3 kg grain per 10,000 litre of water per hectare as against 22.3 kg by aestivum wheat Kalyansona. Even with one post-sowing irrigation dwarf durum gave better performance as compared to Kalyansona, although the difference between the two was less. With a higher number of post-sowing irrigations, aestivum wheat was superior to durum. This opens the possibility of extending dwarf durum wheat cultivation in black soil areas of the country with higher moisture storage capacity, particularly under receding moisture conditions.

Irrigation scheduling based on the ratio between the quantity of irrigation water and U.S.W.B. pan evaporation

The experiments conducted under the All-India Coordinated Research Project on Water Management and Soil Salinity have revealed that irrigation scheduling based on the ratio between the quantity of irrigation water and the U.S.W.B. pan evaporation value has yielded useful results. This approach can be easily adopted by the farmers as well as irrigation engineers for efficient use of water with maximum crop yield.

Since agronomic practices will be location specific, agronomic research in different agroecological conditions will be absolutely essential to make the new strains reveal their full genetic poten-

tial for yield.

f) Improving nutritive and end-use quality

The extensive work done at the University of Nebraska since 1966 on screening to improve nutritional quality through increased protein content and improved amino acid balance has recently been summarized. Large variations in protein and lysine content have been found in the 16,000 wheats which were analyzed. The data suggest that wheat with high grain protein (14-17%) can be achieved from genetically high-protein varieties grown under high soil fertility. CIMMYT work has shown how rapid screening can be done for gluten strength and other protein properties conditioning the end-use property. In further work it would be useful to keep the following in view.

1) As pointed out by Munck (1972), the ranking of breeding goals and splitting of a complex character into its components are two important prerequisites with special reference to nutritional quality.

2) Now that simple tests are available, improvement for protein content and quality should be broken into components:

- a) rate of synthesis (speed) and
- b) prolongation of synthesis (period).

Both the parameters can be measured easily. Furthermore, higher protein accumulation in the sink could be due to

- a) better efficiency of conversion or
- b) more N uptake (better root system).

The above mentioned factors should be emphasized in all proteinaceous crops. Simple selection for higher protein content is inadequate in view of the tools developed in biochemistry and physiology.

3) Screening methodology and breeding strategy should be such that calories are not sacrificed at the cost of proteins (the mode of presentation/expression of data should be standardized).

4) Some microtests for biological value need to be introduced much earlier in the programme than has been done so far. Organisms such as Tetrahemna or confused flour beetle might have a role to play after enough standardization is done.

5) Standardization of analytical tools and formulation of screening sequence schedules for different crops is necessary. Sometimes it may be necessary to simultaneously screen for an antinutritional factor (e.g., interfering carbohydrates) along with a nutritional factor (e.g., lysine or tryptophan).

6) Fundamental studies are needed in genetics (r^2 , stability covariances and control mechanisms) as well as in physiology and biochemistry.

7) The detrimental effects of such ingredients as tannins, polyphenols and oligosaccharides might reduce the biological value (BV) of otherwise balanced protein crops. This might explain the reduced BV of floury-2 as compared to opaque-2.

8) Great potential of alien chromatin in wheat improvement needs to be emphasized and the findings of Riley and co-workers should be exploited.

g) Improvement of triticales

The organization of International Triticale Yield Nurseries by CIMMYT is a very useful service. Several CIMMYT-derived lines indicate promise in some areas in India, although the average yield of triticales strains was significantly lower than that of Kalyansona. The top-yielding triticales strains are being tested more extensively (Table 9). Zillinsky and Borlaug (1971) have reviewed the progress so far made. The following are some areas worthy of more intensive study:

i) Basic studies: Some of the studies needed are

- (a) Basic physiology in relation to kernel development, floret fertility, tillering, ecological adaptation, maturity, yield, etc.
- (b) Genetic and cytogenetic investigations in relation to seed development, floret fertility, combining ability, etc.
- (c) Agronomic investigations for maximizing production and better economic return.
- (d) Differential crossability of wheat and rye varieties and its possible relationship to their combining ability.
- (e) Nature of reproductive system and the possibility of developing out-crossed triticales for taking advantage of hybridity and exploitation of hybrid vigor.
- (f) Suitability of triticales under rainfed conditions and identifying the desirable attributes of the plant such as extensive roots, quick grain filling, water requirement at different stages of plant development, etc.

ii) Stabilizing productivity potential and increasing adaptation

Experience so far has shown that triticales strains lack sta-

bility and are poor in adaptation. This is not too unexpected considering that in triticale two very unlike "systems" have been combined and the resultant system is relatively "new". Further, the system has been developed on a narrow genetic base.

Natural evolution is a slow process. In triticales, evolutionary processes have to be expedited in order to accomplish the same in a fraction of the time nature would have required otherwise. We are not sure how this can be done, but certainly extensive and collective efforts under different ecological conditions should be a step in the right direction. In triticales, so far mostly rye varieties of N. American origin have been used. Photo-neutral strains of autogamous rye resistant to inbreeding depression may prove more useful in increasing stability and adaptation. There is a need for collecting more germ plasm, particularly from Central Asia which is the centre of origin of this species.

With the undertaking of an extensive and systematic program, mainly at CIMMYT, University of Manitoba, Canada and J. N. Agricultural University in India among others, it would be possible to develop widely adapted, stable, high-yielding triticales. This would necessitate, however, a closer cooperation, enabling a free flow of material and exchange of ideas among different centres involved in the improvement of this crop.

iii) Specific adaptation

Triticale, being a combination of two distinct plant species, provides a unique opportunity to develop plant types by appropriate genetic manipulations better suited for growing in a season, and in areas where wheat and/or rye will not grow very successfully. In Mexico, at two higher elevation locations (El Batán and Toluca) some of the triticale varieties gave about a ton more yield than the best wheat variety. Apparently at these locations, the growing conditions were too wet, creating drainage problems and disease infestations not suited to the wheat crop (CIMMYT Report 1970-71). In India, a programme is underway at Indore to develop triticale varieties suitable for planting around mid-August under rainfed conditions to take advantage of the better soil moisture conditions. The growing conditions in the earlier part of the plant growth will be rather wet and the temperatures would be 70 - 90 F until around mid-October. If such a variety is developed, this would solve the problem of rainfed wheat grown in this area, which is planted around mid-October. The yields are very poor due to scarce soil moisture after December. Preliminary results indicate that triticale would grow better under saline soils. This needs to be more thoroughly investigated.

iv) Nutritional quality

(a) Protein and lysine content: Limited studies made to date show that a wide range in protein (12-21%) and lysine content (0.36-0.72%) exists in triticales of different genetic background (Zillinsky and Borlaug 1971). A greater range in protein content

(12.4-20.7%) was observed in different selections from an otherwise pure breeding advanced line (Sisodia 1971). It should be emphasized that this condition exists in the available germ plasm where no consideration for these characters had been given in the choice of parents used for the development of triticale. Utilization of high-protein wheat varieties, such as Atlas 50 and Atlas 66, may help to produce triticales with still higher protein content. Variability for protein and lysine content in rye germ plasm needs to be studied to enable the utilization of high-quality rye parents in the synthesis of triticale. There is also a need to understand the basic factors contributing to the higher protein content of triticale.

h) Biological efficiency of protein

Recent work on bioassay of quality by Dr. F. Elliot at Michigan State University and at CIMMYT using meadow voles has shown that triticales ranged in quality from very poor to nearly equal to the quality of egg protein (CIMMYT Report 1970-71). Variability for Protein Efficiency Ratings (PER) from 0.7 to 3.88 has been reported compared to 2.50% for 7% casein used as a check (Zillinsky and Borlaug 1971). It was also found that triticales high in protein content are not necessarily nutritionally superior, perhaps due to the presence of some antimetabolic (toxic) compounds. The causes for such differences in quality need to be more thoroughly investigated.

It would appear that wheat and rye varieties may differ in PER values since they have been never subjected to selection for this character. Therefore, a programme of screening germ plasm of these crops for PER values to identify nutritionally superior varieties for use as parents in the development of triticale may prove useful.

v) Improving lodging resistance

Isolation of a dwarf plant recently in the rye variety Gator by Dr. Zillinsky (CIMMYT) provided a source of a dwarf gene in rye. This strain has been named Snoopy. Using the Norin 10 dwarf genes, general experience so far had been that the dwarf types E2 and E3 tend to be sterile and have more shrivelled kernels, although Zillinsky and Borlaug (1971) reported isolation of E2 triticale strains having good fertility. Recently, Kiss and Trefar (1970) reported that the wheat variety Tom Thumb is a better source of dwarfness. Using this variety they have been able to obtain highly fertile triticales ranging in height from 40 to 100 cm and having good kernels.

vi) Yielding ability

Until recently, the main problem limiting yield in triticale had been reduced floret fertility and poorly developed kernels. The problem of floret fertility has been largely overcome and new lines comparable to wheat in fertility are available. Considerable

progress had been made in improving kernel type by better parental combinations and by rigid recurrent selection for this character. Lines with well-developed, plump kernels almost comparable to wheat are now available (Sisodia, personal communication). The genetics of this character needs to be studied to see if it can be transferred into other strains easily.

Experience has shown that kernel development in triticales is considerably influenced by growing conditions. Studies on the physiology of kernel development would enable a better understanding of this problem. Selection procedures now in use at CIMMYT for improving kernel density using sucrose or K_2CO_3 solution should be helpful (not used as CIMMYT, editor's note).

The improvement in floret fertility, kernel type, plant type, breeding procedures, extensive efforts and a better understanding of the triticales plant are expected to have an additive effect in improving yielding ability in triticales.

vii) Utilization of triticales

The discovery of a durum type wheat with excellent bread-making quality at the University of Manitoba (Kaltsikes et al. 1968) opened up a new possibility of using triticales in human diets in western countries beside its use in animal nutrition, distillation, pastries etc. Triticales flour is suitable for making "Chapatis" and "tortillas" and this characteristic can be further improved by appropriate genetic manipulations. With the identification of a white-seeded winter rye strain and induction of a white-seeded mutant in a spring rye variety (Sisodia, unpublished), it would be easier to develop white/light seed color triticales preferred in countries such as India.

Table 9. Average yield of triticales strains in different trials during 1969 through 1971 (expressed as percent of Kalyansona)

Sl. No.	Year and trial	Condition of sowing	Number of triticales strains	Av. yield (% of Kalyansona)	Yield of top strain (% of Kalyansona)
<u>1968-69</u>					
1.	Initial Evaluation Trial	Irrigated	5	70.74	84.91
<u>1969-70</u>					
2.	Small Scale Trials	Irrigated	7	84.48	97.21
		Rainfed	5	75.46	90.34
3.	First International Triticales Yield Nursery	Irrigated	11	87.51	109.94
<u>1970-71</u>					
4.	Second International Triticales Yield Nursery	Irrigated	12	55.09	78.19
5.	Selection Trial	Irrigated	17	78.26	99.95

Conclusion

The panorama of possibilities for improving further the yield and quality of wheat and barley and for introducing triticale as a cereal crop in rainfed areas is great. Today's need is for population excellence in plants as against individual and competitive virtue which was essential for survival in nature and under stagnant agricultural conditions where the unholy triple alliance of weeds, pests and pathogens made it necessary for the plant to specialize more on survival than on production. Similarly, there is need for co-operative research among scientists belonging to different disciplines and countries. In the impressive progress made in wheat production during the 1960's, CIMMYT played a catalytic role. It is essential that CIMMYT continues to play a pivotal role during the seventies in both path-breaking research and in fostering regional and national collaborative programmes designed to achieve a scientific destruction of the factors causing instability in production and in obtaining more yield per unit quantity of water, time and nutrient supply. Wheat production will hold the balance between hunger and reasonable nutrition during the seventies, since wheat will continue to serve in the near future not only as a staple for millions but also as a buffer crop whose added productivity will have to compensate for shortfalls in the production of rice and millets.

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Comments by Rao

1. In light of the great role played by CIMMYT in the 1960s that resulted in impressive progress in wheat production in developing countries, it is essential that CIMMYT should continue to play a pivotal role during the 1970s in both path-breaking research and in fostering regional and national collaborative programmes designed to achieve a scientific destruction of the factors causing instability in production and in obtaining more yield per unit quantity of water, time and nutrient supply.

(a) CIMMYT should continue to train young scientists of different countries to make them highly motivated and dedicated to the purpose of solving problems in their respective countries. This could be a short training programme at CIMMYT for 6 months to 1 year.

(b) CIMMYT should arrange frequent get-togethers of senior scientists and breeders of programmes in different countries for exchanging ideas and reviewing progress made.

(c) CIMMYT should continue to generate new materials of bread and durum wheats, barleys and triticales and supply them to needy countries.

(d) The different nurseries and yield trials which CIMMYT is now organizing all over the world should continue since they are serving a very valuable purpose.

(e) CIMMYT, because of its multinational collaborative activities, is in a position to provide international surveillance and warning systems for major destructive diseases. The country programmes should be warned in advance of the new races of diseases that may pose a problem to those countries in the near future. This will enable the country programmes to reorientate their breeding, control or multiplication programmes.

(f) CIMMYT should take up basic research on problems of long range or practical application. These include:

(i) Identification of cheap, efficient and preferably harmless chemicals of a systemic nature which could be used by farmers without undue difficulty in terms of cost and application.

(ii) Minor elements like zinc are limiting production in some areas. Varietal differences to the micronutrients are becoming evident. CIMMYT may help in screening wheats to identify suitable genotypes tolerant to micronutrient deficiencies.

(iii) Large areas in countries like India and Pakistan are being rendered useless and uncultivable due to salinity-alkalinity problems. Varieties of wheat, barley and triticales have to be identified that can tolerate these conditions.

(iv) Physiological investigations to identify photosynthetically more efficient genotypes and development of quick and simple techniques that will help to select such plants in segregating populations. These

studies also should be extended to identify genotypes that will exploit the abundant sunlight of tropical areas. Similarly, techniques should be developed to identify drought-resistant segregates in breeding populations.

(g) In several of the developing countries equipment and chemicals needed for research purposes are not available. CIMMYT should investigate the possibility of securing funds for obtaining these facilities for these country programmes.

2. CIMMYT should work toward the stabilization of dwarf wheat yields by reducing their genetic vulnerability to diseases and pests through:

(a) Development of national, regional and international surveillance and warning systems.

(b) Evaluation of germ plasm under varying conditions and locations and picking up suitable genetic stocks for different breeding purposes and against different diseases.

(c) Development of varieties with the more enduring horizontal or nonspecific resistance to the major diseases.

(d) Development of multilineal varieties of important commercial bread and durum wheats.

3. There is a great need for increasing yield under unirrigated conditions which may be approached in the following ways:

(a) Utilization of winter wheats to develop drought-resistant spring wheats.

(b) Identification of wheat genotypes that are thermo-insensitive and that could be used for planting at a time when the residual moisture available in the soil after the monsoon is fully utilized for uniform germination and growth. They should have tolerance to high temperature and drought at the grain-filling stage.

(c) Development of dwarf wheats with a long coleoptile.

(d) Identification of mixtures of genotypes or varieties that tolerate increased plant density and competition.

4. To improve the capacity to give better returns from unit inputs of fertilizer and water and thereby help to reduce the cost of production on small farms.

5. (a) Exploitation of the high yield potentialities of dwarf durums.

(b) Exploitation of the potential of dwarf durums for greater output per litre of water.

6. CIMMYT should continue to work for the next quantum jump in yield.

(a) Exploitation of winter wheats in spring wheat breeding programmes so that different genes for yield are brought into the spring wheat background.

7. CIMMYT should work for the next quantum jump in barley.

8. CIMMYT should intensify work toward the development of high-yielding-cum-high-quality varieties of food and feed barley. Since barley acts as a collateral host to some of the major wheat diseases like the stem and stripe rusts, there is a need to incorporate resistance to these diseases in barley in the interest of protecting the wheat crop. Besides breeding lodging- and disease-resistant barleys, it is important in countries like India to incorporate resistance to major pests like the aphids.

9. CIMMYT should continue to improve the nutritive and end-use quality of bread and durum wheats.

10. CIMMYT should continue to develop commercial varieties of food and feed triticales for unirrigated areas.

DISCUSSION

Anderson

I would like to make a comment. There may be some erroneous conclusions drawn from your remarks. I feel you are emphasizing certain problems, but I think perhaps you are over emphasizing certain aspects which may be misunderstood by the nonbiologists in the group. First --the risk of Kalyansona-- you have brought out the point that you are bringing in the multilineal approach as one of the protective components but you did not bring out the fact that you have a great many new varieties in your program which show resistance and good results from a yield standpoint. Some of these are under multiplication and will tend to diversify the germ plasm as a protection against epidemics.

On the question of CIMMYT's role in monitoring disease on a worldwide scale --I think this will come out during the week. The monitoring system has been operative for some time in the Eastern Hemisphere and this year for the first time a similar monitoring system has been initiated and we hope these can be crossed over and complement one another on a global basis.

A third point, I think what you said about Alternaria may scare a lot of people. It should be pointed out that certain genotypes are outright killed by the disease but the varieties under production may show some reduction, but not of this magnitude.

You commented on the building of a system similar to that

operative in corn and Puccinia polysori. We must differentiate between maize as a cross-pollinated crop and wheat as a self-pollinated crop. Thus, setting up such a system in wheat will have to go in some other fashion, perhaps multilineal or other means to effectively produce synthetically a similar situation.

Recently, I was in Ottawa, Canada. The physiologists were explaining some of the developmental patterns in wheat. In Pitic 62, a widely adapted variety, there appears to be a system operative wherein you have a continuation of budding off of spikelets along the rachis. There is no beginning of sexual organs during this process of elongation. When elongation has gone as far as the environment allows, sexual differentiation stops the process and proceeds through the florets. This may explain why this variety is very widely adapted since it can take advantage of the environment insofar as it will allow.

In a second variety, Opal, another system operates across the spikelet so florets continue to develop and then sexual differentiation occurs to stop the process. A combination of these two systems could be very beneficial.

Rao

Regarding resistance in Kalyansona and other varieties, we are growing two genotypes extensively over India, particularly in irrigated areas. These two, Kalyansona and Sonalika, have become susceptible to races of stem rust. We asked certain states in the South, from which the inoculum is blown to the North, to grow genotypes other than these to protect them in the North. Some of the newer varieties such as Lal Bahadin, Moti and Hira were not very resistant but UP 301, a triple dwarf, carried resistance and is grown there. It is a little lower yielding than Kalyansona.

We now have material in the assembly line. Nainari 60 x Lerma Rojo, which is called HD 2009 in India, seems to be resistant to all three rusts all over India. About 300 quintals of this are under multiplication and we intend to have 200 to 300 acres of land for summer multiplication.

It is heartening to learn that disease surveillance is being so well covered in the two hemispheres. This should greatly assist our program.

Alternaria has been known since 1944 but it never posed a problem. In 1956, Kenya 48 used to contribute stem rust resistance to varieties of Maharashtra such as Kenphad 25, 28 and 42, which were released and completely killed. One farmer growing Kenphad 25 was hoping to harvest 6 to 7 tons of wheat but the Alternaria killed the crop in one week. The damage, therefore, can be disastrous when it comes. It is a problem where humidity is high. Fortunately, Kalyansona is quite tolerant. At its release, it was resistant to the rusts, and is immune to loose smut, bunts and powdery mildew.

Finally, I wish to comment on horizontal resistance. Recently, an FAO project was circulated to utilize male sterility to build

up horizontal resistance by allowing free interpollination. I have my own reservations on this from a quality standpoint, adaptation and other problems, but I think the multilineal approach or exploitation of the known horizontal resistance of Yaqui 50, Hope or Thatcher is absolutely essential.

Qureshi

It may be very useful to identify the genes which can express their efficiency at different agronomic levels. We recently developed a strain which we compared with Mexipak and Chenab 70 under low levels of fertilization and one irrigation. The number of irrigations was also raised to five and fertility was raised to 120 kg N/ha and 75 kg P₂O₅/ha. At one irrigation and low fertility, Mexipak gave 23 maunds per acre, Chenab 70 gave 25 maunds per acre, and this strain gave 47 maunds per acre (1 maund = 82 pounds). At the high level, Mexipak gave 55, Chenab 70, 59 and this strain gave 50 maunds. This shows the new strain is highly efficient at low levels of fertilizer.

The important point in this was time of first irrigation. When one is given, when should it be applied? We applied it at floral initiation, about 4 to 4 1/2 weeks. The second treatment was irrigation applied just before heading. The first was much superior in effect.

In another strain, germination was very poor at early planting whereas in late planting it germinated well. This kind of variety could be very useful.

Fischer

I am sure you both (Drs. Rao and Qureshi) agree that you can not produce high yields without N. I think this is a dangerous opinion. In the case of a five ton wheat crop at 14% protein, there is 125 kg of N per hectare in the grain. Eventually, if you run down the fertility, you will have to apply N to continue cropping. So that is the sort of lower limit you must keep in mind.

Wellhausen

If I understood correctly, India's goal was 36 million tons by 1985. How does India propose to get this increase? You spoke of a quantum genetic jump. This may take time. How much can you do in the irrigated area to extend the present technology and how much in the nonirrigated areas? Can you meet this goal?

Rao

We have 19 million hectares under wheat. There has been a gradual increase in the area under wheat in recent years. This year, due to the failure of the monsoon, Indian food production dropped by about 12 million tons. How were we to compensate for

this loss? Since we can not predict weather, we had two alternatives. One was to increase area, which is becoming difficult, but the greatest production increase must come from higher yields per unit area. Denmark and the United Kingdom produce 4 to 5 tons of grain per hectare whereas India produces about 1.4 tons. In the National Demonstrations, we were able to get 7 to 8 tons per hectare. When we compare this with the national average, you can see that there is great scope for increasing yields.

What about fertilizer? This is a big factor in limiting production. We are short of fertilizer, both India and Pakistan, as Dr. Qureshi says. This year when the government wanted us to program for 33 million tons of grain, up from the previous 26.5 million tons, fertilizer was the biggest bottleneck since it was short by 40%. This is conflicting. Once imports are available, I am sure production can be raised rapidly.

More electricity needs to be produced for more minor irrigation projects which are developing. Previously, about 25% of the wheat was irrigated and now 50 percent is under irrigation.

The agronomy of rainfed wheat will also make an imprint. Our agronomists have shown that yields can be doubled by minimal agronomic treatment with fertilizer.

Taken together, these factors can allow us to advance the production figure to 36 million tons.

Saari

The potential for production on the land now in use is really very great. In Punjab, which is in addition a real rice basket, average yields are only 2.3 t/ha. Within this area is the Ludhiana District of 94,000 hectares which averages 3.3 t/ha. This is probably the worst soil in Punjab, being largely sand culture. In this northwestern area alone, there is a tremendous potential for increased production.

Wellhausen

You have about 10 million hectares under irrigation. How much of this area is actually under new technology?

Saari

About 60%.

Wellhausen

So there is still a considerable distance to go.

Borlaug

At what level of N is this technified? This is pretty important and this is the thing that will keep it moving, and this is not

just India or Pakistan, but every country in the world. This fertilizer shortage is the biggest bottleneck of all the factors. Also needed are economic policies that will allow the system to work. It is not the resistance of the small farmer. It is lack of planning, lack of availability of inputs, especially fertilizer.

We have moved faster in the genetic production of plants that will respond although we have the whole question of rusts not willing to cooperate. I would like to have you, Paul (Mangelsdorf), explain to some of your friends in the ecological movement that it was not just recently that insects suddenly developed resistance to chemicals because rusts have been changing all the time. It makes no difference whether the organism mutates for resistance to a chemical built into the cell or put on the surface. The principle is the same. Those who are vocal have distorted the whole picture in television and headlines. They have diverted attention from such big problems as fertilizer supply so necessary to replace the extraction of plant nutrients which has gone on for hundreds of years. We are not going to starve to death yet, but this doesn't make me any more complacent about the population monster.

Anderson

I would like to stick my neck out and say that one could roll back the acreage by about three million hectares and if known technology were fully applied, we could get 50 million tons production from this area.

Commenting on Dr. Qureshi's statement, Dr. Fischer is absolutely correct. You take out a measureable amount of N. Thus, the variety Dr. Qureshi, which you report may have a root system which exploits a deeper profile and this is where your N is being removed. This may be advantageous in itself in bringing back N which has leached below the root zone of the previous varieties. You can not look to the variety, however, as a permanent solution to your N needs.

Anonymous

Dr. Rao, there are about 9.5 million hectares of irrigated wheat in India and the figure given for high-yielding varieties (HYV) is only 4 million. Why is the rest of the area not under HYV?

Rao

The problem is one of extension to reach every village, but as I said in 1964-65 the area under these varieties was four hectares and now it is 4 to 5 million and by the end of this season it will be 7 to 8 million. However, the proportion of HYV to native varies from state to state, e.g., in Punjab it is 76%, in Uttar Pradesh, 46%, in Bihar it is 80%, but in Madhya Pradesh and Gujarat it is barely 5%. So, it is a question of extending the HYV to the smaller farmers.

THE ALTERNATIVES BEFORE US IN AGRICULTURAL DEVELOPMENT: AN ECONOMIST'S VIEW

Theodore W. Schultz

Future historians will say that there emerged during the middle of the 20th Century a highly mobile group of agricultural scientists who became the Phoenicians of their day in disseminating new agricultural knowledge. These adept merchants of knowledge traveled widely. They preferred to fly either east or west around the world with their briefcases packed with specifications of new crop varieties. In the long-settled, densely populated countries they provided the ingredients for the Green Revolution. They soon learned that the modernization of agriculture is a complex human activity. They succeeded, however, in coping with this complexity and as they did, it became evident that the new, useful agricultural knowledge provided by them was of major importance in enlarging the production possibilities of these countries and that the social and economic gains were very large.

The historian will undoubtedly report that the success of this new species of Phoenicians was won easily and in a remarkably short period of time. But the personal diaries of these agricultural scientists will reveal all manner of difficulties which the historian will have overlooked. With no further ado about the tricks of history, what are the alternatives before us? Nature has recently dealt harshly with agriculture in many parts of the world. A new wave of food emergencies is once again upon us. Presumably, the importance of increasing the productivity of agriculture is now higher than formerly on the agenda of major food-deficit countries in determining their public allocation of resources to development. The apparent implications of those events and changes in public policy should be favorable to a more rapid adoption of new crop varieties and other modern agricultural inputs. There is room, however, to doubt that most of the countries in which agricultural development has lagged will now become efficient in this respect. The reason for my doubt is not that the technical and economic requirements for the rapid development of agriculture are not known, but that political and, to some extent, budget constraints will fetter the process.

Before considering these and related constraints, a clarifying comment is called for on the topic assigned to me. My approach is much more modest than what is implied by the concept of a strategy.

The notion of a War on Hunger is appealing and to get on with that "war" a strategy is required, as if we in agriculture were projecting and directing a great military movement. I am strongly inclined to leave the concept of strategy to the military brass in the Pentagon of each country, badly as each performs its national task. My concern is about public and private policy choices in the modernization of agriculture because much depends upon the choice that is made whether or not a country approaches an optimum rate of agricultural modernization. I shall direct my comments to the clarification of these policy choices.

It is all too convenient for governments to blame the recent adverse weather for their food deficits. Although it is true that Nature has been less cooperative than it had been for some years, it is also true that the highly centralized governmental management of agriculture, especially so in parts of eastern Europe and in the Soviet Union, accounts for much of the poor performance of agriculture. Furthermore, the impressive progress during the last decade in agriculture development in countries of South Asia may be hampered during the near future by an array of new adverse circumstances. Nationalism has become more acute and normal international trade and investments are being hurt by it. It is also making the exchange of the useful knowledge more difficult than it was a few years ago. Widespread social criticism has placed science under a cloud. The ecology movement has branded modern agriculture as one of the prime polluters. It is alleged and widely believed that welfare is being sacrificed on the alter of the Green Revolution. How can agricultural scientists best cope with these conditions?

My approach to this question is to apply the economic analysis underlying my 1953 study, The Economic Organization of Agriculture for development and stability in searching for solutions. I shall examine two different classes of circumstances about which agricultural scientists cannot afford to remain passive because of the potential effects that these circumstances will have in shaping the agricultural production possibilities in many countries. They are: (1) public attitudes and perceptions of the role of agriculture in development, and (2) the role of political economy in the modernization of agriculture. I shall contend that agricultural scientists must choose among alternative options and that a stance of neutrality will be neither comfortable nor rewarding in getting on with the job of modernizing agriculture.

I.

Turning to public attitudes and perceptions of the role of agriculture in development, there is one basic favorable change; but there are three recent developments that will burden your endeavors. The favorable change is that the public and those who are in charge of technical and economic affairs in most of the less-developed countries no longer believe that a monolithic commitment

to industrialization is the best economic policy. Modernizing agriculture is now on their policy agenda, for they have learned that gains in agricultural productivity are essential and that farmers in these countries also respond to new opportunities to improve their lot. This is a fundamental change that has occurred since World War II. The agriculture scientists associated with CIMMYT, those at work in the Philippines and at other locations can claim considerable credit for this favorable turn in public awareness of the positive economic role of agriculture in development.

One of the main purposes of my book, Transforming Traditional Agriculture, was to lay to rest the then widely held belief that farmers in poor countries are immune to economic incentives. They had long been grossly maligned; for they were viewed as dullards, indifferent to any new and better economic opportunities and as robots who farm solely in accordance with tradition. The Green Revolution has undoubtedly accomplished much more than I did in establishing the fact that farmers in India and in any other poor country are not indifferent to real opportunities to improve their income.

Among the unfavorable developments there is first the recent, narrow and very misleading view of the welfare implications of the Green Revolution. The issue is not whether welfare is important; it is obviously a major social objective in most countries. But the partial and exceedingly narrow view of welfare that characterizes most of the recent literature on this issue is badly biased because it fails to reckon the improvements in the welfare of consumers made possible by the gains in agricultural productivity. Since I have elaborated on this subject in my Pugwash paper, "Knowledge, Agriculture, and Welfare," I shall not repeat the analysis here, except to note that it is impossible and, therefore, wholly unreasonable to contend that no technical advances in agriculture should be made available unless they benefit all farmers equally, regardless of differences in the size of their farms whether the soil is poor or good, and regardless of the difference in level of their farming skills; and equally also at all locations no matter how diverse the agricultural possibilities are within a country in terms of soils, rainfall, other climatic factors, and the availability of irrigation, fertility and transportation. To impose these conditions on agricultural modernization and call it "serving the welfare of a people" is absurd.

The second unfavorable development influencing public attitudes arises out of the new ecological politics. Agricultural scientists cannot afford to remain passive with respect to some of the demands that the ecology movement is making on agriculture. While the major objectives of this movement have real social value, it is patently wrong when members of this movement proclaim that modern agriculture and the ecological requirements are incompatible. The basic reason why they are wrong is that man does not live for ecology. Let me explain what I mean by this statement. Ecology is a branch of biology that deals with the relation of living things to their environ-

ment and to each other. Since living things are altered over time by evolution and by man, the ecological relation changes. The environment is also altered over time and, importantly so, by man. It follows, therefore, that the so-called ecological balance is a transitory, ever-changing state of relationships of living things to each other and to their environment. Were it not so, there would be no ecological adjustments, even to evolution. Moreover, evolution, with or without man, has not and probably never will arrive at a stationary state. Thus, it is not conceivable to me that there is an ideal, all-inclusive ecological balance that could be established once-and-for-all. As an economist, I treat the ecological components of Nature as a scarce resource in the decisions that man makes wherever he may be. It is of course a very complex resource, highly diverse; and, it has been altered vastly over time and the process continues, especially so as a consequence of the advances in scientific knowledge. In thinking about the role of man as he uses and misuses this particular scarce resource, there are many maladjustments, and there is need to learn how better to use this important scarce resource.

The ecological mischief of modern agriculture, despite all the rhetoric to the contrary, is not of major importance. Only a tiny fraction of the worrisome pollution of the air is from agriculture. The processes of nature account for vastly more earth erosion and soil silting than farming. There is some harmful chemical spillage out of agriculture but the social losses from it are being grossly exaggerated these days. These losses can and should be minimized and it would not be difficult to do this by simply internalizing them as part of the cost of farming.

Let me press the ecological issue on you because of the knowledge you have and of the stake you have in furthering agricultural development. You would be irresponsible if you were not contributing to the public clarification of this issue. You must engage in this dialogue for there are ecological proposals that are clearly counterproductive. I have in mind proposals demanding that economic growth be stopped, based on the false proposition that it inevitably reduces the quality of life, that the modernization of agriculture be brought to a halt on the mistaken belief that chemicals are necessarily harmful in what they do to soils and to the nutritive value of crops as food, and that food additives should be prohibited for the same reasons. Being rich, proposals such as these can be lived with for a time until we learn better. But poor countries cannot afford this type of luxury. If they were induced to adopt and enforce these particular bad proposals, it would impose on them continuing poverty and vast food deficits.

My protest is restricted to the particular proposals that arise out of a type of doomsday thinking and they are, as already noted, counterproductive because they preclude rational solutions to the world food problems.

Many students and faculty, both in the U.S. and other rich countries, have embraced the belief that the habitat of living

things is now suddenly in jeopardy and top priority must be given to saving the ecology. The rhetoric that I hear declares that the ecology, including the life of man, is doomed by DDT which, like knowledge, once you get it you cannot get rid of it. Chickens are fed on medicated feed and animals on insidious chemicals. Give us back the sacred cow but don't drink her milk and declare the pig unclean as of old. Then, we are back to food grains, but they are grown from seeds coated with poison. Then comes the new dogma that modern agriculture inevitable destroys the ecological balance, systematically eliminates wild life, fills our streams and lakes with nitrates and phosphates and with even more destructive chemicals from pesticides and hormones. The conclusion that follows from this type of doomsday thinking is that modern scientific agriculture and its economic organization is incompatible with quality of life. Given this dogma, what is the logical solution? Obviously, it is to eat only vegetables and to produce all of them in our own organic gardens! ¹

I confess that I am perplexed by this type of thinking. What is the explanation? I am inclined to attribute it to our being so very rich; for I doubt that this dogma would have become established if we were as poor as the people of India. They urgently want and need economic growth, a modern agriculture, and foods that are fortified with proteins and other additives. We ought to know that organic gardens and "self-sufficient" communes are merely social hobbies that some rich people can afford and enjoy. The intellectual biases that I attribute to our high levels of income are a serious handicap to clear thinking in solving the problems on our agenda. It is a part of your responsibility to challenge these biases, as some of you are doing.

The third unfavorable development is a consequence of the change in public attitudes toward the sciences. Scientists are increasingly on the defensive because of the many antiscience protests, which have created serious doubts about the social value of the sciences, and because of the alleged wrong allocations and the mismanagement in the use that is being made of the vast increases in public funds allocated to research and development.

Nor is agricultural research being spared. In the United States public criticism is clearly evident. The Nader-sponsored report, Hard Tomatoes and Hard Times, is no doubt too shrill and one-sided to be widely believed. But the Committee report of the National Academy of Sciences on federal and state agricultural research is another matter. It charges inept management and poor research. (See Science, January 5, 1973, Vol. 179, pp. 45-47.)

¹A part of this paragraph is drawn from my paper, "The Ecosystem Doom," which appeared in the Bulletin of the Atomic Scientists, April, 1972.

I devoted the last section of my paper "Knowledge, Agriculture and Welfare" to the importance of enlarging organized agriculture research, concentrating on the requirements of the less-developed countries. I also sketched the reasons for the lack of success on the part of FAO, USAID, and the various other governmental bilateral approaches. I shall, therefore, not dwell further on this important issue.

Your research enterprise is fortunately much less vulnerable to the public criticism that is now being leveled at the sciences. You deserve and you are likely to be spared because your achievements are widely known. Nevertheless, there is the ever-present danger that our foundations may also become over-organized in their approach to agricultural research throughout the world. To the extent that occurs, the effectiveness of your research may become subject to the same type of criticism that the National Academy of Sciences is making with respect to agricultural research within the United States: "The agricultural research establishment has an undesirable burden of administrative and planning effort that is, in effect, removing the active researcher from decision-making." It would be well to be aware of this danger.

In my examination of changes in public attitudes and perceptions that influence the alternatives before us, I have featured a fundamental change for the better, namely, that the modernization of agriculture really matters in economic development. On the other side of the ledger, I have placed three unfavorable developments: (a) the biased view with respect to the welfare implication of the Green Revolution, (b) the untenable demands that the ecological movement is making on agriculture and (c) the recent widespread criticism of the sciences. With respect to each of these adverse developments, in my view, it would be shortsighted not to confront these distortions in public attitudes to correct the mistaken public beliefs on these issues.

II.

The other constraints on agricultural development, to which I now turn, are in the domain of politics and in economics. I am sure you see them as rather unfriendly to your "scientific" weltanschauung. You find yourself haggling with politicians who are bent on survival and with economists who talk incessantly about supply and demand. Moreover, their behavior is institutionalized, either by government which is protected by its bureaucratic moat, or by all manner of economic rules, rituals and restrictions. I shall refer to this untidy combination of politics and economics as the Political Economy of the country. It is not an aberration; governments will not wither away, a point on which Marx was wrong and especially so when they are committed to a Marxian ideology. Nor can any country disregard its resource limitations, regardless of the type of government that has been institutionalized.

In thinking about the constraints imposed by the political economy, the first basic fact is that the political economy of each country is to some extent unique. Clearly they differ in natural endowments, they differ in the forms and amounts of physical capital, they differ in skills and in other forms of human capital, and they differ widely in governments and in other institutions--all of which influence in one way or another the capacity of a country to modernize its agriculture. As agricultural scientists you are acutely aware of the importance of taking account of the differences in the biological habitat in which new crop varieties must perform. A similar awareness is called for in coping with the wide array of differences in the political economy for which these new varieties are developed.

A second important fact is that some governments do learn (so do some economists). This learning process is generally overlooked and rarely analyzed. Here, again, your own behavior and experience should help you in perceiving this process. You, of course, know that scientists learn how to do scientific work. You no doubt have been observing that farmers, wherever they may be, are capable of learning how to use new technical inputs and when the incentives are strong they learn rather rapidly. But there is a tendency to underrate the capacity of governments to learn the art of promoting modernization. Although the learning lag of governments is, as a rule, excruciatingly long, it seems evident to me that a goodly number of governments of the less-developed countries have made considerable progress in managing their political economy, given their resources constraints.

In my view, a considerable number of these governments have learned a good deal with respect to the following aspects of agricultural development:

- (1) That agricultural modernization, as noted earlier, is necessary if the country is to approach an optimum rate of economic development.

- (2) That farmers respond, as do nonfarm entrepreneurs, to economic incentives and that an efficient system of such incentives is important. There is, however, as yet much confusion with regard to the requirements of such a system of incentives for agriculture.

- (3) That the supply of modern agricultural inputs cannot be produced by farmers; they must be produced and supplied either by public agencies or private firms in the nonfarm sector of the economy. What has not in general been learned is the optimum division of labor between public and private activities in producing and supplying these modern inputs.

- (4) That organized agricultural research has a comparative advantage in discovering and in pre-testing the performance of new biological inputs and that such research produced what the economist calls a "public good", and because it is a public

good the research activity falls in the domain of not-for-profit agencies which are dependent upon public funds or upon private donations.

But there are important parts of the art of development that many public officials and their advisors have not as yet mastered. Since you have a large stake in their learning this art more fully, it behooves you to become qualified instructors in political economy. The course of instruction that you offer should concentrate on five major lessons: (a) the optimum combination of public and private management of economic activities, (b) the gains from international trade, (c) economic approaches to reduce human fertility, (d) the economic value of schooling, and (e) the payoff on public investments in agricultural research.

The first lesson should analyze the effects of different combinations of public and private management with special reference to agriculture. Large indivisible capital structures, such as large dams, and activities that provide public goods, such as agricultural research, call for public enterprise. Farming clearly calls for private entrepreneurship. In view of the technical and economic possibilities now available, the gains in agricultural production are substantially below optimum because of excessive public control over agricultural production. The most obvious evidence to use in presenting this lesson is the very poor performance of the agricultural sector of the Soviet Union. That country continues to pay an extraordinary price for its highly centralized bureaucratic control of farming. While most other countries are much less overcentralized in this respect, many of them, including both poor and rich countries, are thwarting the economic efficiency of agriculture to a considerable extent by too much government control over the production decisions made by farmers.

The second lesson is no more than the long-established theory of international trade and its application to economic development, including agricultural modernization. There is a good deal of new evidence available to make this lesson clear and which I shall refer to below. The facts are that the gains to be had from agricultural development are measurably below optimum in many countries as a consequence of all manner of import restrictions and of export subsidies and, in some cases, by taxes on agricultural exports. Thus, the full benefits that could be derived from international trade are not realized; moreover, the true comparative advantage of the different parts of agriculture within countries is thereby distorted and concealed from policy makers and economic planners.

The European Economic Community (EEC) has obviously not learned this lesson. The enlargement of the EEC now underway will further impair the agricultural trade possibilities of some less-developed countries. Other industrialized countries are also using price supports and subsidies that cause them to maintain too large a share of their resources to be committed to agricultural production. Studies of my colleague, Professor D. Gale Johnson, show the extent

to which these nationalist policies, which are designed to increase the income of agricultural producers by means of barriers at the border and by domestic price supports and subsidies, have held and drawn too many resources into agriculture, have reduced internal consumption of these products, have curtailed the importation of agricultural products, and have become exceedingly costly. "The annual cost of such protection (borne by) consumers and taxpayers may well approach US\$40 billion, including about US\$13 billion in the EEC, almost US\$10 billion in the United States, at least as much in the USSR as in the United States, and small but significant magnitudes in the rest of Western Europe, Canada and Japan".²

Moreover, as Professor Johnson points out, "The gross domestic product of agriculture at market prices in 1968 in the EEC was US\$23.5 billion and in the United States US\$25 billion. The costs, through prices above world market levels and payment from treasuries, equalled 55 percent of the value added by agriculture in the EEC and 38 percent in the United States".

Although it is obvious that consumers and taxpayers in these advanced countries would benefit handsomely from free trade in agricultural products, it is not obvious to what extent and in what way the poor countries would benefit. Professor Johnson's estimates indicate that the advanced countries would import about US\$8 billion or more in agricultural products annually of which about US\$2 billion would, in the short run, consist of agricultural products from the poor countries. In the longer run, production in the poor countries would have time to respond to these export opportunities, as Mexico has done so successfully, and the amounts supplied by them could increase very much more. Yet, in view of the scarcity of foreign exchange earnings, even US\$2 billion additional earnings from sales abroad would be a significant gain for the less-developed countries.

On the positive side of this trade ledger, it is worthy of note the rapid rise in food prices has induced the U.S. government to eliminate all agricultural export subsidies and to reduce or suspend a number of agricultural import quotas.

With respect to the nationalistic trade policies of the less-developed countries and their adverse effects on growth, there are

²D. Gale Johnson, "Free Trade in Agricultural Products: Possible Effects on Total Output, Prices and the International Distribution of Output", Agric. Econ. Paper #71-9. University of Chicago, Nov. 2, 1971. See also his "Agricultural Trade--A Look Ahead--Policy Recommendation" in United States International Economic Policy in an Interdependent World, Washington, D.C., July, 1971, pp. 873-896; and his two recent papers, "Where U. S. Agricultural Comparative Advantage Lies", Agric. Econ. Paper #71-18, University of Chicago, Oct. 25, 1972, and "The Impact of Freer Trade on North American Agriculture", Agric. Econ. Res. Paper 72-19, University of Chicago, Dec. 29, 1972.

several recent studies that provide evidence for the lesson here under consideration. Moreover, the reviews by Malenbaum³ and Healey⁴ of these studies are, in my judgment, first rate. Professor Healey, who has the advantage of being situated at Stockholm University and the University of Adelaide, concludes his review in part as follows:

"(During the recent past) it seemed entirely reasonable that forced industrialization of the 'backward areas' of the world should be stimulated via heavy industry, detailed government planning and import-substitution, with a minimum involvement in the international economy. If this led to a bias against agriculture, well so much the worse for agriculture which, anyway, was not a 'leading-sector' and whose function was mainly to provide 'surplus labor' for the new manufacturing industries. . . . Forgotten was the rapid growth rate of population in twentieth century developing countries, with consequent rapid growth of the labor force. Nor was it realized how the very system of stimulating industry would involve the creation of an extremely capital-intensive type of industrialization a low rate of absorption of labor. It was not understood, either, that behind high tariff walls would shelter inefficient industries--'infant industries' which would never grow up."

The third lesson pertains to population. It is not enough to point out that the Green Revolution is providing the less-developed countries a decade or two of additional time to solve their too rapid population growth problems. Unless these countries use this additional time better than they have thus far, the social value of the prospective gains in agricultural productivity are very much in doubt. Although theory and evidence for this lesson is still weak and fragmentary, there is enough to justify this lesson. There are biological studies of human reproduction to draw upon. Demographic studies are another major source. Recent extensions of economic theory and their applications are also an important source. "New Economic Approaches to Fertility", Journal of Political Economy, Supplement, March/April 1973, will make available eight recent studies. Another set of studies devoted to "Marriage, Family Human Capital, and Fertility" is scheduled to appear a year hence also as a Supplement of the Journal of Political Economy. The population Council publishes currently several series that summarize and review new developments in the area of population. Not to be overlooked in preparing for this lesson is the U.S. report, Population and American Future, Washington, D.C., 1972, and the related research monographs.

Public officials and their advisors throughout the less-developed world have not seen enough evidence to convince them that the level of schooling of farm people affects significantly their allocative ability in adopting and in using efficiently new techniques in farm production and in farm household activities. Accordingly, the objective of the fourth lesson here proposed is to show

³Wilfred Malenbaum, "Modern Development Activities in Poor Lands", Economic Development and Cultural Change, 21, Oct. 1972. 174-185.

⁴Derek T. Healey, "Development Policy: New Thinking About an Interpretation", Journal of Economic Literature, X. Sept. 1972, 757-797.

that schooling matters both in farming and in family behavior in reducing fertility. The classic study that set the stage for identifying and measuring this aspect of schooling was by Welch⁵, using agricultural data for his empirical analysis. Wallace Huffman's Ph.D. dissertation at the University of Chicago and George Fane's Ph.D. dissertation at Harvard University, now available, provide additional supporting evidence. But for the less-developed countries, there is all too little hard evidence, except for the work of Chaudhri⁶. I have made a tentative evaluation of schooling of farm people, both of males and females, in the context of agricultural modernization and family fertility in a paper that is in press.⁷

The fifth and last lesson on my list is on the investment by governments in organized agricultural research. I am prepared to have you say that this particular lesson has been high on your agenda for years. But, I shall counter that you have not presented enough hard evidence to fully convince the governments of the less-developed countries. You have relied mainly on your own research success and on the agricultural research successes in the United States. But the budgets of poor countries are less ample than your foundation funds and they are tiny indeed compared to the US\$500 million of public funds provided for agricultural research in the U.S.A. Furthermore, the political economy of the less-developed countries requires all manner of public expenditures although the budgets are very small by our standards. It is my contention that you have not produced the necessary hard evidence to prove that the social rate of return to additional public funds allocated to agricultural research is as high or higher than the social rate of return on other public investments in the less-developed countries. You require studies of the type that Griliches, Peterson and Evenson have made, concentrating on U.S. agricultural research. Ardito-Barletta's and Schub's studies pertaining to Mexico and Brazil are examples of the type of analysis that is wanted. Lest I be misunderstood, I have no doubt that the evidence, once it has been marshalled, will strongly support the enlargement of agricultural research as I have argued in the closing section of my Pugwash paper, "Knowledge, Agriculture and Welfare".

⁵Finis Welch, "Education in Production". Journal of Political Economy, 78, Jan. 1970, 35-59.

⁶D. P. Chaudhri, "Education and Agricultural Productivity in India", Ph.D. dissertation, University of Delhi, 1968; and "Farmers' Education and Productivity: Some Empirical Results for Indian Agriculture", Economics Paper 69-04, University of Chicago, 1969.

⁷T. W. Schultz, "The Education of Farm People: An Economist's Perspective", Yearbook of Education 1972-73 Edition, London.

By way of a summary, with respect to public attitudes and perceptions of agricultural modernization, some recent views about welfare, agricultural pollution and the antiscience protests are likely to hamper your endeavors. I have argued that it is a part of your responsibility to help clarify these public issues. With respect to the functions of the political economy of the less-developed countries, I stressed the diversity in the endowment of resources and in governments and the learning capacity of governments. They have a good deal more to learn, however, about the art of development and to assist them in this matter, I have proposed five lessons for you to undertake: (a) the optimum combination of public and private management with special reference to agriculture (b) the gains from international trade (c) the economics of human fertility (d) the economic value of schooling and (e) hard evidence of the payoff to public investments in agricultural research. I know from experience that it is not easy to teach these lessons. I am fully confident, however, that you in your role as international merchants of agricultural knowledge can do the job.

DISCUSSION PAPER: KNOWLEDGE, AGRICULTURE AND WELFARE*

Recent large gains in agricultural production in several developing countries have captured the imagination. The additional wheat and rice is a worthy achievement, which has been personalized by a Nobel Peace Prize. The soft phrase, The Green Revolution, is suddenly popular even among hardheaded scientists. But similar large gains in agricultural production in particular countries (for example, in Mexico) have been achieved since the forties.¹ What is new and important is the more general acceptance of the fact that agriculture can be dynamic and progressive in countries where traditional agriculture has been a way of life for many generations. Thus the big change that has occurred which has the attributes of a minor

*Science Studies, 2 (1972), 361-368. This is a revised version of a paper delivered to the 21st Pugwash Conference, Sinaia, Rumania, 25-31 August 1971.

¹In Mexico, between 1946 and 1962, the yield per hectare of the harvested area devoted to 37 crops doubled inside irrigated districts and increased 30% outside irrigation districts. The production indices of key crops shows the following increases (with 1960=100):

	Wheat	Rice	Corn	Cotton
1946	31	58	63	23
1962	110	129	107	118

Although the rate of population growth has been high (3% per year), the per capita consumption of farm products in Mexico increased by 43% between 1940 and 1965. (From Reed Hertford's 'Sources of Change in Mexican Agricultural Production, 1940-65'. unpublished Ph.D. dissertation, University of Chicago, March 1970).

revolution, is in seeing and believing that agricultural production possibilities can be transformed from niggardliness to abundance. But there is still some confusion, although it is true that the general public, officials of government and also scientists are now seeing with increasing clarity that advances in scientific knowledge can contribute to the process of increasing agricultural production, and thereby enhance the welfare of people.

The main reasons for the residual confusion are the following: (1) An oversimplification of the linkage between the Green Revolution and the sciences. (2) A lack of understanding of necessary economic requirements for the efficient adoption and use of the new, superior agricultural inputs. (3) Seeing the welfare implications of such gains in agricultural production in terms of the detailed effects upon different classes of farm people in an area, and not seeing the more general effects of cheaper food grains on the welfare of a total population. (4) A lack of clarity about ways of developing efficient systems of agricultural research, in spite of many decades of experience with organized agricultural research, and the worthwhile lessons that could be drawn from this rich experience.

I shall elaborate briefly on each of these four reasons for the confusion that still continues to hamper and delay the modernization of agriculture.

Dependence of the Green Revolution on the Sciences

The Green Revolution reveals clearly the value of organized agricultural research. It demonstrates once again that nothing succeeds like success. But what is not revealed is that the new varieties of wheat and rice are only a part of the contributions of the sciences. Modern agriculture would be impossible were it not for advances in scientific knowledge. From an economic point of view, this knowledge, when it has become transformed into inputs, techniques and into the skills of man, is the most important factor in production.

There is a long history in prescience agriculture, during which there were some innovations, some discoveries and some learning from trial and error. But prescience agriculture, then and now (for it still prevails in many parts of the world) is at the mercy of the vicissitudes and niggardliness of nature. Raw land and brute labour are not sufficient to dispel the ancient fear of starvation, out of which arose the age-old prayer, "Give us this day our daily bread". Surpluses of agricultural products are a recent development; Mexico now has a surplus of wheat, and even Japan has a surplus of rice. Thus, the niggardliness of nature is transformed into abundance, and the sciences are playing an important role in that transformation.

The first lesson of the Green Revolution is that modernization of agriculture is dependent upon a wide array of scientific knowledge -- physics, chemistry, and biology; and also upon engineering,

with respect to irrigation and transport facilities, and agricultural machinery. There is, however, a strong tendency, which is very human, to claim too much for that bit of new knowledge about which the particular scientist or engineer is an expert. The second lesson, which is not obvious, is that the large gains to be had from the improvements in the technical production possibilities of agriculture depend in large measure upon the combinations of technical factors and the gains from the interactions among them.

Even in undergraduate chemistry, one learns about interactions. It is obviously not a new idea in the sciences. R. A. Fisher, distinguished for his small-sample theory, designed agricultural field experiments to control for, and to take account of, interactions. Charles Kellogg, a soil scientist, extended the concept to the more aggregative interplay between the state of the soil, a new variety, additional fertility, better control of water and more effective pest control. Several inferences can be drawn from these interactions.

(1) Norman Borlaug would be the first to agree that the new dwarf wheat varieties developed by his Rockefeller-Mexican enterprise require fertilizer, water management, control of pests and a lot of dry-season sunshine. Similarly, in attaining these gains in agricultural productivity, fertilizer is not a panacea, no matter how cheap it may become or how abundant the supply. Thus, neither the highly productive new varieties nor the cheap fertilizers are by themselves sufficient, although the contributions of the plant breeders and of the engineers in developing the high compressor processes to produce cheap nitrogenous fertilizer have both been necessary parts of the process. So have been the contributions of the irrigation engineers, although these engineers tend to have a built-in bias for large systems and therefore neglected small projects and tube wells. When it comes to pesticides (which are also necessary) the types of pest control that will be required in conjunction with the new agricultural inputs in India and other developing countries, are as yet, in large part, not known.

(2) The popular urban view, which includes the view of scientists who think of agricultural scientists as second cousins, is that modern agriculture is necessarily soil depleting. But in general this is not so. The 'interaction' between farmers and soils is usually beneficial; the goodness of the earth as agricultural soil is in substantial part man-made. For example, the renowned soils of Iowa are presently better than they were, say, four decades ago; average corn yields since then have risen from around 30 to 100 bushels an acre. But this 'interaction' also precedes modern scientific farming; even in India, after centuries of cultivation, the soils are, in general, presently better than they were a century ago. Moreover, as a consequence of the Green Revolution the productivity of the soil in the Punjab is becoming better still. The crisis-bent ecologists would do well to ponder this important fact.

(3) A closely related interaction concerns the effective supply

of land. It is not true, as all of us were taught, that the supply of agricultural land is fixed once and for all by the surface of the earth. On the contrary, it is a fairly elastic economic variable over time, depending on the interaction between new knowledge, additions of complementary forms of capital and the value of farm products. It can be augmented in many different ways, but mainly by increasing its capacity -- in much the same way as the aeroplane now carries several times as many passengers as it did in earlier years. Thus, for example, in the United States the increases in crop production per acre have been so large that over 50 million acres have been taken out of crops during the last several decades. A similar development is under way in parts of western Europe. When the agriculture of India has become fully modernized, India also will require less crop land than the acreage presently under cultivation, provided the serious high rate of population growth is checked.

In short, the old maxim of turning swords into ploughshares should now be interpreted to mean turning defence-oriented science towards agricultural scientific endeavours.

The Economic Part of the Story

Turning next to the motivation and capability of farm people in adopting and in using efficiently the new scientific inputs, there are several necessary economic requirements. These requirements include efficient economic incentives, adequate information, and the learning of new farming skills. Throughout much of the world, in both rich and poor countries, farm people are thwarted by distortions in economic incentives and by a lack of information. Moreover, the process of modernization is delayed because of the time required to learn the new farming skills (mainly due to the low level of schooling).

It is unfortunately true that the dominant elite view, both in capitalistic and socialistic countries, tends to be that farmers are dullards, inherently backward, strongly inclined to farm in accordance with tradition, and fundamentally indifferent to any new and better economic opportunities. Thus, they have long been maligned. One of the main purposes of my book, Transforming Traditional Agriculture², was to lay to rest this widely held, mistaken view about farm people. The Green Revolution has undoubtedly accomplished much more than my book did in establishing the fact that farmers in Mexico, or in India, or in any other country, are not indifferent to real opportunities to improve their economic lot.

But the trouble is that governments are slow to learn. Agricultural policies once established are then maintained by the vested interest of the bureaucracy that administers the farm pro-

²New Haven: (Yale University Press, 1964).

gramme. Land reform is as a rule promoted to attain particular social and welfare objectives. But land reform without the scientific inputs is not sufficient to attain large gains in agricultural production. Land reform, even with scientific inputs available to farmers, but without economic incentives, is also unsuccessful. Similarly, the reorganization of agriculture into large farms, along with modern tractors and machinery, fertilizer, new varieties of seeds and pest control but without effective economic incentives that reward farm people for adopting and using these new inputs efficiently, is somewhat less than successful. The governments of most of the rich capitalistic countries have made the mistake of establishing inordinately high price supports for farm products which require vast subsidies. The scientific inputs have been available; the economic incentives to apply them have been very strong. But the economic distortions caused by the price supports and subsidies are serious and very costly in terms of unwarranted 'surpluses', of high taxes, high cost of food to consumers, and of the regressive effects that this policy has had on the distribution of personal income within agriculture. Thus, this policy, too, is not successful in providing the essential economic requirements.

The gains in agricultural production associated with the Green Revolution also have several important economic implications that should not be overlooked:

(1) The increasing dependence on imported food grains of some of the major densely-settled, poor countries that occurred during the early post-war II period, is being reduced markedly by the gains in their agricultural production. The OECD view, expressed as late as the mid-sixties, is no longer tenable. A few of these less-developed countries are now prepared to export some farm products to the European Economic Community countries, but the barriers that the EEC has erected to keep such imports out make it very difficult.

(2) The increases in production of food grains give the less-developed countries some additional, much-needed time in which to cope with the complex problems of excessively high human fertility and population growth.

(3) The entire economy of these countries is much more dependent upon the gains in agricultural production than is the case in the rich countries. The possibilities of attaining general economic growth in the less-developed countries is measurably enhanced by these agricultural gains.

(4) Although in many less-developed countries the ratio of farm workers to the area of land under cultivation is still rising, it would be an error to infer from this that the modernization of agriculture cannot proceed. The scientific agricultural inputs are, in general, highly divisible: a bushel of high-yielding dwarf wheat, a bag of fertilizer, and a few pounds of pesticides. Similarly, small farm machinery and garden tractors can be had, and can be efficient, as the farmers of Japan and Taiwan have demonstrated.

(5) Last, but not least, is the important implication that the agricultural productivity from the advances in knowledge means cheaper food, and a rise in the real income of consumers. In a well-managed economy, these gains become a consumer surplus.

The Green Revolution and Welfare

Much of what is being written on the welfare implications of the Green Revolution is wrong. There are two unsettled questions. Who is to be the judge in determining welfare? What is the evidence? The thrust of the misleading welfare argument against the Green Revolution runs as follows: although the gains in agricultural production are being attained efficiently on narrow economic grounds, they are bad in terms of welfare. It is asserted that rich farmers profit and poor farmer become poorer; landless laborers become even worse off than they were before; and the welfare of the country is impaired.

Welfare considerations are indeed important. There are, however, two pitfalls in the path of the outside observer, given his standard of value and ideology. The welfare objective of, for example, the people in India, is an internal matter. It cannot be determined by the values of outsiders and their preferences. It is up to the people of India to decide what their welfare objective should be. The other pitfall is in the inaccuracy of the evidence that is being presented on the economic consequences of the Green Revolution. In the Indian part of the Punjab, where the new highly productive wheat varieties are doing exceedingly well, it is true that those with 'huge' farms (i.e., of up to 20 acres,) are in clover. But what is overlooked is that the farmers with five acres, or three acres, or even less, are also benefiting from producing more wheat. The scattered evidence now available suggests that substantially more labour is now required in the Punjab, and, in real terms, farm wages have risen appreciably. It is undoubtedly true that given time the in-migration of farm workers from other parts of India will beat down these wages to the very low levels that characterize farm wages generally in that country. But the most important consequence of the Green Revolution is lost sight of -- that is, the consumer surplus that it is producing for India. Cheaper wheat means that the real income of consumers rises. Farm laborers also benefit from this consumer surplus. Thus the evidence pertaining to the welfare effects of the Green Revolution is not what it is presumed to be by those who are belabouring the particular, local welfare consequences of these gains in agricultural productivity. A major issue is, however, emerging.

The opportunity to modernize agriculture is as a rule quite unequally distributed within any large country. The heterogeneity of the agricultural production possibilities, in a large country, sets the stage for income disparities between areas, and for differences in population pressures among farming regions. What this means is that the modernization of agriculture alters significantly

the comparative advantage among agricultural areas within the country. Western countries are not exempt of this score. Clearly, parts of agriculture in Italy and France have long been depressed. The USSR, despite her centralized planning and administered economy, is not spared, and the depressed Appalachia is poignant testimony of the very uneven agricultural development in the United States. Among the poor countries, Mexico and India illustrate the implications of this development. Mexico, which is now well into the third decade of successful modernization of parts of her agriculture, faces increasingly serious income disparity between major agricultural areas. Agriculture in northern and central Mexico has progressed, but the less successful southern Mexico has, by comparison, become a major depressed area. Internal migrations have profound implications in terms of the redistribution of the Mexican population. In India, the agricultural comparative advantage of the producing areas is shifting to the northern parts, and to the major 'rice bowls' of the South, as a consequence of modernization. A large triangle in central India is losing out competitively. Scores of millions of people who are dependent upon agriculture reside in this large area. They will be left behind. The new varieties of rice, wheat, corn, millet, etc., that are responsive to the larger and cheaper supply of new fertilizers, are decisively less productive within this large triangle because of the lack of rainfall and of water for irrigation. The burden of a lecture that I presented at Delhi University in 1967 was directed to this economic and social problem that would emerge in India, and my plea was that it should be high on the agenda of Indian economists.

Enlarging Organized Agricultural Research

It is obvious that the Green Revolution would have been impossible without organized agricultural research. The remarkable gains in agricultural production, especially since World War I, mainly in the scientifically advanced countries, could not have taken place without this research. Organized agricultural research has a long rich history. The system of land grant colleges and experimental stations, which was established in the United States fully a century ago, has been generously supported with public funds. (By comparison, the use of significant public funds to sponsor organized research in other parts of the sciences is a much more recent development.) European countries, Canada, Australia, Japan and notably Russia, have long histories of successful organized agricultural research. But the less-developed countries have been much less fortunate; for they have not, in general, benefited until very recently from this important development. Moreover, they are still benefiting all too little in view of the high pay-off to be had from investment in agricultural research.³

³The recently completed analysis by Nicolas Ardito-Barletta of the costs and returns from the Mexican-Rockefeller Foundation agricul-

tural research programme, covering the period from 1943 to 1964, leaves little room for doubt that this programme has been an exceedingly profitable investment. Capital is scarce in Mexico inasmuch as the rates of return to capital range between 15% and 25%. This agricultural research programme up to 1964, analysed as an investment, shows an internal rate of return between 54% and 82%, more than twice as high as the rate of return of alternative investment opportunities. (See Nicolas Ardito-Barletta, Costs and Social Benefits of Agricultural Research in Mexico, unpublished Ph. D. dissertation, University of Chicago, June 1971.)

With special reference to the less-developed countries, why has there been so little progress since World War II, in view of the efforts of the United Nations, including FAO, and of many governments pursuing bilateral approaches? The following reasons are suggested:

(1) In part, it is a consequence of the overwhelming importance that has been given to national defence-oriented scientific research. This has usurped an inordinate amount of the increases in research funds.

(2) While governments in developed countries tend to give agricultural scientists within their own countries substantial authority in selecting research projects, when these same governments provide funds for agricultural research in the less-developed countries they tend to sponsor narrow, inefficient mission-oriented research. Moreover, the support is subject to the vicissitudes of foreign policy; it therefore lacks a long-run stability that is absolutely necessary in developing effective organized agricultural research.

(3) The agencies of the United Nations, including FAO, despite good intentions, have not succeeded in establishing centres of sufficient scale, and with sufficient long-run horizons to attract highly competent agricultural scientists. (There are, of course, some exceptions).

The one notable success story has been the agricultural research enterprises sponsored by private foundations. The most outstanding, in terms of achievements, has been the Mexican-Rockefeller research establishment in Mexico, which was launched in the early forties, and to which the Ford Foundation is currently also contributing funds. 'Borlaug' and 'dwarf wheats' have deservedly become familiar words. The International Rice Research Institute, to the credit of the Philippines and the foundations, is another success story. There are also several others that are doing well, and a major project of this kind is getting under way in Nigeria.

What this brief review adds up to is rather discouraging. Governments of countries that are rich in science do badly in assisting less-developed countries in establishing organized agricul-

tural research. Nor have the National Academies of Science in the rich countries developed realistic and meaningful plans that would maximize the division of research between rich and poor countries. But the best of plans will not suffice if only foundation funds can be had, because the foundations simply do not have sufficient resources for this task. Since the rewards from organized agricultural research in terms of consumer welfare, are very high, it behooves the governments of the less-developed countries to enlarge greatly their own investment in such research.

My overall conclusion is that the Green Revolution will turn out to be a godsend, provided we learn from it how important agricultural research can be, what the economic requirements are for the adoption and efficient utilization of the results of such research, where to look for the gains in welfare and what must be done to extend the benefits from organized agricultural research to all of the less-developed countries. Once we learn and act accordingly, the age-old niggardliness of agriculture will be transformed into abundance, provided of course, that human fertility is checked.

Discussion

Anderson

I think we have to start from one of your assumptions that governments are always short of money and the priorities which they establish will be governed by the situation they find themselves in at any given time. If we went into a country and gave an overall plan for agricultural development, this would scare all governments from a psychological standpoint. Let me take a concrete example. In India, if they were to have considered the amount of investment in fertilizer that they would need to fuel the change, they would never have embarked in the ship in the first place. There is a danger always in looking at all the ramifications of any action. There must be starting point and the simpler the better. You then create certain vacuums in the economy that arise from the first actions taken and these develop as you proceed. The vacuum, once the seed spread, was that there was no fertilizer in the country. There were fertilizer-responsive varieties but no fertilizers. Thus, the fertilizer industry began to develop to fill this vacuum.

Later, storage formed another vacuum. I remember very well going with Dr. Borlaug to see the Minister of Food and telling him the country was going to need more storage. This was in the preharvest season of 1968. The Minister replied, "We have three million tons of storage and everything is empty. As the ships are unloaded, the wheat is consumed immediately after distribution. If I go to Parliament now and say we have to have more storage, they would laugh me off the floor." This is one of the things a government leader is faced with and another of those things which are not pressing on government. Thus, it is after the vacuum is created, even though you may lose a little in the process, that is the time you begin to get the ancillary things to come in.

One of the factors I would have to be critical of in your talk, Dr. Schultz, is the need you express to depend entirely on hard evidence and not operate on psychology. This is danger. The psychological state in which the government enters into a program is extremely important.

Schultz

Isn't that evidence, too?

Anderson

In the beginning we were asked by the economists in India whether we could give them exactly how much they would get if they put in x units of fertilizer. We could not give this assurance. There arose a sustained argument in which both sides were correct. The economist said if you put 30 pounds of fertilizer on $3x$ acres, you would increase production to a higher level than if you applied 120 pounds on x acres. This was true. On the biological side, we argued that the latter condition should be followed because of the psychological shock effect on the farmer. At the 120-pound level, he would harvest 2 to 3 times the grain he did formerly. At 40 pounds he would show a modest increase, but it could be attributed to weather, acts of God, etc. With the high yields, there was no questions but what he was a convert to the use of fertilizer.

Schultz

The evidence you speak of must be created by the farmer. I use the term "hard evidence" because of the return of agricultural research. Now that is a bit more complicated because it is the public good; it is not a private good you can put a price on which you can on rice or wheat or the inputs that go into agriculture. So I would have said vis a vis hard evidence that this is an area where a decision has to be made about facts which have not been brought to the surface in convincing way or it is at least somewhat unclear.

Now I would carry this trend of thinking a little further, I would have said what you were saying right at the close of the last 3 to 4 minutes of the last session when you were speaking of the 50 or 36 million tons and the fertilizer problem was brought up, it seems to me that you know that fertilizer is going to be the essential ingredient in getting to that figure. You ought to know that fertilizer in India is priced way too high in terms of its real value in cost of growth to India. India has itself in a box in the international trade scheme. That is a little harder to talk about. I think you would know better than anyone that the high price of various sources of N and other fertilizers is extraordinarily delicate in moving to an optimum. Ultimately, what a society or country wants is to put its resources where it will get the highest return and the return would be greatly enhanced even if the Green Revolution as it presently stands had had fertilizer prices at $1/4$, $1/5$ or $1/2$. We have just approved a very fine Ph.D. research after a couple of years of hard work. The price that India is

paying in the way it has managed the fertilizer industry and the revenue collection from the farmers, the import restrictions on fertilizer, etc., have been very dear in terms of agricultural performances. I think you can say a great deal without becoming economic planners. If you become economic planners and say this I hope they send you home and send Indians back to start saying these things because you will get yourself in a box. I think you agree with that comment.

Dr. Borlaug

I would like to comment on how political decisions get mixed up with economic ones. I refer to some of the same points that Dr. Anderson was making. In practice, although you would like to lay out a nice plan, you have to be simple when you are starting out. You have to start with one thing, the catalyst that is self-evident or can be exploited to show a tremendous change. In India it happened to be the variety and then on a very modest scale fertilizer response was shown. But in the early stages it never convinced the people who controlled the purse strings to invest in fertilizer plants or even much more directly in importation.

The second phase occurred when there were a few thousand of these demonstrations around. Then there was steam in the boiler and you go around and stir things up a little and you say, "now if we just had fertilizer". Then the politicians become vulnerable, by this I mean government policy makers because they are vulnerable.

Schultz

That's what they learn.

Borlaug

I suppose the most productive hour of my scientific life was spent in speaking very bluntly to the man in India who controlled the purse strings for import of fertilizer and possible future plant construction, saying that the government would lose power unless they acted to supply fertilizer immediately. At this time it was evident across the land what fertilizer would do. Action was taken. But we could have said this a thousand times three years before and nothing would have happened. I use this to illustrate how decisions are made and the moves are made one by one.

Schultz

Beautiful! You are a marvelous teacher.

Borlaug

You just have to look ahead and when you see light under the door you have to move dramatically and without fear if you think that the probabilities are 80% that you are going to get a payoff. If you don't, the door may never open again.

Schultz

I feel this is extremely instructive, just the way you put it, and I will underscore one aspect that you have made by implication. In getting a rapid change, it is important to make a big gain, a big gainer. A lot of things begin to fall into place if you sense what is called for and argue for it. I am going to maintain that excruciatingly slow as this learning process is by some governments you say they are vulnerable and I say that is when they have to learn and you better be there and help them in the process. So, you have made my speech much better than I could have made it. Thank you.

Havener

Dr. Schultz, we learned greatly from your discussion with us, but I should like to throw the challenge back to you to help us. Most of the men in this room and about a hundred fold more than this are scattered around the world working in international agriculture and you would like us to become political economists. Borlaug happens to be one of the best I know and there are a few others, but as international scientists worrying about where the next bag of fertilizer is to come from, where the grain drill is or is not, and where the tractor will be next week, it is extremely difficult to stay abreast of the biological sciences, let alone the science of political economy. Fortunately, because some of the men in this room have made credible their biological skills, they do have access to senior policy makers around the world and are often called upon to give economic advice even though they are not qualified to give it.

Schultz

Let me interrupt because in terms of what the world needs there is probably not another acceptable Ph.D., in pure biology. It is the biologist who has a second talent, that is entrepreneurship in the present world --the world we have been talking about. I think that skill is much scarcer and will be for a long time. Alright, you can't have everything. Let's get the scarce skill up to par and this would be my answer to you in the way you started out.

Havener

The problem is we do not have access to nor do we read the journals that you mention. We need a much better network of political economy information going both to our biological scientists and made available to policy makers and administrators in the developing countries. Its amazing how isolated many of them are from the kinds of mental systematic cultural problems we have just been discussing. Periodically, when I would give one of these books to an administrator or policy maker he would say, "That was great. I wish I could have access to more information or material like that." Often, however, it is only what we happen to run across that is available. We do need help from the social scientists to identify those publications that are superior, that are on the

mark, that are new and fresh and may be useful to us as merchants of change.

Schultz

The economists are not really merchants of the entrepreneurial role that you really have evolved and done rather well. I am afraid there are a lot of economists who have gone into rigorous economic planning and didn't see that that was an impossibility in the context of the complexity and diversity of the training situation for these men. Now many of us did, you see, but they are, by and large, at least I know very few who have a relationship to their government or other governments where they could display or use their entrepreneurial ability. I think we are a poor second best at this stage in history at planning this unique role which you have already played rather successfully.

Borlaug

I would like to point out one other aspect of this. There is a continuing need to be close to people who are making decisions, very often without adequate timely information. The world situation changes. I went to Pakistan the early days of October and to my horror found there was virtually no phosphate fertilizer in the country. A year ago you could get phosphate delivered in three months and the lead time now is 8 to 10 months and you can't get it then in some cases. This goes completely past those who are making decisions about when to order fertilizer because of the shortage of foreign exchange and all of the other complications.

Even though they had made the right decisions to invest in fertilizers, a certain amount, it couldn't be present when it was needed because it wasn't ordered in time. They had not watched the change in world fertilizer production --it is growing very tight, especially on phosphate-- and so you get into a series of dilemmas because you don't watch all of the different factors that enter into the total production package. You can get trapped in these boxes, even with the right decision if it is off in timing.

Schultz

You have been holding the questions pretty close to the last of the five lessons. Let me, however, reaffirm or restate the capacity in which you are really an authority and, therefore, you can't afford to be neutral. You have to enter the public arena to help clarify issues. A number of my colleagues are involved in the welfare issue. This is the antiscience view. Its implications scare me as far as some of them are a part of the public process. In some real sense, one has to get into these issues and face them, then the specific untangling of what is socially desirable and valuable in these ecological movements. There is much, and the movement is away overdue, particularly in the rich countries since they can afford it. But also separate out in that untangling the specifics on which they are wrong with respect to agriculture in which you have

such a large stake. You have to get into that act.

Wellhausen

I would agree with Dr. Schultz in that many of the people in this room could be, by virtue of their accomplishments and prestige in research, more effective in influencing the policy makers in making the kinds of policies needed for a rapid acceleration of agricultural production than the economists themselves directly. Now this is no reflection on the ability of the economists. Most of us who are in agricultural research in the developing areas of the world rather quickly at least think we have a big stake in the economic development of the country. I think there are people here who are mainly engaged in biological research that think they are pretty good economists, too. I think your suggestion that people here have a big role to play is well taken. The job is not easy and it will take the help of all.

Stakman

I think more people such as those represented in this room have to develop the ability to talk rationally and articulately about some of these basic things. There are biological problems and they should have pretty good judgement, and if we don't do it somebody else is going to do it and those who do it will continue to bungle the job like is happening now. I want to add one note of caution and that is this. Keep some of them away from the politicians; keep some of them away from the public. After all, you have those who can teach and they can teach by demonstration, but keep the people who are not articulate and haven't got sense enough to give facts and try to execute instead of giving partial facts and try to propagandize and play the game. Keep them away. I have watched from the very beginning of extension work in the U.S. and so have some of my colleagues, although none of them have watched as long as I have because I started watching earlier. But they didn't really make any progress until they started educating instead of propagandizing, until they started demonstrating things to people that they themselves could see. It was not until then that they started to make progress. And then the general public began to get confidence in what the scientist said and if they were asked in legislative assemblies, if they were asked what's your evidence for that, it is the statement of some of these scientists because we have found they are right. They have told us the truth. I want to comment on what Dr. Schultz said and, if its proper for me, to commend it. I think you were distinguishing, Dr. Schultz, in a sense between education and propaganda. We can tell people facts and if they have the responsibility for acting on the basis of those facts, they have that responsibility but they are entitled to those facts and I think we are remiss in our duties unless we give them the facts. In education, if everyone gets the facts, the whole idea should be to help them to arrive at wise decisions on that basis. They will arrive at their own decisions. I say there is a big difference between education and propaganda in this respect.

CIMMYT's PAST ROLE, PRESENT POSITION AND FUTURE CHALLENGES

N. E. Borlaug

Let me give you a brief background of CIMMYT's predecessor organization in Mexico. I feel that many of the activities of CIMMYT today and in the future stem from what was begun a long time ago. It is, therefore, basic to an understading of our present activites.

Let me go back nearly 30 years. The development over this period is like the metamorphosis of an insect. The first instar, was the one mentioned by Dr. Harrar, the Oficina de Estudios Especiales or Office of Special Studies. This instar lasted from 1943 to 1961 and at its termination it had achieved what it had set out to do --to assist in building the National Institute of Agriculture of Mexico. Its aim was always to change its agriculture-- to produce the food it would need for its people.

This instar produced varieties for Mexico but also developed a number of ways to approach problems in the process. The situation in Mexico was very different from that of the U.S.A. where large numbers of trained scientists were available. Thus, it was not only development of research and assistance in helping to solve agricultural problems that were needed, but in addition it was necessary to train corps of young scientists to man the program. To sum up, it was necessary to go through this training aspect as early as possible but the period was much longer than I think Dr. Harrar imagined. I don't believe that the three horsemen --Mangelsdorf, Bradfield and Stakman-- either were aware of all the implications when they first recommended to the Rockefeller Foundation that they should accept the invitation of the Government of Mexico to come in with an assistance program.

This period of 17 long years exemplifies what is needed to develop young scientists in countries where few exist to take over the full responsibility of research, as INIA has so well done from 1961 to the present. Of course, this first instar developed into its successor INIA as a new adult. In our international work the background has had an important effect and the collaboration with INIA continues through a very close liaison and work conducted at INIA's Ciano Station in particular. It is at this latter station that much of our training of young scientists from many countries is conducted. It is here that most of our research is also carried out. I would like to publicly express our deep appreciation to INIA and especially its regional centre, CIANO, in the Northwest for its very large contributions to the international programs of CIMMYT. I would also like to express our thanks to the Government of Mexico in a more general way for making CIMMYT's work possible.

During the period in which the Oficina was under development, the Rockefeller Foundation had several other centres in different instar stages. One was in Colombia where Dr. Jerry Grant is now located. Another was developing in Chile where the late Dr. Joe

Rupert was in charge and it was during this period that a program was getting underway in India in the same type of cooperative program.

At the time INIA was formed, the older Rockefeller hands like Wellhausen, Johnson, Niederhauser, Laird and myself were left in Mexico. The Foundation in this transition period set up the Inter-American Food Program. There was much discussion on how best these people could be utilized to better spread the information and materials coming out of the country programs to neighbour countries. There were not sufficient funds to set up all the needed national programs like those in Mexico, Colombia, Chile and India. This Inter-American Program looked at how the information could be spread and from 1959 to its termination in 1963, these scientists travelled widely in different countries to see how international activities could fit into national programs in a different way than as full-fledged members.

In my particular case, I had a chance to look over the country programs of South America. I also, I believe in 1960, had an opportunity to spend three months with FAO assessing the opportunities of helping with wheat research needs in North Africa and Asia. It was a very enlightening experience for I saw that with the exception of India there were few trained scientists in the entire region and in many cases those that were trained were working on nonapplied problems having little to do with food production. Their work was often an extension of their graduate problem from a European or North American University. In other words, research where it did exist was not organized to solve the food production problems.

It was my view that the only way we were going to be able to get on with filling bellies was to build competence in these countries. Further, since the universities were not teaching application of agricultural research to the problems in the general sense, there seemed no other way to accomplish the desired ends than to begin in a simple way to train young scientists in a practical way. I felt --and still do-- that sweat, physical exercise and field experience, which is gained after all where food is produced, should form a good part of such training.

With these observations in mind, a proposal was made for starting this type of training in Mexico in collaboration with INIA in the Inter-American Program. The Rockefeller Foundation, subsequently, gave a grant to FAO to sponsor this program in 1960. People were identified and brought into this program from Middle Eastern Countries. I should go back at this point and indicate that practical training had been given much earlier during the days of the Office of Special Studies, in Mexico. Primarily, this program was designed for young Mexican scientists but we had colleagues from Colombia, Chile, Peru and Central America who today are leaders of agriculture in their countries. Thus, it was not new to Mexico to have scientists under training who had come from other countries. These had been quite informal and the real departure in 1960 was to bring in a more formalized type of training and extend this to people from countries of the

Near and Middle East. This has been expanded and continued since that time and is now done on a larger scale in CIMMYT.

I would like to give you some background on how CIMMYT came into being. In 1962, the late President of Mexico returned from the inauguration, in the Philippines, of the International Rice Research Institute. At a farewell dinner he thanked the Rockefeller Foundation for their assistance in developing agricultural research capability in Mexico. He went on to say "I went to Asia and saw this beautiful new institute for rice research which was being sponsored by the Rockefeller and Ford Foundations in cooperation with the Government of the Philippines. What was my surprise when I found it was modelled after the Mexican Office of Special Studies in my own country. Here we are saying good-bye to this group but why cannot we here in Mexico, since we were involved in the original idea, be --at least in the case of corn and wheat-- a base for such an international program." Thus, an international program was begun in 1963 in an informal arrangement between the Rockefeller Foundation and the Mexican Government. For three years it functioned in this fashion until in 1966 it was reorganized into its present form where it has an international board of trustees and broad financial support from many different countries and organizations.

What are some of our past contributions of significance and what do we think we should be doing in the future?

I would like to say a few words on the question of selecting scientists for training. It is not just a question of training so many people and this is especially true in those countries where there is a shortage of funds for agriculture and where agriculture is usually considered to be on the last rung of the socioeconomic scale. All too often, nobody wants to be an agronomist or plant breeder or a member of any of the agricultural sciences. It is better to be a lawyer or a doctor or a philosopher, or any other profession. This seems to be the rule in countries of the developing world.

This is particularly tragic in view of the fact that frequently up to 80% of the people live on the farms or are closely associated with agriculture. Also, when it comes to budgeting, agriculture invariably gets what is left over. We must be careful, therefore, in the selection of scientists to get those who are able to operate in spite of these handicaps. I have no interest in the most brilliant scientist in the agricultural world if he has no social motivation, if he is interested only in his own personal advancement or he will never be a team player. It is wasteful of the limited funds available for fellowships. It is better that such a person become trained as a lawyer, with all due respect to the law profession.

The scientist I want is one who is willing to work with his hands as well as his brains, because after all, agriculture does have a lot of sweat and a lot of struggle in the production of food. A scientist who is unwilling to get down into the dust and the mud and the sweat of daily work needed to bring new technology to modernize agriculture, will never contribute much beyond confusion in an agricultural development program.

Moreover, it is important to me that the prospective trainee have a personality capable of stimulating people. He is going to be a teacher; he is going to be a person who is to multiply himself; and if he is a "loner" he isn't going to do this. There is also the question of how many we can train. This is decidedly finite and we cannot spend the time to train the wrong persons.

I should like to return to the aspect of team playing. Perhaps this is the most important aspect of all. We who are working in the agricultural sciences are so few and the needs are so great. If we don't work as a team, we will accomplish little. Yet, during the last 70 years or so, the team concept has been largely ignored in our teaching institutions. We have tended to work alone without communicating effectively with one another with the result that much of our research has only served to confuse the basic issues we are attempting to solve.

Thus, for those of us working in developing countries, it is all important that we work in a team effort, across disciplines. Society and civilization tends to become more and more complicated with each specialist digging a hole deeper and deeper, looking for new grains of truth in his own specialty but in the process losing sight of the fact that other colleagues are digging other holes with which he has lost communication.

The net result of all this activity is that these little grains of truth being exhumed are never collated into anything useful for society. All too often the other trained people who sit on the ground and don't dig into the holes never put the facts together. We must, therefore, build people with a very strong, broadly based interest. Imagination and ambition are other important characters of our desired scientist. This is difficult to measure since much of this develops with experience. However, I am firmly convinced that evidence for this develops early. It is a part of that undefined whole known as leadership. I have dwelt on this point but consider it of paramount importance.

Let me turn now to the contributions of the Office of Special Studies, INIA and CIMMYT to the international agriculture. In addition to training, I feel that the contribution has been made primarily in the field of plant breeding. We were in a hurry and because of this we began to grow our breeding materials in two generations per year. We moved the wheat plant from one geographic and ecologic area to another in alternate generations. We wanted to build in wide adaptation. It was not an accident that the Mexican wheat varieties had this attribute when they went out into the world. To achieve this goal, the material was moved from the coast at latitude 28° in Sonora to Toluca at 18° latitude and an elevation of 2,600 meters.

It was also here in the Mexican program that the idea evolved that plant breeding is a numbers game. As Len Shebeski has pointed out in a number of publications, one must deal in large numbers if the one desirable combination is to be found. We can have the best plan, the right parental combination and the proper screening technique but without numbers the chances of getting that plant are remote. We depend in part on making very large numbers of crosses.

We try to know as much about the parents as possible and this requires a good deal of detailed study;

In the program we developed technicians who could do this. One of our most valuable field staff today is a man who started out as a ten-year-old bird boy. He has been on the staff for 30 years and has probably made more actual wheat crosses than any living man, and no doubt more than any other has ever made. This laid to rest the concept that only a scientist was capable of putting tweezers to floret. Nowadays capable technicians effect all crosses but people tend to forget how it was such a short time ago.

In the process of moving the wheat plants back and forth and up and down twice a year, wide adaptation was built into the varieties with a consequent simplification of producing seed for the highly variable Mexican wheat ecology. One variety could serve a wide area and we did not need one for each valley. We were not aware that we had done so well and it was only after international testing began that we found that adaptation was carried by these for countries around the world. We saw it happen here. It reminds me of an occurrence early in the program. I was sowing the nursery when I was visited by a very eminent and dear professor of genetics and plant breeding. I described how we were moving plants back and forth in alternate generations. He said "Young man you didn't absorb the first principles of plant breeding. You are alternately taking one step forward and one backward". Well, not knowing better and believing in the approach, we continued and I believe the results justified our beliefs.

Most of these wheats were daylight insensitive but from the results it is evident that we can get the whole gamut from complete photo insensitivity to complete daylength sensitivity. These can be used for different ecological niches. The simple varieties, however, that were designed for Mexico, later showed their abilities in other parts of the world.

In the early work we found that the varieties being produced were not too efficient in use of irrigation water and fertilizers. Water being Mexico's scarcest commodity made it important that our varieties do well on the water provided. This brought us into the problem of straw strength and Dr. Rupert and myself spent many years looking for strength of straw from different sources. It was not until Dr. Vogel received and used the Norin dwarf sources in Washington State and supplied us with some of his material, that we had a satisfactory source of dwarfness and straw strength. When we had combined this with wide adaptation, the varieties were set for moving broadly in the world.

Sometimes, we need a disaster to provoke international cooperation. With the appearance and spread of race 15B of stem rust in North America, a new era of cooperation ensued. Dr. Stakman had seen this race for some years but in 1949 again in 1950, and later in 1954 when it caused widespread destruction, Dr. Rodenheiser who is with us today, organized the First International Rust Nursery. It was grown in perhaps 20 locations, mostly in America in the first

year. Subsequently, it has moved around the world and has become an institution. It is the source of genes for resistance used by all wheat breeders today. This opened out an era of international collaboration in testing materials. As our share in collaboration, we submitted a large number of unnamed advanced lines some still segregating. This was in line with our policy of sharing what we had in the widespread interest.

Unfortunately, there are and probably will always be, great egos among plant breeders who are reluctant to part with their materials and put them in the hands of other scientists in case they did not receive full credit. This is strange when the scientist is employed by the public and he is dealing with public property. It seems to me that this represents confused thinking but that was the way it was only a short time ago. Today, we see unnamed lines moving into this and other international nurseries, because people now see the value of having the material tested. All that is required that the institution of origin and the individual responsible for deriving the lines be acknowledged. This all seems very simple but in my opinion represents a great step forward in international exchange.

This exchange of genetic and plant material is being fostered by CIMMYT with its various international nurseries. The International Spring Wheat Yield Nursery (ISWYN) is now distributed to more than 100 locations around the world. Dr. Virgil Johnson, three or four years ago, organized under USDA and the University of Nebraska sponsorship a similar nursery for the winter wheats. These nurseries and others subsequently formed a means to have a flow of materials and information to all countries.

The first such nursery sent from Mexico was the Uniform Yield Nursery established after it was recommended by a conference of Latin American scientists held at Santiago, Chile. This American Cooperative Spring Wheat Yield Nursery comprised all of the main commercial varieties of the U.S., Canada and the countries of Latin America.

We responded in Mexico by growing these varieties, making up the nurseries and sending them out to cooperating centres. A couple of years later when we had the Middle East training program in operation, a new nursery was named the Near East Nursery. We knew from the first two years of testing that the daylight sensitive varieties of the northern areas were no use for this area, but the FAO trainees were interested in Colombian and Mexican varieties, etc., which were included. Thus, all the long-day types were eliminated.

In 1964-65 we decided to combine the two nurseries and this became what we now call the International Spring Wheat Yield Nursery, which as I said is grown around the world at more than 100 sites. These tests have provided a considerable body of information. It was, for example, largely based on what we had seen in these tests, that material useful to Pakistan and India could be identified early. They were able to use this information in going ahead with large imports of seed. Surely, a lot of the data was developed in

India under the program in which Drs. Cummings, Swaminathan, Anderson and all the other collaborated. Similar data were being produced by the group associated with Drs. Qureshi and Narvaez in Pakistan. In spite of this, confidence in making the decision for imports was strengthened by the data of the ISWYN. Thus, with only limited years of yield and disease testing, the decisions which proved to be right were taken. Production, as Dr. Rao indicated yesterday, was speeded up.

This does not mean that the disease reactions will not change as we know it will always change even though our ecology friends fail to understand this. They seem to think that something new has been discovered when insects build up resistance to insecticides which is just the same thing as Dr. Stakman and his friends have found with the diseases. This war has been on for the last 50 years, but we have learned to become allies against these diseases.

We learned here in Mexico how to organize a crop production campaign. We put research to work on the farm as soon as possible and did not want to get the perfect package of practices. Thus, as soon as we knew a little about fertilizers and cultural practices, we tried them on the farmers and found they were receptive. As time went on, we learned to work with policy makers from the standpoint of pricing, not only at the Ministry but also at that time with our friends in Conasupo, Secretaria de Recursos Hidraulicos, and in different aspects. At that time, the Productora de Semillas, or seed organization, had been established. Since extension did not exist, we had to work as extension people as well.

We work with farm groups in Mexico and I would like to pay tribute to citizens of the State of Sonora and the governor of the earlier days, who was a man of great vision. He supported agricultural research and was primarily responsible for establishing CIANO. He arranged with the farmer organization to supply funds from their own crops for research support which eventually became the present Patronato de Investigaciones Agrícolas. Corresponding support was given for plant protection. The money now voluntarily contributed by farmers for research runs to nearly one million dollars. The governor, unfortunately, passed away the year before the first large wheat shipment went to India. I am sure that this man of vision would have enjoyed seeing this happen.

In the crops with which we work, and most particularly bread wheats, our prime interest at the moment is in stabilizing yields. I agree 100 percent with Swaminathan and Rao. We have a high yield potential in our present varieties and thus far have been unable to exploit it fully. For example, in Mexico two years ago, when the national average was three tons, good farmers were harvesting five to seven tons. This means there are still a large number of farmers producing a ton and a half. It seems reasonable, therefore, that we get more out of what we have through better extension, more fertilizer, better moisture use and better weed control. A large part of this shortfall is an extension problem.

I do not mean to infer that we should not continue to raise the basic yield plateau, but the basic problem of the rust races and other diseases, we know are continually attempting to negate our efforts. Thus, this is the area in which we should expend our greatest effort in these next few years. We need to attack this problem from all angles. We must try to combine horizontal and specific resistances derived from this whole network of nurseries. The regional nurseries are very important, they must be effectively coordinated. Saari, Prescott and all these other pathologists are giving us the information. It is our joint duty to put all these pieces of resistance together. It is a tremendously complex problem which will not be achieved rapidly and will never end. We seldom stop to think of the magnitude of the difficulties with the several hundreds of races of stem rust and the like number of the other rusts. This then becomes further complicated with Septoria, scab and so on whose variability is not even known yet. With all these if we superficially look at it, perhaps if we lived to three or four times the age of Methusaleh, we might achieve part of the need. As I said, it is an extremely complex problem which we must attack from all angles.

Genetic manipulation is a part of the answer but we need to continue to use different kinds of chemicals wisely to protect our crops from insects and diseases. If we do not continue to use common sense in protecting our crops by the means at hand, and not devote all our efforts to something that might solve our problems such as biological control, we may well walk into a scientific morass from which we will spend years extracting ourselves.

Without prejudice to any country, and I want it clearly understood there are no political implications, I want to use an example to point out the dangers of following new messiahs to unknown utopias such as is being done in the extremist part of the environmental movement. In 1935, genetics was suppressed in the USSR and there followed 30 years of Lysenko. The consequence of this period of new science is, in my opinion, a large part of the problem in food production at the present time, even though I realize weather conditions played a major role. These 30 years have been discredited by the present government and science has regained its previous high standard in that country. I wish them well in their wheat improvement. Who knows how much more fertilizer would have been available, how much more irrigation developed or disease resistance or cold resistance built into the varieties? Let us, therefore, profit by experience and not be led into a scientific swamp.

How are we going to handle the disease situation? Firstly, we will use many F1 crosses to be later combined in double and triple crosses to pyramid resistance. I believe the multilineal concept is still valid and we intend to employ it widely.

We need to improve protein quality. We are closely following Dr. Johnson's group and if they find interesting new sources, we will try to incorporate higher lysine or other amino acids in CIMMYT materials.

We have done nothing on breeding for insect resistance. The greenbug in Argentina, the sawfly and Hessian fly of North Africa, the Sunn Pest of the Middle East are still problems to be solved.

In Brazil, resistance to aluminum toxicity requires immediate attention. Da Silva and his group have done a very good job of incorporating resistance to aluminum in their material. CIMMYT must now incorporate these genes in its material so the resistance can be spread to other countries. Soil problems of other kinds exist in many countries.

The durum wheat breeding program is making rapid advances and you will see a revolution in durum production in the next three to four years. The new durum plants have excellent architecture. We had earlier transferred dwarfness to the durums from bread wheat, but because we did not have support it was put on the shelf. We didn't have the full yield but when the program was again taken on as a full time activity, under Dr. George Varughese in 1968, we gradually developed very superior plants, a process still going forward under Dr. Marco Quiñones. In my opinion, the durum wheats have the best combination of genetic architecture, yield potential, and grain type of all the wheats. Quality work was not conducted until a year ago. There may still be deficiencies in pigment or in spaghetti quality. The best durum today is one from Argentina but it has certain quality defects. These defects will be rapidly remedied.

I have not mentioned triticale, but I anticipate that this will be covered by Frank Zillinsky, Ed Larter and colleagues from the University of Manitoba. Dean Shebeski and his group at Manitoba, as you know, began this program in the middle Fifties. Later, through a Rockefeller Foundation grant, a joint program was formed, which was later given full Canadian Government support. This program is progressing very well indeed. It is nearing a position where it can be a commercial crop, but there is still some problem with shrunken seed. This is improving rapidly and we are confident of overcoming this problem. This will be the first new species in the cereals produced by scientific man. You have a new crop and all the agronomy has to be worked out again.

Barley breeding is now in its third cycle at CIMMYT. We have high hopes that the new nutritional levels found recently will provide much better food for people in the very poorish areas. We are confident this crop can be much improved in disease resistance and yield.

In North Africa, subterranean and buru clovers originally introduced from there to Australia, are now being returned by Doolette to provide a new farming system to that area which will add N for the wheat crop and assist in the control of weeds, the area's greatest problem. Seed production training is now beginning in North Africa under the direction of Johnson Douglas. Fischer and his group here in Mexico are carrying out investigations to determine what kind of a wheat plant we should put together for the future.

When I look back at all that has been done and ahead at all there is to do, I am at once amazed that we have come so far, but at the same time that we have so far to go. I can assure all of you that in your and your childrens' lifetimes there will be no shortage of work to satisfy your ambition.

GENETIC IMPROVEMENT OF SPRING AND WINTER BREAD WHEATS AND DURUM WHEATS

R. Glenn Anderson

Wheat, as indicated by Dr. Borlaug, acts as a measure of the food supply situation throughout the world at any given time. It occupies this position due to the fact that it is the important, relatively nonperishable crop produced in abundance in those nations with exportable surpluses of food. It, therefore, acts as a granary for countries with food deficits in certain years. Its importance has recently been exemplified by the dire shortages in Russia and China in the past year which have reduced stored wheat grain to a 20-year low in exporting nations. The record or near-record crops of the developing countries in tropic and subtropic areas has been the only saving feature preventing starvation on a massive scale. Our situation is indeed precarious.

In dealing with the present subject, I will endeavour to walk midway between the general overview given by Dr. Borlaug and the more exacting treatment given to the various topics by the speakers following.

Of first priority, if production gains are to be maintained, and looking at the problems from the genetic viewpoint, is the protection of present genetic potentials for yield from deprecations of weather, disease and insects. Any reduction in vigilance on this side of the coin invites disaster. Any further advances in establishing new yield plateaus must take second place to this greater need.

In the spring bread wheats, varieties have been developed with wide adaptability. This has allowed their spread to many countries with equally beneficial effects. This feature cannot be overemphasized since weather variations at specific locations from year to year are buffered by the same mechanism which makes them widely adapted over many regions of the world. The type of selection pressures which led to their development in Mexico is now being duplicated in a considerable number of country programs through the use of differing environmental conditions in alternate generations through the use of the two-generations-per-year growth provided by suitable summer nurseries. This width of adaptability has not been achieved to anywhere near this level among the winter bread wheats and varieties of durum wheat.

In general, stability through the use of widely adapted varieties can be ensured in irrigated areas. This is not as easily achieved for rainfed culture. Today yields are still very variable. It is certain that improvements in cultural practices and water management will have a great stabilizing effect. However, increasing attention is being given to, and will in the future need to be increased, breeding for various types of rainfed culture. The winter wheats and the durum wheats can be very valuable sources of genes for adaptation to drought for the spring wheats. Two of the features which could be used are deep-set crowns leading to stronger

secondary root development and ability to withstand atmospheric drought without reaching the wilting point. These two are realities and can be a very valuable by-product on the spring wheat side from the presently expanding winter x spring crossing program. As a class, durumms exhibit greater ability to withstand drought than the spring bread wheats and, although the basis is not well understood, this avenue must be explored.

Turning to diseases, varieties on a worldwide basis have been developed in spring wheats with resistance to most of the major diseases. No variety has or will be developed with resistance to all and if one should be developed, its resistance would be only transitory. New biologic forms of the pathogens are continually arising to frustrate the achievement of this universally resistant type. We must, therefore, establish priorities as to which are most important, and concentrate on those while attempting to incorporate genetic resistance to those of lesser importance or of regional concern.

Among the diseases, the three species of rust occupy a central position on a broad scale. Septoria is equally destructive, but fortunately its attacks are governed by a rather precise set of climatic factors and its importance, consequently, is regional. Where it operates, however, its destruction may exceed that normally encountered with the rusts. Alternaria in other regions can regularly reduce yields, but complete crop destruction is only rarely encountered. The smuts as a group act in a similar fashion. A whole host of other diseases may produce varying attrition effects on yield, but normally occupy regionally defined areas.

In the durum wheats, which are subject to the same array of diseases, Giberella zeae, or scab, to which most bread wheats are resistant, is important in those areas where Septoria prevails and its attacks are governed by much the same climatic factors. Durum wheats, without genetic resistance, can suffer 100% destruction from this disease.

Among the winter wheats, disease resistance to the major diseases has not yet been developed to a level equal to that in the spring wheats. This historically has arisen as a result of the fact that in those countries where research has been most active, the winter wheat crop has usually escaped. This is not true of many other countries. Temperature relations in the United States, for example, where the winter wheat crop is of paramount importance, and where research has been very active for many years, are such that the development of stem rust is late and losses to it have been confined primarily to the northern Wheat Belt. Leaf rust has been more important. Stripe rust is absent aside from an isolated area of the Northwest and that only in recent years. This disease, favoured by lower temperatures, is of extreme importance in many other areas, including several of the countries represented at this meeting. European varieties are, in general, resistant because of its importance in that area, but these have not been found suitable to production in such countries as Turkey, Iran, Algeria, Afghanistan and Korea, where much research has yet to be done on these problems. Probably

their relatively late maturity and susceptibility to stem rust have been major retarding factors.

Other pests of importance include such insects as the Hessian fly, the sawfly, Sunn pest, cereal leaf beetle and various species of aphids and mites. Another group is important in damaging the stored grain. Genetic sources of resistance to the field insects are being uncovered and incorporated into the collaboratively developed germplasm of the CIMMYT group of national collaborative programs. Work has recently been intensified as the countries where these insects are important have joined the group. In the case of stored-grain insects, hard-grain texture, as opposed to soft-grain texture, appears to be the best genetic means of control.

All of these genetic control measures for stability of present genetic potential must continue to be exercised. The means which will be used to achieve these will be further explored by following speakers. I wish to mention that disease resistance in winter wheats can be developed from crosses with resistant spring and winter types and that the potential for improving durum for disease and insect resistance can be realized through known sources under proper selection pressures.

Let me now move to the enhancement of present yield potentials. Several approaches seem indicated. Firstly, a great deal of empirical and physiologic observation and research is needed to uncover which combination of plant characteristics will lead to increased yields. In other words, what type of plant will be best suited to given production needs. Are varieties required suitable for early sowing under monsoon climates or winter wheat production where conserved moisture is used for germination? The available evidence suggests yes as the answer. Such a variety would need to have a long vegetative period and an ability to delay heading until frost damage periods are past.

Are there physiologic reasons for the triggering of onset of the reproductive stage? Recent unpublished research data developed by scientists at the Ottawa station of the Canada Department of Agriculture, shows, for example, that among Pitic 60 sibs and derivatives, the spikelets and florets are cut off and develop fully before sex organs appear. In other varieties, the development of sex organs appears to stop the cutting off of additional spikelets. In a European variety, a different mechanism is operative wherein all florets within spikelets develop before sex organs begin, leading to multiflorous-type heads. In the case of Pitic, this may account for at least a portion of its obvious wide adaptability as it would have the ability to adjust to various conditions.

Many other features, some morphologic and others physiologic, appear to be important from empirical observation and their value may differ greatly according to the conditions under which the crop is produced. Time does not allow for enumerating these, but the principles would include: open canopy leading to greater sunlight penetration and reduction of favourable microclimate for diseases and insects; varying straw height for varying moisture levels; different forms of rooting for different crop conditions; superior

balances between seed size, tiller number, and grain number and density to provide necessary sink capacity; better nutrient translocation from leaves and stem to grain; retention of greater photosynthetic area for longer during the grain-filling period. These are a few of the principles which require investigation and the formation of various plant types involving genes for the various characters concerned is necessary if we are to learn which constellations of characters are most beneficial in producing yield.

A continuation and expansion of the trend to greater variation in germ plasm must be pursued. This is particularly true for the improved durum varieties. One thing, however, is certain --exotic germ plasm must be added to the improved gene base. It can only lead to frustration if we try to improve land races which, as a group, have a low intrinsic yield base.

I previously referred to the need for developing varieties for crop rotations. For example, Korea needs varieties which can be rotated with rice, their principal crop. These varieties must be winter hardy, delay heading until spring frosts have stopped and mature very rapidly from heading to maturity. Because such varieties have not yet been developed, barley in place of wheat is the rotational crop despite a great desire to move to wheat. In Bangladesh, adjacent areas of India, Thailand, Indonesia and other warm areas where rice predominates, short duration varieties capable of producing after late rice harvests can open up considerable vistas for increased production. Similar examples are manifold.

Factors influencing the industrial quality of wheat have traditionally formed the basis for most quality considerations. In the bread wheats the making of leavened bread has received most attention. Only in recent times has any study of value for other forms of leavened and unleavened bread been attempted. Even more recent have been the attempts to investigate nutrition as a basis of quality. These fields are still pristine. We have some information on protein of varieties, some of lysine values, but as yet little information on whether massive improvement is possible. Even worse, authorities on the subject are as yet unable to provide a picture of which combination is best --high protein content with low lysine levels or low protein content with high lysine levels. Our standard procedures for estimating nutrition seem to concentrate on quality of protein and there is much less known about the effect of protein quality or general nutritional properties of wheat. Ways must be found to establish these premises and then to provide rapid tests which will allow for breeding suitable types.

In the durums, tests are available for establishing which characteristics are most suitable for pasta production. Again, nutrition level has been ignored. Present improved high-yielding varieties are not yet available with desired pasta quality and this aspect must be developed.

In conclusion, we must increase yield stability through resistance to weather, disease and insect hazards. We must maintain width of adaptability. We must fit varieties to cropping

systems in a tailor-made fashion. We must continue to widen the germ plasm base. We must look increasingly to plant structures and physiologic internal mechanisms as the basis for increasing yield potential. We need to consider both nutrition and industrial quality in both bread and durum wheats. This includes both marketability and ability to provide greater quantities of protein for those countries where the cereals form the principal source.

I have tried to bring out some of the principles to be followed in yield protection and enhancement together with some of the quality considerations we need to follow. I am sure that the following speakers will fill in the details of how we might accomplish these ends.

BREEDING FOR YIELD POTENTIAL, STABILITY, AND ADAPTATION

Arthur Klatt

Since the science of varietal improvement was initiated, we have worked to increase maximum yield potential. Today, I would like to discuss this as well as a new topic, stabilizing minimum yield levels.

Yield per unit area or yield potential is the eventual criterion used by breeders and farmers for the acceptance or rejection of any new variety. However, yield potential is a complicated character involving characteristics such as disease resistance, plant height, straw strength, tillering potential, head size, kernel size, responsiveness to fertilizer and moisture, and, under certain conditions, cold and drought resistance. The interrelationship or balance of these characters determines the genotypic yield potential. Actual yield will be determined by the interaction of these characters with the environment.

Yield potential in spring wheats grown under irrigation or high rainfall has received widespread breeding efforts in the last 25 years. Prior to 1962, plant height and straw strength limited yield potential to about 4 tons per hectare due to susceptibility to lodging. With the first semidwarf spring varieties (Pitic 62 and Penjamo 62), yield potential was increased significantly to 7 tons or more per hectare under ideal conditions. Recently isolated triple-dwarf types may raise this figure even higher. Also in the last decade, advances have been made in breeding varieties with better disease resistance, wider adaptation, yield stability, and better quality. These varieties have been distributed widely and have greatly increased yield per unit area and total production in many countries.

However, the winter wheats and spring and facultative wheats for dry conditions have received far less international breeding effort than the above-mentioned spring wheats. This research lag is now being closed with the work of Rupert's spring x winter program, Nebraska's IWWPN, the new Turkish winter wheat program, Algeria's program to find wheats for their high plateau, the research programs in the U.S. Pacific Northwest (Washington and Oregon), the Russian and closely related programs, and others. Most of these programs have started recently and will require additional time before better varieties can be isolated.

In the last decade many other programs have made significant contributions to winter wheat breeding; the incorporation of the semidwarf characters in U. S. Pacific Northwest wheats in 1961 and more recently in the varieties Sturdy and Tam Wheat 102 from Texas, high yield and good adaptation of the Russian varieties, high yield potential of the European varieties, drought resistance and winterhardiness of the central U.S. Great Plains varieties, and many others. However, all of these varieties have limitations and no single variety or group of varieties has demonstrated superior yield potential over a wide range of environmental conditions (the possible exception is Bezostaya) as have the semidwarf spring

wheats. What are the reasons for this situation?

Probably the main reason is the climatic instability of the winter wheat growing regions. Most winter wheat areas are characterized by large annual fluctuations in temperatures and precipitation and also large monthly fluctuations. This creates a need for yield stability as well as a need for increased yield potential. A vivid example of the affect of adverse climatic conditions and the lack of yield stability is the production figures for food grains in the USSR in the last two years. In 1971, the USSR was essentially self-sufficient, but in 1972 imports will probably exceed 25 million tons. Yield instability is also evident in Turkey. Between 1965-1971, annual production ranged from 8.5 to 13 million tons; the difference of 4.5 million tons represents about 35 to 40% of Turkey's annual needs. Similarly, yields per hectare have varied greatly from year to year. The difference between the highest versus lowest average yield per hectare is 500 kg/ha, which is more than 40% of the average yield/ha. Yield fluctuations of this magnitude must be eliminated as yield potential is increased. How can we accomplish these two feats simultaneously?

Since yields in most winter areas depend on the precipitation received during the growing season, we must first devise better tillage practices for moisture conservation. Adaptive tillage research trials have been conducted for the last three years in Turkey and results are very encouraging (Dr. Bolton will discuss these experiments later in this conference). At this time let me simply state that with the improved techniques and present varieties in a wheat-fallow rotation it is possible to stabilize minimum yields at about 2 t/ha, even with 290 to 310 mm of precipitation per year in the Central Plateau. With 350 mm of rainfall, this yield level is raised to 3 to 3.2 t/ha (results obtained with the variety Bezostaya). Further increases in yield potential will come primarily from new varieties bred for adaptation to wheat-fallow rotations and unpredictable moisture patterns of most rainfed areas.

Of primary importance in this adaptation is better drought resistance or better water use efficiency. Currently in Turkey with a wheat-fallow rotation, using the best tillage practices and an improved variety (Bezostaya) and with 350 to 400 mm annual rainfall, we are obtaining approximately 3.5 to 4.0 kg of grain for each millimeter of rainfall received in the two-year crop season. Lower annual precipitation levels reduce the water use efficiency values. These data indicate that current varieties are quite efficient water users, but better varieties must be isolated. To do this, physiologists must identify characters which will increase water use efficiency, especially those which can be visually selected by breeders. If characters such as fewer leaves, leaf rolling, waxy leaf coatings, upright leaves, or reduced number of stomata, etc. are of little or no value; then breeders and physiologists must cooperate to identify other morphological and/or physiological characters which will increase the water use efficiency of plants. Physiologists, do you accept the challenge?

Other traits that might enhance drought resistance are extensive root systems and deep setting of the crown node. Extensive and deep root systems will more effectively utilize the available moisture in the soil profile, thereby minimizing the yield reduction under adverse conditions. Similarly, types with deep crowns are generally more resistant to adverse conditions, including drought and cold temperatures.

The three main yield components, tillers per unit area, head size, and kernel weight, must also be manipulated to permit maximum yield stability under adverse conditions while maintaining responsiveness to favorable conditions. The relative importance of each yield component will vary with environmental conditions; however, in most winter wheat areas with a wheat-fallow rotation, tillering and head size are the most responsive components. In these areas there are three critical moisture periods: fall moisture for tillering and plant establishment (also for germination if insufficient moisture was stored in the fallow); late winter and early spring moisture for heading and filling. Current improved varieties (Bezostaya and Bolal) respond to favorable conditions but are not sufficiently stable under adverse conditions, while old varieties are quite stable but lack responsiveness. This can be demonstrated by the performance of Bezostaya. At yield levels of 3 t/ha, Bezostaya has a 15 to 20% yield advantage over the old varieties; however, at yield levels of 1 to 1.5 t/ha, Bezostaya is frequently inferior to the old varieties. How can this response be altered to combine stability and responsiveness with minimum breeding effort?

Kernel size is the least responsive component and large kernel size has consumer preference; therefore, new varieties with large seeds are needed. New varieties must also have sufficient tillering potential, although not prolific tillering types, to respond to favorable conditions. Prolific tillering types may frequently tiller too much for subsequent environmental conditions, thereby expending large quantities of plant energy and water and causing greater water loss from the plant when the excessive tillers are sloughed off. Because of this, types with intermediate tillering potential would probably be more desirable. Most current varieties already have sufficient potential and little breeding effort will be necessary to properly refine this trait.

A variety with a large head is needed to complement the above two components and to furnish additional yield stability. The spike should have a large number of spikelets, and each spikelet should have good multiple floret fertility. In this way, tillering will serve as the responsive component for favorable conditions in the fall and spring and head size can fluctuate with environmental conditions in the late spring. If tillering is low due to poor early moisture, head potential is still present to increase yield potential if conditions are favorable in the late spring (conditions similar to those occurred in Turkey during the 1971-72 season). Increased stability will be obtained by selecting types which retain the greatest number of tillers under all conditions and by selecting types which have a large spike on each tiller, in which at least two kernels per spikelet are set regardless of conditions. In this way, minimum yield, even under severe conditions, becomes a function

of plant population and spikelet number.

In regard to tillering, it would also be advantageous to have upright plant types, that is types with a closely grouped tillering pattern. This plant type might give an additional yield advantage due to reduced mutual shading and the possibility of getting more heads per unit area. Tillering must also be synchronous in time and length of head extension. This character will facilitate ease of harvesting and will reduce loss at harvest, especially if combines are used.

Several other characteristics are also essential to improve yield potential and to give maximum yield stability. Winter varieties with reduced plant height and better straw strength are needed to prevent lodging and to permit higher maximum yield potential. In most cases, the height will be sufficiently short. Proper maturity will be an important character of all new varieties. Generally, selection should be for early winter varieties which will escape the hot, dry conditions of early summer; however, extreme earliness is undesirable because of the problem of late spring frosts. In many facultative and spring wheat areas it is desirable to find types which mature rapidly but which have a long vegetative cycle to avoid spring frosts. Present varieties which have a short reproductive stage generally have poor yield potential. We must find types with higher photosynthetic and translocation rates during the reproductive stage to break this relationship.

Winterhardiness, resistance to shattering, and responsiveness to inputs are also needed in new varieties. The importance of varieties with good cold resistance has been recently demonstrated by the crop losses in Russia due to winterkill. We must incorporate sufficient resistance to withstand the coldest temperatures of the region, not just the average winter temperatures. Resistance to shattering is especially important in regions where harvest is delayed due to lack of machinery or custom as is commonplace throughout North Africa and the Middle East. Responsiveness to inputs such as fertilizers, herbicides, insecticides, etc., is essential and efforts must be made to maximize response.

One remaining factor which is very important for yield stability is disease resistance. Our present system of major gene or specific-type resistance is less than satisfactory because the pathogen is generally only one step behind us, waiting for us to slip. New varieties with a more permanent type of resistance must be isolated, utilizing minor gene or nonspecific-type resistance, or a combination of specific and nonspecific resistance. Hopefully, with this type of resistance predominating and if the pathogen cooperates, more time can be spent breeding for some of the above traits and less time will be required for disease resistance.

In the discussion above, I have mentioned what I think would be improvements and in some cases, additional features in the wheat plant as we know it today. But will this restructuring of the plant solve our basic problem-sufficient food for the world's population? We are facing the challenge of a rapidly increasing

population; estimates predict 6 billion people in the 1990s. To feed these people, we must double food production in about 30 years and we must start now. To meet this ultimatum for increased wheat needs there are essentially two methods of approach: by gradually increasing yield potential or by identifying a "new" wheat which will give us a higher yield plateau. Most current breeding programs are following the first alternative, trying to identify types which will give a stepwise increase in yield potential which hopefully will keep pace with increases in population and food requirements. In my opinion this approach may not give the answer and I will use the Mexican breeding program to justify my statement. Since the incorporation of the semidwarf character in 1962, little increase in yield potential has been accomplished. Great steps have been taken to stabilize yields, or to permit expression of yield potential, by incorporating better disease resistance and better adaptation into the recent varieties. These characters have enhanced total production and production per unit area in many countries. A recently introduced character, the 3-gene dwarf, may significantly increase yield potential if types with better disease resistance and adaptation can be found. If these types are superior, their use will probably be limited to irrigated and high-rainfall areas, with little advantage in yield potential for the dryer regions.

If the above statements are true, then we must use the second approach, which will require a long-range and intensive research program with full cooperation of the various disciplines. The "new" wheat may actually be a new plant type such as triticale or other interspecific or intergeneric cross, or the branched or ramified plant types. It might also be similar to our present wheats, except with much greater plant efficiency to achieve yield potentials unknown today. Breeding programs utilizing diverse crosses such as springs x winters, improved x natives, etc., might also isolate the types which will permit us to achieve the new yield plateau. Regardless of the method used, a wheat research team comprising breeders, pathologists, physiologists, agronomists, entomologists, etc., will be needed to achieve this breakthrough and ultimate realization of our objective --food for billions.

PROTECTION: DISEASE AND INSECT RESISTANCE

Sanjaya Rajaram

I would like to deal with the problems we now have in handling disease resistance. There are more than 50 diseases of wheat. I want to point out that the problems indicate the types of diseases important in different parts of the world with which CIMMYT cooperates and how the information is gathered so that we may breed for resistance to those diseases. I should like to begin with showing you some slides.

For each country, I have listed the diseases as they appear in order of importance (see Tables 1, 2 and 3).

TABLE 1. Major diseases of wheat in CIMMYT-collaborating countries of Latin America.

Countries	Prevalent diseases and insects in wheat belt
Mexico	Stem rust, leaf rust
Guatemala	<u>Septoria tritici</u> , stripe rust
Ecuador	Stripe rust, stem rust
Colombia	Stripe rust, stem rust
Peru	Stripe rust, stem rust, powdery mildew
Chile	Stripe rust, stem rust
Brazil	Stem rust, leaf rust, powdery mildew, <u>Septoria tritici</u> , <u>Septoria nodorum</u> , aphids
Argentina	Stem rust, leaf rust, <u>Septoria tritici</u> , aphids

TABLE 2. Major diseases of wheat in CIMMYT-collaborating countries of Asia.

Countries	Prevalent diseases in wheat belt
India	Stem rust, leaf rust, stripe rust, alternaria
Pakistan	Stem rust, leaf rust, stripe rust
Afghanistan	Stripe rust, stem rust
Iran	Stripe rust, stem rust, leaf rust
Turkey	Stem rust, stripe rust, <u>Septoria tritici</u>

TABLE 3. Major diseases of wheat in CIMMYT-collaborating countries of the Middle East, North Africa and East Africa.

Countries	Prevalent diseases and insects in wheat belt
Lebanon	Stripe rust, stem rust, <u>Septoria tritici</u>
Egypt	Stem rust, stripe rust, leaf rust
Tunisia	<u>Septoria tritici</u> , stem rust, Hessian fly, sawfly
Algeria	<u>Septoria tritici</u> , stem rust, Hessian fly, sawfly
Morocco	<u>Septoria tritici</u> , stem rust, Hessian fly, sawfly
Kenya	Stem rust, stripe rust
Ethiopia	<u>Septoria tritici</u> , stem rust

These are the major diseases of the countries with which CIMMYT cooperates. The problem is that there is such a wide spectrum of diseases. Most of the time, the same diseases occur in many countries. How do we handle these?

To have the efficient use of resistance in the CIMMYT breeding program, we have to first have hard information on an international basis. We use this information from the various international nurseries and feed the resistant strains into the breeding program. Table 4 lists the various nurseries from which we bring together these resistances. These nurseries originate from various places in the world. The information is brought together.

TABLE 4. Evaluation of resistance to various major diseases through international nurseries.

Nursery	Operated by
International Rust Nursery	USDA
International Spring Wheat Yield Nursery	CIMMYT
International Winter Wheat Performance Nursery	University of Nebraska
International Spring Wheat Screening Nursery	CIMMYT
International Septoria Nursery	CIMMYT
Regional Disease and Insect Screening Nursery	FF, Lebanon
Latin American Disease and Insect Screening Nursery	CIMMYT
Elite Trials	CIMMYT
Preliminary Observation Nursery	FAO - FF, Lebanon
International Winter Wheat Screening Nursery	Turkey

In Table 5, I have shown how these materials are arranged in the CIMMYT crossing block according to the particular use they may have.

TABLE 5. Arrangement of resistant-gene pool in CIMMYT crossing block; geographical representations as source of genetic diversity.

Group I	Varieties or lines highly resistant to stem rust and leaf rust.	
	Section A	Varieties from Canada
	B	Varieties from USA
	C	Varieties from Australia
	D	Varieties from Kenya
Group II	Varieties or lines highly resistant to stripe rust.	
	Section A	Varieties from Ecuador
	B	Varieties from Colombia
Group III	Varieties or lines resistant to <u>Septoria</u> sp.	
	Section A	Varieties from Argentina
	B	Varieties from Brazil
	C	Varieties from Ethiopia
	D	Varieties from North Africa
	E	Varieties from Turkey
	F	Varieties from Israel

We have divided the rust-resistant materials according to countries because, theoretically, they should have resistance to different races, depending on their geographical source.

Based on the last nurseries, therefore, we have divided the group, for example, into lines with high resistance to stem rust and leaf rust and subdivided this group into varieties from Canada, U.S.A., Australia and Kenya. These are typical leaf rust and stem rust areas in which considerable work has been done. Resistances from these countries usually cover the needs in most other countries. Similarly, those varieties derived from Ecuador and Colombia are major sources of resistance to stripe rust. Septoria resistance is organized into varieties from Argentina, Brazil, Ethiopia, North Africa, Turkey and Israel because it is in these countries and regions that this disease is most prevalent and where the greatest resistance has been built up.

A very wide germ plasm pool is thus represented in the crossing block. The material is much more efficiently used when the crossing program is being conducted.

In Table 6, I have indicated possible ways of incorporating resistance insofar as we would prefer to do at CIMMYT. Specific resistance is based on single genes or many major genes and also specific adult-plant resistance. In the nonspecific genes, we have the second class we can use. In the multiline concept, both types of resistance are incorporated in combinations in the different lines. We are concentrating on building in as much horizontal resistance as possible and on the multiline.

TABLE 6. Breeding for resistance.

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A.	Specific resistance
	a) Based on single gene
	b) Based on many major genes
	c) Specific adult plant resistance
B.	Nonspecific resistance.
C.	Multilines utilizing specific genes or combination of both specific and nonspecific genes.
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In Table 7, I would like to indicate the present position of CIMMYT materials. Stem and leaf rust are under control in one germ plasm as a whole, but we cannot slacken our efforts in continually incorporating new sources. There is further need to strengthen and broaden resistance to stripe rust. There is still a general lack of Septoria resistance in the total material, but we are rapidly correcting this problem through widespread crossing with sources of resistance. We now have the possibility of selecting at Patzcuaro and Toluca in Mexico and in the cooperating programs of the important Septoria countries. We, at the same time, maintain rust resistance in the material.

TABLE 7. Present position.

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1.	Stem rust and leaf rust problems are under control. However, there should not be any slackening of effort.
2.	There is further need to strengthen and broaden the stripe rust resistance in the CIMMYT gene pool.
3.	There is a general lack of Septoria resistance in the CIMMYT gene pool. Efforts are underway through Toluca and international testing to correct this problem in a very short time while maintaining the rust resistance.
4.	Scab screening is optimum and CIMMYT bread wheat lines have satisfactory resistance to this disease.
5.	Lines resistant to Hessian fly and sawfly are used in the crosses and F ₂ s are screened in North African cooperative programs.
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Screening for scab is easily done since it is very severe each year. Although the durumms are attacked quite severely, there appears to be adequate resistance in bread wheats. Lines with resistance to Hessian fly and sawfly are used in the crosses and F2s are sent to North Africa for screening. This sums up the present position of disease factors in the CIMMYT materials.

In the future, CIMMYT will attempt to further increase the knowledge on nonspecific resistance against many diseases so that the genetic mechanism of resistance is clearly understood. This will facilitate the breeding of varieties which carry specific and nonspecific resistance. CIMMYT also intends to produce multilines in varieties like Siete Cerros and believes this will stabilize yields through stabilizing resistance.

Horizontal resistance has been mentioned by different speakers. We use multilocal testing which, for us, is the best way presently available of ascertaining whether a line is likely to carry genes for this type of resistance. That is, if a variety is resistant at many widely dispersed geographic locations, it is likely to possess nonspecific resistance.

QUALITY: INDUSTRIAL AND NUTRITIONAL

Arnoldo Amaya

I would like to tell you very briefly what is being done at CIMMYT in regard to quality. I am sure that on your upcoming visit to the laboratory, you will get a better idea of what we do. The laboratory is set up for evaluating materials at both the microtest and macrotest levels. This is important for the breeder since he can select for quality simultaneously with selecting for agronomic characters. We have seen in our programs that before we began using microtests, 95% of our lines at the end of the test period were not of the quality which we desired. Now, with the microtest applied throughout the breeding program, only about 5% are the undesired type.

How have we changed quality and how have we been able to combine quality with the yield of the semidwarfs? Many people said earlier that quality could not be combined with the semidwarf characteristics. This, of course, has been shown.

We first bring in the F3 and F4 generations. In the past crop at Toluca, for example, we screened this material for gluten strength using the Pelshenke test which we have found to be very suitable for early screening. About 14,000 samples were so assessed before they were sent to Obregon for sowing. Among these 14,000, we later classify how many are of the weak gluten type, how many are medium and how many are strong gluten. We found that 28% were weak, 30% were medium, and 42% were strong gluten. Before starting with the Pelshenke test, as I said earlier, 95% had weak gluten. This has been changed and we now have a more or less balanced program of weak, medium and strong types to serve the various industrial uses of flour in different countries.

This has been made possible through the introduction of varieties from many countries. It is very important to have this diversity since it allows us to assess the quality of their commercial varieties to give us an idea of the quality each country feels is desirable. This then allows us to more closely supply the kind of quality which each country desires. It is certain that different countries require different types of quality for the various preparations most commonly found in each.

One of the nurseries which CIMMYT sends to different countries is the International Bread Wheat Screening Nursery. How do we prepare this? In Obregon, all the advanced materials of F5 and F6, those tested in yield trials and some of the lines of the crossing block, are first selected for their desirable agronomic and disease responses. The material selected at this level is then sent to the laboratory where it is checked for seed type, and test weight (very important since it reflects the flour yield). Over time testweight has gradually been improved. The material is then assessed for protein percentage and gluten characteristics as shown by the alveogram, mixogram and sedimentation tests. When we have all of this information, we place the best types in the screening nursery which we send out. In addition to the seed, we include this quality information which we have developed in the laboratory. This information, we hope, will help you in

choosing material of possible use. We include different types of material. There are lines with white grain as preferred in certain countries. There are red grains as preferred by others. Some have weak gluten, medium gluten or strong gluten. Each country can then select materials of value in either breeding or direct use.

With respect to nutrition, our advance is much slower. We are screening all lines collected from different countries for protein and lysine content. Unfortunately, like the University of Nebraska, we have found that wheat does not appear to have great variability for lysine. However, the Nebraska workers have reported that several lines combine high protein and higher lysine content. We are attempting to cross some of these with our materials. However, the F1s are generally poor and in many cases the breeders discard the lines for agronomic reasons. With our new approach, we will observe these more carefully in a three-way and double cross program. It is the F2 of these crosses that we will first screen for protein and lysine. In this way, I am sure, we can improve our protein quality from the nutritional point of view.

DISCUSSION

Shebeski

Dr. Anderson referred to the need for open-canopied varieties for dryland conditions. I was wondering if this type of variety would not leave the soil open to greater chances of evapotranspiration? Is there concrete evidence that open-canopied varieties actually outyield the prostrate types under dryland conditions?

Anderson

In my references, I am sorry that I gave this impression. On the irrigated tracts, I feel that it is particularly important to have the open crown. There we have considerable evidence for the advantage of these types. It may be achieved by upright crowns, by having upright leaves and so on to allow for light penetration and also make the canopy a poorer refuge for insects and diseases. There is also one other feature not mentioned this morning which plant breeders might consider. This is the long peduncle above the flag leaf and below the head. Assuming the area is free from disease, it provides a photosynthetically active area in which little light interference occurs.

On the question of the dryland, I am not sure how I should answer this. Dryland is a compendium of many degrees of water availability. Dryland goes from overirrigation from the sky, through intermediate conditions, to the other extreme of no rainfall during the entire season. I think the plant type which would fit the different conditions would vary considerably. If we think of the very dry conditions, the prostrate or semiprostrate might be the best kind for the very reason you give.

If we go back to Dr. Klatt's remarks and if I may speak for him on this question of saving moisture on the surface, they are promoting a dry mulch surface which would tend to keep down evaporation during the early period before the rains begin. In this condition in Turkey,

it is then cold during the time it rains so that there is a lower degree of evaporation.

We must consider what type of dryland we mean. Each of us tends to think in terms of the dryland best known to us rather than the global variation classed as dryland.

Schultz

In the case of varieties that have been promoted very successfully, where there is water control, reaching out then to the need for fertilizers and other complementary factors, the story has now become quite complete.

Under dryland, however, you didn't mention the complementary factors that come with modernization, for example, the power availability and mechanization seem very remote. The timeliness of certain kinds of fieldwork seem to me to be very important. Last year in the Great Plains (U.S.A.) where we had unusually heavy rains, it was difficult to get into the fields. If this had to be done with horses, there would have been a great deal of delay once it was possible to enter the fields. The farmers had to work night and day, but they were able to get the work done despite the adverse beginning. Twenty-five or 30 years ago, with horses, it would have been impossible to reach this level in the same time.

Is there some such sort of complementarities in practices to take advantage when adversity strikes to cut down on the time necessary to get the crops in the ground or off the field to make the best of the moisture available.

Anderson

On this question of mechanization, Dr. Rao spoke yesterday of some of the driest lands in the world. There is virtually no rainfall and the crop grows almost exclusively on residual moisture in the soil profile. With traditional agriculture using bullocks, it is very difficult to work those heavy clay soils so that the seed can be placed in moisture for germination at the time that present varieties are apt to give their greatest yields. Speaking philosophically, I am not at all sure but what these areas should be amalgamated into large tracts which could then underwrite the use of power in the mechanized sense. Dr. Bolton or Dr. Nelson will no doubt speak on this aspect later in the week.

One of the ways we might be able to circumvent part of this problem is by genetic manipulation to produce varieties which will better fit the conditions. Dr. Bolton, for example, finds that he gets a considerable increase in yield by sowing on residual moisture. There is enough water stored in the profile with proper agronomy to carry the plant to the rainy season. He finds that the plants are stronger and better able to withstand the onset of winter. So, he has good establishment. We need, however, some sort of genetic mechanism that will allow us to seed at an early period to keep it from shooting or else the crop will freeze. Thus, this tailoring of

varieties has many variables. The whole field is broad. We must consider soil texture, time rains occur, whether they are dispersed across the season or whether there is a special time for rainfall. I hope that during the discussions on agronomy, this will be more fully illuminated.

Smith

I would like to ask Dr. Rajaram about the present status of the multilines. You intimated that single-gene resistance was not being used; would you tell us how you are sure that it is not single-gene resistance. I would like to comment on scab. You said that it was not severe on spring bread wheats. Does this mean they do not get scab under conditions where scab is present?

Rajaram

Three years ago we began to work toward a multiline in Siete Cerros (8156). This variety is known by many different names such as Kalyansona in India and Mexipak in Pakistan. This variety is widely grown from Morocco to India. It has become susceptible to all these rusts in most of the countries plus Septoria. It is one of the highest yielding varieties ever produced. Thus, we decided to develop a multiline in this variety. We would not be absolutely sure but insofar as possible we would put a wide variety of resistance genes into various lines of this variety. The sources of resistance were derived from varieties from widely separated geographic areas and with the information derived from multilocation testing.

We feel that we have at least 10 lines which have been placed under test. These have come from different crosses. Early testing in the greenhouse for rust indicates that the genes involved are quite distinctly different. These lines may have either specific, horizontal, or a combination of these two types of resistance in their composition. At this stage the lines are showing good resistance to the three rusts at both Obregon and Toluca. We hope that we will have comparative yield data at the end of the current season.

Experience has indicated that single-gene resistance is short-lived. Sometimes a variety becomes susceptible in the first year after release. We have found, as I indicated, that it is best to use varieties having resistance at many locations. Testing of varieties identified in this fashion almost invariably shows resistance controlled by many genes. In our opinion, the single-gene specific resistance is unlikely to have multilocation resistance. The few exceptions to this rule include resistance derived from Agropyron, Aegilops or rye. However, we are not placing full faith on these types of resistance.

As you know, scab (Giberella zeae) is prevalent at Toluca every year because of cloudy skies and low temperatures which are favorable to the disease. Susceptible bread wheats can be affected to a level of 100%. In our selection criteria we accept only those lines which have a very low incidence. We can hardly say that a wheat line is absolutely immune under these conditions but all our advanced lines which are cut carry an acceptable level of resistance. This was what I meant by our having no problems with this in the bread wheats.

We would accept 2% to 5% scab, depending on how prevalent scab is that season.

Bradfield

I would not challenge Dr. Borlaug's statements on wheat, but I am going to challenge one of the statements he made on history. When the Mexican program was supported by the three investigators, I remember Warren Weaver of the Rockefeller Foundation making this statement: "For the US\$50,000 set aside for this Mexican program, it meant that US\$1 million was tied up from the Rockefeller Foundation endowment for the period of the project." So he asked, "How long will it be before the Foundation can withdraw its support?" I am proud to say that the estimate given at that time was 20 to 25 years.

Borlaug

I think this is a very good point for it shows how the whole world situation has changed with respect to looking at the food problem and agriculture as a way of life. It demonstrates how our attitudes have changed in this period of time.

I would like to make a couple of comments on the idea of plant type. I think we don't know what the ideal plant type is. I hope the physiologists will show us something of this but I am not yet convinced. I am not convinced that it must have narrow leaves or that leaves have to be outright. This may be true for rice growing under a heavy cloud cover, in certain parts of the world. It may also be true for wheat in North Africa under the overcast Mediterranean climate. There are some curious inconsistencies. The dwarf durum, for example, have so much foliage they should not get much light and yet they will run the bread wheats out of certain areas just as they are. Yet everything we hear on plant type indicates they should not do this. We should be a little careful about what is the ideal type. When we are speaking about other characters we also must tread carefully as the whole question is very complex. I refuse to be hidebound to any particular phenotype. Plant breeding is an art and a game of numbers. You have to eyeball the material and then set up good screening tests to make the plants talk to you in terms of kilograms and quality of grain. Let us not become oversophisticated before we have data to show that we are not going down a blind alley.

On the question of disease resistance, I would like to comment on Fusarium. Since we started working on the wide international basis, our ideas have changed on what is resistance. In Toluca, resistance to Fusarium is one thing, in Argentina or Brazil most are susceptible when the conditions are right.

Similarly, Septoria resistance in Toluca has nothing to do with resistance in North Africa, East Africa, Coastal Turkey or Argentina. But I am convinced that in spite of no one knowing the social make up of these populations that these can be combined. Only when we move the lines that have come from such crosses to collaborators in these areas after giving a preliminary screen to them at Toluca can we make progress. This is now being done for the first time with Septoria. No one knows

how long these varieties will be stable. Assuming we get stability, we still don't know how much variation there is with this variety compared to the rust. Hopefully, it won't be as shifty, but it probably will.

Fischer

I would like to comment on Dr. Borlaug's remarks on plant type. I agree with him. The question is wide open. I think it is interesting to contrast this with the conclusion that is to be found in the 1970 report of the conference at IRRI where they said that no further advance could be made now from change in plant type. There is an interesting contrast of philosophies in these two crop plants. My question is one of breeding strategy. I want to deny any suggestion that this question implies that I know anything of breeding. Let that be as it may, I would like to mention what to me seems a dilemma. CIMMYT and the international centres seem to be trying to do everything for everybody in the sense that it is trying to achieve in this material broad adaptability to climatic conditions, to water supply in particular, to a whole spectrum of diseases, to soil problems, and to types of quality for different countries. There is this philosophy on the one hand and then Dr. Anderson says we need to tailor varieties to certain climatic situations --early sowing, for example, in monsoonal areas of India. Dr. Klatt says we should tailor varieties to dryland situations and it seems to me there is a conflict of philosophy. I would like either of the two speakers to comment on this.

Mangelsdorf

Dr. Stakman, would you care to deal with this question?

Stakman

I would like to answer a lot of questions. I would like to add to what Dr. Bradfield said about the length of time required for this program. I say this not because I think you were wrong Dr. Borlaug, but I don't think you were exactly, and if you were I wouldn't say this in public, necessarily. It was a perfectly obvious thing when the Mexican Program was undertaken that it would take considerable time. To be precise, the statement was made that concrete results should not be expected in less than a decade. Now because of the genius of Dr. Harrar, Dr. Borlaug, Dr. Wellhausen and those other scientists who had not only scientific sense but common sense and knew how to get along with others, concrete results came in a shorter time. But we also said that if the job were done as it should be done it would take at least two decades and probably two and a half. I would like all of you to understand this because we needn't think that these jobs we are undertaking are all easy. We have immediate objectives but we should also have ultimate objectives and they should be long-time objectives. One of the most profound things said by several people in this meeting was that we must not mistake temporary fluctuations for long-time trends because the weather changes all the time.

One more point: we have been speaking of disease resistance. I think that from what Dr. Anderson and some of this colleagues have said and what Dr. Borlaug has said, that we must shift our emphasis

from individual characters to the totality of health in plants. Total health in plants means the total performance, whether from morphological reasons or other reasons and the only way you can do this is to get a good sample of what they will do. I agree with each of you that the ultimate test is the performance.

Now I can't help saying that in reference to disease resistance, and this has been brought up a number of times, we must avoid two things. We have had enough painful experiences and have learned enough that we should not make the same mistakes the pioneers made. We could not foresee the future as clearly as we now can and we made terrible mistakes. One was in relation to the question of scab. Over and over again, as some of you older people know, we just traded problems. We suppressed one disease temporarily and reduced it to a minor status only to find we had elevated another disease to a major status. A beautiful example is scab in relation to rust. Marquis, which was produced in Canada, was early enough to escape rust for a number of years and a lot of people thought it was resistant. It wasn't. But never until Marquis was introduced to the spring wheat region did scab become a problem. Scab then became a problem, not in the entire spring wheat region but in the Corn Belt where wheat and corn had the unholy alliance whereby corn furnished a lot of inoculum and the Corn Belt furnished the humidity and the high temperatures. Toluca is not a good place for development of scab, in my opinion, except for certain races that develop at a lower temperature. We had to abandon Thatcher, which was an elaboration of Marquis in which we had incorporated genes of Kanred, on all except about 15 million acres in western Canada. In that area climatic conditions were not favorable for development of scab.

We must not make the mistake of elevating one disease while we are suppressing another. That is why we have to think more in terms of total health in plants. In the case of disease resistance, we must not repeat the previous mistakes. People are talking now of horizontal resistance. It is a different name than that previously used but it is not a different phenomenon. In 1892 Cobb, a Yankee, went to Australia. He worked with Fauer there and developed a theory of mechanical resistance to rust, but that was discarded. Why? Because they were looking for a universal cause of resistance and an exclusive one. This demand for a universal explanation really blocked progress for a long time. So when we speak of resistance, I say there are many factors concerned with resistance. Many people talk as though the generalized type of resistance had never been used. It's been used since 1910. It was used when we first discovered that Iumillo was slow to rust. It had a long incubation period but no one knew why. It was placed under adult plant resistance. All of the breeders have taken advantage of morphological characters, but not necessarily consciously, but because of their performance. Thus, a lot of this has been incorporated.

I would like to say a word on trends and in connection with insurance and stabilization of production. I want people to stop and think of a continental climate and the amount of wheat and other crops grown in this type of climate. You can't tell when the moisture is coming. Data for the spring wheat region of the U.S. indicate that in six out of nine years, because of drought and rust, the yields of wheat were six bushels or less an acre when good yields were 16 bushels.

Walter Kugler, Chairman

It is a pleasant experience for me to be here in Mexico. I remember two events which impressed me 25 years ago. I was at the University of Minnesota at that time, 1947, when Norman Borlaug came to visit from Mexico. At that time he told the people in the Department of Plant Pathology (Dr. Stakman was not there) of what he was attempting to do in Mexico. This was only a few years after he began his work here. I see that today he still has that enthusiasm with which he infected the people there. We were looking for training and advice on plant breeding. It is a real experience to me to see the evidence of what has been accomplished in those 25 years.

In 1948, the next year, at the Fort Collins Meeting of the American Society of Agronomy Dr. Wellhausen gave a talk on what was being attempted on corn improvement in Mexico. His talk also impressed me at that time.

You have all referred to in the past day what these people have done. But it was not easy to start such a huge job and complete it so that there is really such a thing as the Green Revolution in the world. It was the enthusiasm, aggressiveness and initiative of these very few people that is responsible for the benefit we see to the population of the world.

After that we have kept in touch in an informal way and began cooperating with the scientists in Mexico. We, in Argentina, owe a debt of gratitude to this organization. We benefitted from this special philosophy. We took advantage of this experience in improving our wheat and corn production. As you may know, this is the first year we are going to sell the varieties to our farmers that Borlaug helped to create through his yearly visits and encouragement of our Argentine scientists. I feel that these varieties will show the same success as have the dwarf varieties in other parts of the world.

The same will happen, and has already happened with corn. The advice and cooperation of Dr. Lonnquist, Dr. Sprague, Dr. Ortega and others have helped us to build better hybrids and populations of corn.

For these reasons, I am very happy to be here to visit this institution.

POTENTIAL AND PROSPECTS OF DWARF DURUMS

George Varughese

Durum wheats are the second most important cultivated species of the genus Triticum. Table 1 shows the worldwide distribution and production figures for this crop.

TABLE 1. Regional Distribution of Area and Production of Durum Wheat.

	Area 1,000 ha	% of world area	Production 1,000 tons	% of world production
Near East	4555	23.1	3931	19.2
North Africa	3350	17.7	2020	9.9
EEC and other				
European countries	2475	13.2	3369	16.4
North America	1850	9.8	2900	14.1
Central and				
South America	620	3.4	700	3.4
U.S.S.R.	6000	31.8	7600	37.0

Durums have evolved in the Near East and the Mediterranean area, and even today this is the biggest region of cultivation of this crop. The eating habits and the agricultural economies of the Near Eastern and North African countries depend a great deal on the production prospects of the durums. Many of the countries of this region were, until the mid-1960s, exporters of this crop. Unfortunately, rapid expansion of population coupled with traditional (static) agriculture (outdated varieties and cultural practices) dropped them from the status of exporters to that of importers.

Solutions to this grim situation must be found. The problem of low production of the durums is not limited to this region in particular. The varieties available from the largest exporters of this crop as well as the largest importers, that is the EEC, are also low in yield potential or outdated. This calls for immediate attention on the part of all wheat scientists.

The first and foremost factor is the urgent need for varieties which are capable of boosting production. Once we have varieties of high productivity then we need the package of agronomic and economic factors to make these varieties successful.

What are the attributes we need for these varieties? These can be summarized in the following points:

1. High yield. All the yield characteristics which influence yield should be considered, for example, height, maturity, fertility, seed weight, etc. Table 2 shows varieties now available with good yield potential.

TABLE 2. Yield Improvement at Different Stages of Durum Breeding in Mexico.

	Yield	% of Siete Cerros
Tehuacan C. 60	4.822	53
Oviachic C. 65	7.563	84
Jori C. 69	9.060	100
Cocorit C. 71	9.722	108
Siete Cerros 66	9.036	100
Inia 66	8.065	89

*1970 yield data from CIANO, Sonora, Mexico.

2. Stability in yield, in other words, the potential of the variety to yield well under various environmental conditions. This we may measure as general adaptation. Table 3 gives the summary data of the 1st IDYN. It looks as if the Norin 10 dwarfing genes put under proper genetic background are able to provide this attribute.

TABLE 3. Results of the First International Durum Yield Nursery, 1969-70, averages for 22 locations (14 countries).

Variety or cross and origin	Yield kg/ha	Test weight kg/hl	Stripe rust	Leaf rust	Stem rust	Height cm
Crane (Mex.)	3818	78.1	1.2*	3.3*	3.9*	79.8
Brant (Mex.)	3707	77.9	2.0	3.0	4.4	76.8
Albatross (Mex.)	3657	79.5	1.6	2.1	3.2	82.3
Gerardo V-Z-466 (Italy)	3633	79.3	1.8	1.4	4.3	89.5
Anhinga "S" (Mex.)	3579	81.8	1.9	3.3	1.1	101.5
Capeiti (Italy)	3218	81.1	2.5	3.8	4.6	106.5
61.130-Leeds (U.S.A.)	3200	79.5	4.9	3.8	1.0	85.2
Inia 66 (bread wheat) (Mex.)	3196	80.9	1.3	1.1	1.0	90.5
Local variety	3142	79.8	2.2	4.1	2.8	108.4
Tehuacan (Mex.)	3127	81.0	2.1	2.7	3.8	125.3
S-9 (India)	3109	78.2	2.9	4.0	4.8	68.6
GaB. 125 (Italy)	3105	78.4	2.3	2.5	3.9	106.7
DurE-Turg x St464-Tc2 (Iran)	3047	76.1	1.8	3.0	4.5	85.6
Wells (U.S.A.)	3043	79.8	3.8	3.9	1.3	123.9
Castel del Monte 1 (Italy)	2962	80.7	1.5	2.1	4.0	91.9
Leeds (U.S.A.)	2904	82.2	3.2	4.0	1.5	127.3

*Average rust values were numerically transformed as follows:
1.0 is no disease and 10.0 represents 100 S reaction.

3. Specific adaptation. This calls for selection of material and varieties in the environment where they are going to be grown. Local problems of different diseases, pests and adaptation should be considered based on their order of priority. However, even at this point, a wide-adapting type disease resistance will guarantee a greater viability of the variety.

4. Last but not least, quality.

Now the question is, where do we get varieties with these attributes? Since the problems involved are many and complex we can eliminate mutation breeding as a major method for all the needs we have. It calls for a breeding program with the proper emphasis on the factors to be modified and improved. From an export point of view and consumer preference, quality is a bottleneck towards progress. I do not mean to state that we should not pay attention to quality. Our main problem is to find strains with high, stable yield with adaptation to the important durum-growing regions of the world. Once we achieve this, we can worry about the quality.

DURUM WHEAT YIELD PER UNIT AREA, STABILITY, CLIMATIC ADAPTATION AND FIT TO CROPPING ROTATIONS

Marco A. Quiñones

Durums are particularly important in most of the dryland areas of North Africa, Ethiopia, Italy, Turkey, Syria, Transcaucasian USSR, Iraq, Jordan and India. Durums constitute the principal food grain in most of these countries and in the past, a valuable source of foreign exchange.

Local varieties possessing a low intrinsic yield base are planted in most of these areas. As a result, yield per unit area has remained unchanged for decades. These varieties under a high level of technology produce yields not much different than the poor crops of the farmers. Thus, low production of unimproved durum varieties, coupled with the increased demand for more food grain due to population expansion has in those countries stopped the once abundant exportable surpluses and in all of these countries, importing some grain has been contemplated.

Heaviest consumption of durum products probably occurs in southern Europe and the western part of North Africa. It is in these markets that exportable surpluses are absorbed. Traditionally, the North African countries as well as Argentina and North America supply much of the needs. In Tunisia, Algeria and Morocco, durum is still the major species of wheat grown but the introduction of high-yielding dwarf types of bread wheat have made some inroads on the acreage sown. These countries, through increased production, are again nearing self-sufficiency in wheat and will soon again be able to resume substantial exports to the countries of the European Economic Community. It becomes increasingly important in their case to have improved durum varieties of high genetic yield potential, widely adapted, disease resistant and good quality if they are to have available this very lucrative source of foreign exchange. Other countries of the Eastern Mediterranean could also profit from this trade.

When the CIMMYT durum program was expanded in 1968, the main objectives were to develop materials (1) with high genetic yield potential and yield stability, (2) with a broad spectrum of disease and insect resistance and (3) with good quality. Hopefully, the varieties emanating from this program could be responsible for a second impact of the Green Revolution.

High genetic yield potential and yield stability or adaptation are the vital characteristics that the modern plant breeder aims for when producing new crop varieties. Cultivars of this sort should perform at their highest potential when a high level of technology is used for their cultivation. Under less optimum management, they still should produce a reasonably good crop.

High yield and adaptation result largely from the operation of additively operating gene complexes. The plant breeder depends

largely on the hybridization of diverse germplasm to bring together these additive genes which can normally be identified from materials of diverse origin. Multiple crossing as devised in the double crosses or three-way crosses helps in bringing together co-adapted gene complexes from diverse sources. However, the hybridization of material possessing desirable attributes has little value unless the proper type of selection pressures are used to identify those genotypes combining the desirable characters in their optimum intensities.

To diversify the durum germplasm, the CIMMYT program is using as source materials the durum varieties from the USDA Collection, new durum varieties received from collaborating countries and promising materials, principally land varieties, observed by CIMMYT scientists travelling in other countries and later supplied by these national programs. Such materials are crossed to the best CIMMYT dwarf types available. Segregating populations derived from these crosses are then distributed to some 50 locations throughout the world. Under this system, segregants are selected under a wide array of climatic and disease conditions. Many of these selections are recirculated to the CIMMYT program in the regular interchange of materials. Some are reincorporated into the crossing program or they may be again sent for wider testing in the international Nurseries. Hence, of course, width of adaptation becomes apparent and the more widely adapted types may become varieties in different countries. This is an excellent method of developing and ensuring yield stability. Also, materials with a broad spectrum of disease resistance can be identified. For ensuring adaptation, some amount of genotypic variation which does not affect the uniformity needed for agricultural exploitation and in commercialization of the product should be allowed to remain in the variety.

The breeding program needs, as well, to pay some attention to the quality aspect. For durums, a reasonably big seed size is preferred in order to separate the grain from the bread wheats. This is perhaps the main drawback of the American and Canadian durum varieties, which otherwise are acceptable from the quality standpoint. In addition, high carotene content and, of course, good overall macaroni quality is required. With the help of the CIMMYT Milling and Baking Laboratory, due attention is being paid to this aspect. The quality aspect is of tremendous importance in the export market since a premium price is paid for the best quality durums.

The CIMMYT durum program has not yet developed a fully acceptable variety. Some varieties tested under certain favorable conditions have yielded more than the best dwarf bread wheat varieties, but under other conditions which seem nearly identical, yields have frequently been disappointing. In analysing the cause of unstable yield in the dwarf durum varieties and lines, it has been established that it is primarily related to sterility of many florets, particularly when grown under high population densities. Sensitivity to daylength and perhaps to temperature may also account for a part of this infertility. This problem is expected to be solved as the germplasm base is diversified. In fact, the newest durum variety, Cocorit 71

which already combines more diverse germplasm as its predecessor varieties, possesses very high yield potential and appears widely adapted to both irrigated and rainfed conditions in many countries where disease is not severe. In areas of high rainfall in North Africa it still needs a high degree of resistance to stem rust, Septoria and mildew in order to give stable yields. It suffers in quality, having a tendency to produce yellow berry when grown under low soil fertility.

The enhancing of the present yield potential of durums would greatly depend on the continued use of new germplasm and on the identification of those characters not only morphological but physiological and biochemical which are conducive to high productivity. This high yield potential, however, would never be realized fully, even under optimum crop management, without genetic protection against insects and diseases.

Turning to the necessity to tailor the durum varieties to fit certain crop rotations, it should be noted that a range of maturity types are needed.

Most durum areas are presently under two-year rotation with a fallow period to preserve soil moisture. However, as high-yielding varieties become available, they may move to irrigated or high-rainfall areas. Thus, a range of maturity types would be required to fit the intended crop rotation.

THE DISEASE PROBLEMS OF DURUM WHEATS

J. M. Prescott

Durum or macaroni wheats (Triticum durum) are grown in many regions of the world but are of significant importance in North Africa, southern Europe, and the Middle East countries. In this Mediterranean-Middle East region, durum wheats are a favored dietary input of the people. It is generally understood that there is a ready market for all that is produced. In fact, production presently lags behind the demand; there are several reasons for this insufficient production. One of the principle reasons is the lack of adapted varieties with adequate resistance to the prevalent diseases. Most of the countries within this region have varietal improvement programs which devote considerable time and effort to this problem. Many of these country programs and those countries without programs of their own are looking more and more to CIMMYT for assistance and guidance. Therefore, CIMMYT is in a position to influence the wheat situation within this region. However, almost all of the CIMMYT derived durum material, while effective in some parts of the world, does not now have adequate disease resistance for this Mediterranean-Middle East region. The spectrum of virulence genes found in this region differs from that found in Mexico or other regions of the world.

As a class, durum wheats do not differ greatly from the bread wheats with respect to the pathogens that can attack them. The prevalent diseases within this region which limit production are: stem rust (Puccinia graminis tritici), stripe rust (P. striiformis), and Septoria leaf blotch (Septoria tritici). In addition, leaf rust (P. recondita f. sp. tritici) and, in high rainfall areas, scab (Fusarium spp.) and powdery mildew (Erysiphe graminis tritici) are of moderate importance and cause damage each year. The other diseases that attack wheat are usually present but on a more limited basis; however, they can become important on a local basis, depending on the prevailing conditions. These other diseases include the bunts (Tilletia caries, T. foetida, and T. controversa), smuts (Ustilago tritici and Urocystis tritici), take-all (Ophiobolus graminis), foot rot (Cercospora hipotrichoides), root rots (Helminthosporium spp, Fusarium spp, and Pythium spp), black chaff (Xanthomonas translucens), basal glume rot (Pseudomonas atrofaciens), several virus and several nematode diseases. Almost every pathogen that attacks wheat is found within the region; however, some have more severe effects than others.

The magnitude of the disease resistance problem of the CIMMYT-derived durum wheats within this region varies with respect to each disease and even country or subregion within this Mediterranean-Middle East region. The level of resistance to stem rust of most of the durum varieties is not adequate for this region. To illustrate this, 11 varieties commonly grown or used in breeding programs within the region or at CIMMYT were selected along with their respective reaction to stem rust at one location in Egypt and three locations in Turkey (Table 1). In Egypt, the varieties Wells, Leeds, and Hercules provided excellent protection to the 1971-72 virulence spectrum. However,

TABLE 1. REACTION OF ELEVEN VARIETIES OF TRITICUM DURUM TO PUCCINIA GRAMINIS TRITICI IN EGYPT AND TURKEY IN 1971-72.

VARIETY	EGYPT	TURKEY		
		ANKARA	IZMIR	DIYARBAKIR
WELLS	5MR	60S	20S	10MS
LEEDS	5 R	30S	30S	40 S
TEHUACAN 60	70S	100S	50S	20MR
COCORIT 71	60S	20MS	40S	30 S
HERCULES	10MR	80S	30S	60 S
CHAPALA 67	40S	10S	60S	10 R
OVIACHIC 65	40S	100S	50S	80 S
JORI C-69	80S	80S	30S	TMR
BARRIGON YAQUIE(BYE)	-	20S	30S	10 R
LANGDON	-	60S	30S	20MR
STEWART 63	-	40MS	20S	20MS

in Turkey, for the same period the resistance of these three varieties was not effective. There are a number of differences in reaction between the Egyptian and Turkish locations as well as among the three Turkish locations. The main point of this table is not that there are obvious differences in the pathogen population but that within this population there are entities that can overcome the resistance genes or gene combinations being used. There is an explanation for this phenomenon. In Turkey the explanation is that we have stem rust race 189. This is a highly virulent race and has virulence for all of the standard differentials, including the durumms and even Khapli. It points out that the genetic base for disease resistance must be broadened. In the same context, the advanced lines and their range of reaction to stem rust listed in Table 2 convey a similar idea--the level of resistance within these lines does not provide adequate protection.

TABLE 2. RANGE OF RUST REACTIONS OF VARIOUS SELECTIONS OF TRITICUM DURUM IN TURKEY IN 1971-72.

VARIETY	N. OF LINES TESTED	PGT	PRT	PS
ANHINGA 'S'	4	10S-50S	5S-50S	30S-50S
CRANE 'S'	5	30S-80S	20S-30S	10S-60S
GANSO 'S'	4	80S	30S-40S	30S-50S
GARZA 'S'	4	20S-70S	10S-60S	20S-80S
PELICANO 'S'	3	70S	40S-70S	20S-30S
FLAMINGO 'S'	7	70S-90S	TR-50S	30S-80S
PINGUINO 'S'	8	20S-80S	10S-30S	40S-70S
BOOBY 'S'	9	30S-50S	20S-40S	20S-30S
BRANT 'S'	3	5S-10S	50S-70S	5S-10S

TABLE 3. REACTION OF ELEVEN VARIETIES OF TRITICUM DURUM TO PUCCINIA STRIIFORMIS IN TURKEY IN 1971-72.

VARIETY	ANKARA	IZMIR	DIYARBAKIR
WELLS	40S	60S	20S
LEEDS	5S	30S	10S
TEHUACAN 60	20S	5S	0
COCORIT 71	TR	10MR	0
HERCULES	20MS	60S	10S
CHAPALA 67	-	20S	10S
OVIACHIC 65	20S	5S	TR
JORI C-69	30S	10S	0
BARRIGON YAQUIE (BY _E)	20S	20S	10S
LANGDON	20S	80S	20S
STEWART 63	-	40S	10S

Stripe rust presents much the same situation (Table 3). While the pathogen differs in virulence, the reaction to stripe rust of these same 11 durum varieties was susceptible with the exception of Cocorit 71. Of these varieties with fairly low severity ratings but susceptible infection type, several may provide adequate protection. However, these data were recorded under artificially inoculated conditions where the range of virulence of the inoculum was narrow. Greenhouse and field data suggest that the inoculum utilized had virulence for only YR-6, YR-7, YR-8 plus virulence to Bezostaya and Siete Cerros. The reaction to stripe rust of the nine advanced durum lines (Table 2) indicated that all were susceptible in Turkey in 1971-72.

There is not much data available on the reaction of durum varieties to Septoria leaf blotch, but the data from two locations within the region (Table 4) in 1971-72 suggest that there is a degree of resistance or tolerance in some of the durum varieties. The notes from Turkey were recorded in an extremely low disease year but may be used to indicate trends or support for the Tunisian data. The varieties Wells, Leeds, Tehuacan 60, Hercules, and Langdon appear to have adequate resistance, whereas the others do not.

TABLE 4. REACTION OF ELEVEN VARIETIES OF TRITICUM DURUM TO SEPTORIA TRITICI IN TURKEY AND TUNISIA IN 1971-72.

VARIETY	BEJA, TUNISIA	IZMIR, TURKEY
WELLS	5	3
LEEDS	4	2
TEHUACAN 60	5	2
COCORIT 71	8-9	5
HERCULES	6	2
CHAPALA 67	7	3
OVIACHIC 65	8	6
JORI C-69	9	4
BARRIGON YAQUIE (BY _E)	7	5
LANGDON	5	3
STEWART 63	8	6

These data serve to illustrate that the majority of the durum varieties being grown or tested within the region do not have adequate resistance to the main prevalent diseases. Furthermore, crosses among susceptible varieties or lines are not likely to produce significant results with respect to disease resistance. There are several varieties and advanced lines which have a fairly low severity rating but with a susceptible infection type. If this interaction remains stable, it can be a useful type of resistance. The problem faced by the durum program of CIMMYT and the various country programs of this region is of identification and utilization of new and different sources of resistance to the prevalent diseases. It is also important not to overlook these diseases presently of minor importance, because they can suddenly become important. Witness the case of Septoria leaf blotch.

What is the solution to this problem? If 10 different people were asked this question there would probably be 10 different answers. What I would like to suggest are several possible solutions. It is desirable to assemble as many lines and varieties from as many sources as possible and establish disease screening nurseries at several high-disease locations. For example, the USDA World Collection, the various country collections, FAO collections, etc., should be utilized in this search for new and different sources of resistance. In addition, the RDISN and other existing nurseries will be of value. At the present time in Turkey we are screening from the USDA World Collection about 5,000 durum varieties for resistance to stem and stripe rust, and cold tolerance. Hopefully, several promising lines will be identified. Since pathogens neither require passports to cross international boundaries nor food, liquor and imports to exist in the foreign environment, the identification of locally resistant wheat varieties may not be worthwhile. The entire effective region must be considered. A complicating factor is that many of the older varieties are not agronomically suitable and crosses with them may require extra time and effort to recover desirable plant types with adequate resistance.

It may be necessary to attempt to incorporate genes for disease resistance by means of interspecific or intergeneric crosses. However, this again requires a lot of time and effort since the resulting progenies, when obtained, often do not resemble high-yielding wheats. But it may be necessary so that new or at least different sources of disease resistance can be utilized.

Another approach may be in utilizing a different type of resistance, one that will convey protection to a broad spectrum of diseases of virulence genes. This type of resistance has many names but probably general or horizontal resistance is the most common. This generalized type of resistance (GR) is thought to be conditioned by many genes, while the specific type of resistance (SR) is conditioned by one or only a few genes; however, there appears to be no clear dividing line between the two. Furthermore, resistance is considered to be general when it is spread evenly against all races or biotypes of the pathogen and there is only limited or no interaction. Conversely, specific resistance involves an interaction between

entities of the host and specific races or biotypes of the pathogen. General resistance has also been defined as that resistance which on adequate testing in nature has shown to confer an enduring and stable protection against a pathogen. There is no way of being certain that a variety or line is resistant to all variants of a pathogen population that now exist or that may arise in the future. In fact, there are essentially no clear rules or characters established for identifying those varieties or lines that possess GR. However, there seem to be several characters either comprising GR or resulting in GR. Some of these characters are: (1) time required for establishment of the infection, (2) time required for sporulation, (3) amount of sporulation, (4) size of individual lesions, (5) location of lesions and (6) longevity of sporulating lesions. It should be possible to observe the many varieties and lines in the various screening nurseries and note those varieties or lines that appear to have GR. These selected lines then should be assembled into a special nursery and tested in as many locations as possible. The outstanding varieties or line then need to be incorporated into the breeding program. The testing procedure then continues and expands. Most of these criteria are not new to most wheat workers, what is new is the idea that a concentrated effort should be undertaken to utilize these characters. Since we must broaden the genetic base for disease resistance in durums, why not try to utilize this type of resistance? There are good indications that it may provide adequate protection. In a study of stem rust, the varieties Lee, Langdon, and Sentry showed initial rust severity of 2% to 5% after artificial inoculation. Under identical conditions, the susceptible check was 10% to 15%, and the subsequent rate of rust increase was much faster on this check variety. The three test varieties tolerated 50% to 70% levels of stem rust much better than the check variety. They produced about 80% of the yield of their fungicide-sprayed controls, while the check variety yielded only 40% of its control.

With leaf rust there is the example of exclusion from leaf sheaths by the stomata. In the case of Septoria leaf blotch there is exclusion of pycnidia from the neck of the plant as with the variety Penjamo 62, while other varieties are severely infected in the neck area. If the resistance utilized can slow down or limit the epidemic, remain genetically stable, and allow for good yields even in the presence of the pathogen, it may be adequate. Generalized resistance that expresses itself as a high type of resistance would be both valuable and a unique phenomenon in wheat diseases. What does all this mean, and can we utilize these traits in breeding varieties for the future? It means that after GR is achieved and incorporated into adapted commercial varieties, more effort could be expended elsewhere in varietal improvement.

It may prove more worthwhile to rely exclusively on the SR type of resistance. However, experience tells us that this type of resistance is not stable and the life of varieties with SR is relatively short. It does provide a quicker, more immediate solution to the problem. There are many specific genes in the hexaploid wheats; these and the tetraploid wheats have been in existence for a long time and have probably evolved along similar pathways. Extensive testing will probably reveal that the same or similar SR genes exist in the tetraploid wheats as in hexaploid wheats; it may even identify new genes. However, those genes in the D genome may be difficult to recover in a tetraploid. Whatever the case, if we rely on SR, the base for disease resistance must be widened in the durum wheats.

Since most of the known examples of GR in wheat are of the low level type, some loss in yield can be expected. It may be possible to intentionally combine GR and SR to come up with a high level of protection. The techniques for doing this are as yet undefined. It may be that we have accomplished this very thing already. It is also probable that this combination exists in many native or unimproved varieties grown today. We must find a way to tap these varieties for their yielding varieties. There is also the possibility of using the multiline approach to minimize the dangers and damages caused by plant pathogens. The challenge is here, what do we do about it?

DURUM WHEAT QUALITY

Arnoldo Amaya

Dr. Varughese indicated it was more important to produce yield than quality at this stage in durum wheat breeding. I do not agree with him; he will be forced to work into a program in which both yield and quality are developed side by side.

The first thing we have to define is quality for different countries. In India, much of the durum wheat is used for chapati. Another product made from durum wheat is couscous. We must learn the best type of quality for these products.

There are several regions in which quality means still other things. In Mexico, we have two varieties which were introduced, called Cocorit and Jori. For Mexican industry, these two varieties, even though quality is not good, are better than the bread wheat they have always used for production of macaroni and spaghetti. Cocorit and Jori give very good yields, but they have certain weaknesses.

In the CIMMYT program, we have just begun the evaluation of quality. I am sure that in the future we can provide both quality and yield in the same variety.

What are we at CIMMYT doing to improve quality? In general, it is similar to what is being done for the bread wheats. We have to find a method for evaluating quality in early generations if we are to use parallel selection for agronomic characteristics and diseases. At present, we do not have a microtest for cooking quality. Earlier, we thought we had a test, but it did not correlate well with cooking characteristics. We are, however, beginning to select for semolina color in the early generations. We are selecting for pigments of individual F3 and F4 plants. We were going to do this after the next generation had been planted, but now Dr. Quiñones is asking for some modification which will allow the determination to be made before the next generation is sown. As a modification, we are trying to step down from the usual 18-hour process to a half-hour process. Instead of allowing the mixture to sit over night, we shake the whole wheat from individual plants. We find this is giving good results and I feel we can evaluate plants before sowing. This will save space and time.

Selection for color, of course, simply covers the color of semolina, but it is well correlated with the spaghetti color produced. Only when lipoxidase is very high does this correlation disappear. We are beginning to work on lipoxidase activity, particularly in the advanced material.

In advanced generations, we have found that our materials have good test weight. This year, which is the first year of quality work with durums, we were surprised to find that the test weight of the varieties of the crossing block and advanced material ranged from 80 to 86 kg/hl with an average of 83 kg/hl. This is an excellent test weight which is reflected in semolina yield. In the early generations, they are selecting against yellow berry, or starchy mottling of the wheat kernel. This usually is most severe with low fertility. There are some

lines that even when grown at low fertility are relatively free of starchy kernels. Thus, selection should remove this problem.

We evaluate lines of advanced material for spaghetti-making appearance, color and cooking quality. We find a lot of variability and also that the program has plenty of low-quality lines. The range of color was 1 to 8. One was very poor color while eight was very good color. In general, the Mexican lines averaged about 3.0, so there is a big need to improve color. We have examined the germ plasm for cooking desirability. We find again that the range is wide. The breeders have received these reports and I hope they will give greater consideration to quality.

We are learning more about durum quality and we hope to increase our knowledge as we work with these materials more.

DISCUSSION

Rao

I was happy to see the data of Dr. Varughese showing the yield potential of durums. I was disappointed, however, by the data on lack of stem rust resistance given by Dr. Prescott for some of the high-yielding varieties.

In the world collection of durums, did you not find resistance to the prevalent races in North Africa? How do these durums perform under rainfed conditions? Do they compare well with traditional tall varieties?

Quiñones

In regard to disease resistance of durums from the world collection we have found some lines with good levels of resistance. We have tested this collection in Tunisia and Turkey. It is presently being screened in Israel and was screened in two places in Mexico. The information from these sites indicated superiority of certain lines to leaf, stem and stripe rust and Septoria. There were only a few with good resistance. In general, those resistant to, let us say, stem and leaf rust, were susceptible to stripe rust, Septoria or other diseases. There is resistance, however, and we have sown those lines and are crossing them into our material. We have already sent F2 populations of crosses in which we expect Septoria resistance to Argentina, North Africa, Cyprus, Turkey and other countries.

Rao

Could you name some of them.

Quiñones

I could give you the PI numbers of all of them but I don't have them with me. I can provide these to anyone who wants them.

Returning to the question of dwarf durum performance on rainfed areas. We have information from many countries of the Mediterranean

area showing that durums are performing very well under rainfed conditions. We are positive that the yield potential is there and stability is there. We need to stabilize the lines for disease resistance and for quality. In the beginning, we needed to get yield before quality and we did not have the means of assessing quality. Now, we can get quality along with the desirable agronomic and disease characteristics. For rainfed conditions, we do have lines which have done well in yield performance.

Rao

In India, 99% of the durums are produced under rainfed conditions. Barely 1% is irrigated. Under these conditions, the dwarf durums have not been able to show superiority over the traditional tall varieties. I would like to know if Cocorit and Jori are superior.

Quiñones

Cocorit 71 is producing better in North Africa than any of the local varieties under rainfed conditions.

Prescott

I did not want to frighten anyone with the information I presented. To answer your question on screening, we screened a little over 5,000 entries at Izmir last year, primarily for stripe rust. We found resistant lines, but many of them grew very tall and lodged because of favorable moisture and high fertility. It is a long way to go, but the new dwarf durums have many superior qualities and all we have to do is put a little more disease resistance into them. We are rescreening this nursery for resistance to leaf and stem rust and for cold tolerance.

Borlaug

I want to throw a little light on why the situation is such as it is in durums. In the first place, I go back to a comment that Fischer made earlier. Many of you are not aware that CIMMYT does not produce commercial varieties. It is not its responsibility. Any varieties released in Mexico are released by INIA, or if in Argentina, by INTA, or if in Tunisia, by the Tunisian-Ford Foundation-CIMMYT program, and so on. Fischer said, "Are we trying to produce for broad adaptation or for local high-yielding adaptation and disease situations?" CIMMYT's role is to produce this "stew" or genetic soup that is sent to all national programs to supplement their own crossing programs and from which they isolate material which can best fit into their own region. We in turn, as our staff travels or works with your national programs, see things that should be incorporated in the "soup" in the next cycle. They are brought here and intercrossed again. They again go back to the national programs. We also select within these generations as a part of the INIA program and screen for whatever diseases are present here. These go into the screening nurseries after having been subjected to those races present in Mexico. These nurseries are sent out to the other countries for reselection. The best identified there come back to CIMMYT as well as being used for further crossing. All of these things flow back and forth and for the first time, insofar as I know in the

history of the world on any crop, you have here an entirely new and different situation. Hopefully, we can combine in a reasonable period a better spectrum of disease resistance than we have ever had.

One other point--why was the first cycle of durumms susceptible in North Africa and Turkey? The answer is perfectly obvious. The races evolved on durum wheat can be considerably different and since we have virtually no durum wheat here, the incidence of such races is very low. It is curious, however, that many of these are resistant in Argentina where they do grow durumms. The genes for pathogenicity, in other words, in the Mediterranean area are different than those here. This is an old story and we all understand it but let us not make something complicated when it is not. It is simply long-time selection pressure on pathogens in a different region. They are expressing their personality. We simply have to move material around and stir the "stew". All this can be solved very promptly.

Referring to dryland yield potential, Dr. Rao, these dwarf durumms outyielded the tall ones two to one. The fear INTA has in releasing one is that they are unsure of the quality because of export. But inside two years, I predict there will no longer be any tall durumms.

Rodenheiser

Dr. Prescott, you haven't mentioned root rot or ergot. Are these of no importance in the Mediterranean area?

Prescott

I can answer this for Turkish conditions. One finds a little ergot in durum varieties grown more in eastern Turkey at higher elevations. It has not been worked on to any extent and we know little of its prevalence. With regard to root rots, in Turkey if we go to earlier planting and higher fertility, I expect we will get more *Circosporella*. We have seen it in many bread wheats on state farms on the plateaus, but we have little information.

Da Silva

In Brazil we do not grow or import durum wheat. Nonetheless, we eat a lot of macaroni and other pastas without using durum wheats. The same points should be raised regarding bread wheat quality. In South Brazil we have completely locally produced supplies for consumption. By the quality standards of which you speak here, they would be poor varieties. Still, the bread is good. We can have good bread if we change to a different technology. We have two solutions, therefore, for making good bread. You can also use bread wheat for macaroni and still have a good food. This is important to importing countries. For example, we had a trainee who tested a Brazilian variety with methods such as you use here. The first thing he did on his return was state to the press that all Brazilian wheat was inferior for bread. This had repercussions in that the millers were given support for importing wheat instead of using the national varieties. I feel we should change the techniques for handling the bread making instead of spending so much

money for breeding wheats to fit.

Ramirez

My question relates to the scarcity of resistant material or ingredients for this genetic soup. Are you considering introduction of the very different germ plasm of winter durums to give more diversity?

Varughese

Durums have had real attention in our program only very recently. In the beginning, we had to set priorities on what things were most important. The first and most important thing to do was to stabilize yield, exploit the better plant type and isolate lines with greater yielding ability. As a result, we have not yet entered into breeding lines with winter hardiness. Our present aim is to breed high yield and stable yield in varieties for the spring wheat areas. I would add in answer to Dr. Amaya's view that I have understated the importance of durum quality. I do not want to understate it, but I wish to reiterate that we must set priorities. Yield and stability are more important. We have started with this crop and quality is of no concern unless and until yield is stabilized. That was our first priority and Cocorit is a landmark. Now, we can worry about quality and we can breed for it.

Quiñones

I want to add one comment on winter durums. We are now concerned with mixing germ plasm of winter and spring types. We are already requesting winter and semiwinter types from countries where they grow. We understand that southern Chile is one place that winter types are grown. We have already made approaches to get some of these.

McCuistion

From last year's genetic soup in the International Durum Screening Nursery, we grew it at three locations in Algeria--on the plains under high rainfall, in the hill areas under medium rainfall, and on the high plateau with low rainfall and high altitudes. On the average of these three locations, one variety which was interesting to us was Parana 66/270 from Argentina. It was resistant to all three rusts and Septoria tritici. In yield rating, it placed fifth. One line of Triticum dicoccum var. vernum x rulla "S" provided good stem rust resistance in North Africa. It is susceptible to leaf rust. We are using it heavily in crosses for resistance. In general, we find leaf rust resistance is quite adequate. For Septoria, we have some breeding lines with fair tolerance, but we are still short.

Bolton

It was mentioned in the durum presentation that the short durums might move into the irrigated area. The comment was also made that they are growing under rainfed conditions. I feel that if they are doing well under dryland conditions, we should pursue this rather than go to irrigated conditions. If durums go under irrigation, it will force bread wheats into dry areas and they are less adapted there. I suggest

we concentrate on durums for dryland areas.

Varughese

How do you distinguish what type of plant we need for dryland? In the nursery under irrigation, we do get the expression of genetic potential. I do not think we can select high-yielding, dryland-adapted types in early generations if we grow them in a rainfed nursery. I welcome suggestions.

Bolton.

You misunderstood. I didn't say selection, but I meant for testing and evaluating under rainfed conditions.

Hafiz

Production is the number one priority in durums. My view is that quality has first priority in durum wheats. In the Mediterranean countries they have established a market in Italy for the varieties they have been growing. They are selling a considerable quantity each year, particularly from Syria, at a high price. The dwarf varieties have not been accepted. I consider that if you want to push these varieties, quality is very important.

Borlaug

The CIMMYT Quality Laboratory has been functioning for all of one year. I don't think we should be that concerned about quality at the moment. Things do not happen that fast, but I assure you that within two or three years the whole quality picture will change, as Dr. Amaya has said. I agree with Dr. Varughese. When you start a new program, you must set priorities and you can have the best quality in the world and still starve from an empty belly. Let us get this straight. You can have both, but you need the wherewithal, the equipment and the trained personnel at any one time and that has never been so in the history of any program with which I have ever been affiliated. Now, we do have the Quality Laboratory. I assure you there is no magic in putting quality into durum wheat or into bread wheat to meet the national needs, as Dr. Da Silva has said. This will be done. It is interesting, Ing. Kugler, that Parana selected at Parana and Balcarce is doing so well.

Kugler

Recently, we had a visitor from a group of Italian millers. They were interested in the kind of durum wheat we are producing in Argentina. They were eager to know about quality at a level that met their requirements for spaghetti. They are unable to get this from many places in the world. According to them, quality of Argentine durums is outstanding. The problem we have is one of standarization due to failure in our commercial channels. The new variety Dr. Borlaug mentioned has double the yield of our present types. If the Italians are prepared to pay enough to compensate for the yield differences, the farmers may continue to grow the old varieties. If the differential is small, the new variety will be grown.

Anderson

In Algiers they had a heavy epidemic of scab and Septoria late in the season. The nursery looked gray, but because of its lateness, Septoria did not affect yield too adversely. One of the Indian varieties, NP 401, was resistant. Cocorit and Jori were 100% infected with scab. A new variety from Tunisia, INRAT 69, was virtually resistant to scab. In the Izmir nursery, there was a group of Turkish land races with fair tolerance to stem rust. The resistance does lie in the durumms and we should not be discouraged at the prospects of breeding for it. There is plenty of resistance in the common wheats which can also be tapped.

Schultz

I have heard that the durum wheats were at a point where they would begin to eat into the bread wheats as a supplier of total wheat, i.e., that the bread wheats had reached a sort of yield plateau and the durumms were on the make. As I listened this afternoon, this seems not true.

Borlaug

I would just not like to be a bread wheat breeder and make the statement that durum wheats are second rate. Despite present limitations, durumms probably have the best yield potential among the wheats. This is particularly true when we consider the small amount of work that has been done. If 1% of the money which has gone to wheat research as a whole has brought durumms up to this level, they should look out.

Varughese

Slide 4 which I projected showed clearly the potential we have. You can see from the plant type what kind of potential exists.

Shebeski

At the 1958 First Wheat Genetics Symposium, there was a fair amount of evidence presented by European plant breeders that with little breeding work, the tetraploid wheats were outyielding the hexaploids at that time. I think Dr. Borlaug is quite correct. My only concern with Cocorit was that it was tested as an F₄ population when it was still highly heterogenous and had heterozygosity. As a result, its yields would be high by heterosis.

Varughese

It was F₃. Since then it has advanced by four generations. It is still showing very high yield on a broad scale. If it is due to heterogeneity and we have morphological uniformity, we would like to trap that heterogeneity.

Quiñones

INRAT 69, I am told, was ready for release about 1964. It took another five years to get it released. In 1969 it was released to the farmers and now it is going down to rust. So if you wait that many years

to get a completely homozygous variety which is already on its way out at release, the plant breeders' pay is not justified. Varieties should not remain in experimental plots for years.

McCuistion

In microtrials during the last three years, Cocorit has yielded with Inia and Siete Cerros consistently (3.5 to 5.5 t/ha) under good rainfall. We also have new selections in field production which are yielding equally with the bread wheats. Last year in the IDSN in spite of susceptibility to stem and leaf rust, some durums outyielded the bread wheats. Our concern is only the susceptibility to stem rust and Septoria. There has not been an epidemic thus far, but we can expect it and we want to ensure that the farmer is protected. In 1968 there was a disaster in Morocco --10,000 hectares of Siete Cerros were destroyed by Septoria. This hurts a research program as well as the farmers. We want to be sure. Perhaps you have not heard how aggressively the Algerian government is pursuing the policy of spreading high-yielding varieties. They want a short durum variety. Last year all we could offer was Jori. They asked for 15,000 tons which is now seeded. Unfortunately, Jori is susceptible to Septoria and stem rust. It has given good yields but we are keeping our fingers crossed. To ensure against a epidemic, we have placed it in low-rainfall areas (under 500 mm). We will let you know how it turned out. The important fact is: on the basis of results they wanted Cocorit and would have purchased all they could get, but it was not available, They wanted INRAT 69, but it also was not available. This is why Jori was purchased. We need to replace this with resistant types at the earliest possible time.

The durums yielding 5.5 t/ha doubled and tripled the yields of the locals in those nurseries. Once farmers see this, just get out of the way.

Taha

I can't see the validity of comparing results from different regions of the world when a small change like sowing date or application of fertilizer will change the potential of the variety.

Varughese

Stability means this: if we test a variety for 15 years at one locations and come to the conclusion it yields well, this means it has done well under changes of climate. We can measure this type of variation by growing the crop in various latitudes and different climatic conditions. If it performs well, it is indicating its stability of yield potential at any one location over many years.

Hafiz

Do you have Florence Aurore in these nurseries and do these durums have good stability?

Varughese

We did not, In the second IDYN, we have placed INRAT 69. We felt we should put in as much improved material as possible.

Quiñones

INRAT 69 has stability, but it is low yielding. We talk about high-yield potential and yield stability. These two terms should not be confused. One variety may be a very high yielder under specific conditions, as happens with spring wheat varieties of the U.S.A. and Canada. Once you take them out of their adapted environment, they are very low yielding. Using international testing under varied conditions, we can select those genotypes which consistently should be in the top group on the average. There are varieties with stability and with high yield potential. We use these heavily in the program. We try to incorporate all information we can in crossing.

Borlaug

That is what happened in the first international yield nursery. Five or six varieties were always up at the top. It is self-evident when this occurs.

Quiñones

The first 10 varieties of the ISWYN are dwarf varieties. In the early years, CIMMYT varieties were at or near the top. We are now happy to see that such varieties as Chenab 70 from Pakistan are at the top. It was bred in Pakistan from a Mexican x Pakistani variety. It is the cooperation of the national programs in testing varieties that allows each of us to screen varieties and uncover the genotypes showing stability.

Fortiz

I would like to know if there is a way to judge bread wheat by color.

Amaya

There is no correlation between color and quality. There is a correlation between texture of grain and gluten strength. If the grain looks starchy, it is usually weak in gluten, but if it is vitreous, it is usually strong gluten.

BARLEY, AN INTRODUCTION

W. L. McCuistion

Barley is a crop with tremendous adaptation.

Barley is grown from the Arctic Circle to the tropical plains of northern India. It is found beside pools of frozen water in Ethiopia as well as beneath date palms in the Sahara Desert. Barley adapted itself to the high plateaus of Bolivia, South Africa and Tibet; to the hills of western China; and to the alkaline desert lowlands of Egypt, Turkestan and Australia. One form of barley with recurved stalks grows on the slopes of the Himalaya Mountains, well above 4575 meters (15,000 ft) elevation. Barley is one of the most dependable crops where drought and frost are encountered. The barley plant is considered to be more tolerant to soil salinity and alkanity, but more sensitive to soil acidity than are the other cereals.

Some varieties of spring barley mature in 60-70 days, or even earlier than spring types of rye, wheat or oats. Certain strains of naked spring barley from Tibet are characterized by remarkable resistance to cold as well as by early ripening. Consequently, spring barley is grown farther north and at higher altitudes than any other cereal.

Uses

In the Old World, barley is grown largely for human food. Japan, for example, uses 65-75% of the crop directly as human food, generally as pearled barley cooked with rice. In China, barley is often ground into flour with either broad beans or lentils for human consumption. In Tibet, the grain generally is roasted or parched, ground, and mixed with yak milk to form a dough which is eaten directly.

In the New World, barley is produced mainly for livestock feed. Barley has maintained its eminent place in agriculture, in some regions, largely because of its malting properties.

As an example, Table 1 shows the uses of barley in the USA.

TABLE 1. Uses of barley in the USA.

	<u>% of total</u>
Malt	27.3
Seed	6.0
Human food and export	6.0
Animal food	60.7
	<u>100.0</u>

a) Approximately 27% of the annual US barley crop is used for malting purposes.

b) Regeneration of seed comprises approximately 6% of the total.

c) Another 6% is used for human foods and for exports. The barley used for human food is processed into soups, dressings, baby foods and breakfast cereals.

d) The major portion is used for animal feed.

From one-fourth to one-third of the barley grown in the United States is fed on the farm where it is produced. Barley has about 95% of the feeding value of corn grain. It is best used for animal production, being an especially popular feed for hogs because its use results in desirable proportions of firm white fat and lean meat. It is ground or steam rolled before feeding. Malt sprouts and by-products of brewing are also used as livestock feed.

The naked barley varieties make excellent poultry feed. These could be very profitably used in many countries where attempts are being made to increase poultry production.

General Cultivation

Fall or early winter seeding is recommended under mild winter temperatures. Spring varieties seeded under these conditions consistently give higher yields than spring seeding.

TABLE 2. Cereal grains average annual world area and yield(1959-61).

Crop	Area (1000 ha)	Yield (Qx/ha)
Wheat	202,834	12.3
Corn	105,263	21.7
Rice	117,409	26.2
Barley	61,538	16.7
Oats	45,749	24.9
Rye	30,064	12.2
Sorghum	50,607	10.8
Millet	48,178	190.5 (kg /ha)

Note: Barley is an important crop in: Europe, North Africa, much of Asia, North America, Argentina and Australia.

Barley is usually grown in lower rainfall areas. This makes it an important crop in many of the developing areas of the world.

TABLE 3. Average barley yields for world and region (ton/ha).

Year	World	Region
1948-52	1.13	0.73
1952-56	1.25	0.76
1961-65	1.46	0.74
1966	1.65	0.61
1967	1.67	0.74
1968	1.76	1.00
1969	1.76	0.91
1970	1.65	0.73

1) There has been a noticable increase in the world average since 1948. However the Near East Region has remained essentially the same with the exception of two good years—1968 and 1969.

2) These Near East regional averages include Syria and Libya with 200 kg/ha and Egypt under irrigation with 2.4 tons/ha.

TABLE 4. Percentage of wheat and barley area by country in Near East (1970).

Country	% of total area	
	Wheat	Barley
Afghanistan	87.3	12.7
Egypt	94.0	6.0
Iran	82.4	17.6
Iraq	65.6	34.7
Jordan	75.8	24.2
Lebanon	87.0	13.0
Saudi Arabia	79.4	20.6
Syria	54.4	45.6
Algeria	75.8	24.2
Libya	43.4	56.6
Morocco	48.6	51.4
Tunisia	72.8	27.2
Turkey	76.9	23.1
Total	72.5	27.5

Note: Barley is an important crop in: Iraq, Syria, Libya and Morocco.

In these areas with strictly winter rainfall pattern, other feed grains cannot be grown because temperatures are too low.

In most of North Africa and the Near East, temperatures are not high enough for planting maize (corn), sorghum and millet until early April. There is often very little or no rainfall in this region after April. Irrigation, of course, allows for good production but, with the exception of Egypt, very little land throughout this region is irrigated. When water is available, it is utilized for vegetable and fruit production.

Barley is thought of as a poor land crop and marginal lands are normally barley areas. These areas are characterized by rough terrains, shallow and often rocky soils, small individual holdings, limited mechanization, little or no fertilization and normally low rainfall.

When bread wheat, durum wheat and barley are grown under these conditions in an area, barley will give the best yield. It is normal in a given region for the cultivated barley varieties to mature 2 to 3 weeks earlier than the bread wheat varieties. This earliness in a low rainfall region often allows barley to escape serious drought and rust attacks. Commercial barley varieties generally lack good straw strength. Thus, lodging commonly occurs under high nitrogen fertility. Yields equivalent to those of bread wheat are consistently possible, however, with proper management in the medium and low rainfall areas.

Barley culture does not require much change in the present technology being used for wheat production. As improved varieties and cultural practices of bread and durum wheats increase wheat production, barley can easily replace other cereal areas for increasing livestock feed, a critical need in the developing world.

There has been some interchange of material regionally and internationally, but we must emphasize wide movement of screening nurseries composed of varieties and advanced lines worldwide.

Spring varieties from northern Europe and southern Australia look good in North Africa.

PRESENT STATUS OF THE BARLEY CROP IN MOROCCO

Aristeo Acosta

INTRODUCTION

Barley is the most important cereal crop grown in Morocco, where the grain cereals grown include also: wheats (durum and bread), corn, oats, rice, sorghum, millet, rye and canary grass. The area planted with barley exceeds or is equal to that of both wheats combined. The total production of barley has been higher than that of the wheats (see Table 1).

TABLE 1. Morocco barley and wheat statistics.

	S P E C I E S	25-year average 1938-62	5-year average 1967-71	1971-72 (Esti- mated)
AREA (has)	Barley	1,813,000	1,968,000	1,947,000
	T. Durum	968,760	1,375,000	1,528,000
	T. Vulgare (Bread)	427,800	462,400	504,000
	Both Wheats' TOTAL	1,396,560	1,837,800	2,032,000
PRODUCTION (metric tons)	Barley	1,340,900	2,308,600	2,350,000
	T. Durum	585,836	1,362,400	1,700,000
	T. Vulgare (Bread)	293,900	509,600	600,000
	Both Wheats' TOTAL	879,736	1,872,000	2,300,000
YIELD (kg /ha)	Barley	739	1160	1210
	T. Durum	605	988	1112
	T. Vulgare (Bread)	687	1082	1190

Most of the barley, if not all, is grown under low rainfall conditions (400 mm or less), and a greater part of this is grown under even lower rainfall (300 mm or less). In Morocco barley can be considered as a "marginal" or a "fill in" crop because it is grown where the wheats cannot be grown, mainly because of the low rainfall and the low quality of the soil. In other words, barley is grown by a great number of poor farmers because no other cereal can be cultivated under these extremely poor conditions.

As far as the utilization of the barley grain is concerned, about 51% of the production is used for human consumption (bread), 26% for feeding animals, and the rest is used for seed, beer manufacture, and other purposes (see Table 2).

TABLE 2. Barley area, yield, production and consumption from 1959-60 until 1971-72 (estimated).

Year	Area (1000 h)	Yield (Ton/ha)	Production (1000 tons)	C o n s u m p t i o n		
				Animal	Human	Seed, beer, etc.
				(% of Production)		
1959-60	1750	.79	1390	25	53	22
1960-61	1560	.37	570	28	50	22
1961-62	1140	1.25	1420	30	69	11
1962-63	1940	.90	1750	25	51	24
1963-64	1720	.81	1400	25	44	31
1964-65	1650	.87	1430	26	51	23
1965-66	1770	.34	610	27	37	36
1966-67	1810	.73	1320	26	54	20
1967-68	2105	1.66	3494			
1968-69	2037	1.08	2204			
1969-70	1890	1.03	1953			
1970-71	1998	1.29	2572			
1971-72	1947	1.21	2350			
(estimated)						
Averages	1794	.95	1728			

In general, barley yields are not too low, considering the conditions under which the crop is grown, and are higher than those for the wheats (see Tables 1 and 2).

PROBLEMS

Agronomic. The most important agronomic problems are resistance to drought (low rainfall conditions), and adaptability to low fertility and "shallow" soils. Most of the barley crop is confined to the plains south and east of Casablanca, the hilly region around Oued Zem, (low rainfall and low fertility soil), as well as in the Middle Atlas, the Rif, and south of the Atlas.

Rotations. The most widely spread rotation is fallow-barley. Others include: Leguminose-barley, Leguminose-wheat-barley, and Leguminose-wheat-barley-corn or sorghum.

Stability. Area, production and location can be considered fairly stable in the past (see Tables 1 and 2). However, the yields have increased during the last six years.

Diseases. Rusts (leaf and yellow), bunt, smut, mildew, *Helminthosporium*, and *Rincosporium* are among the most important diseases. Occasionally some root rot attack can be observed, especially on relatively high-rainfall and poor-drainage soils.

Insects. Certain flies (Hylemya hordeacea, H. Cana), Hessian fly, and aphids also attack barley. One serious threat to barley is the Spanish sparrow (Passer hispaniolensis).

BREEDING

A breeding program was started in 1960 by the Agricultural Research Institute. This program included testing of a great number of introductions, further selection, and finally, crossing. Several varieties, both six-row and two-row, have been selected and developed (see Tables 3 and 4). Six-row barleys include Arig 8, Rabat and Merzaga. Esperance and Brasserie Maroc are two of the two-row barleys recommended. Several lines have been developed by crossing with relatively higher yields (Table 4).

TABLE 3. Five-year averages (1967 to 1972) of 12 six-row barleys grown in Morocco (experimental plots) at nine different experiment stations.

Name of the Variety	Number (Morocco)	Origin	Yield, q/ha 9 stations/5 Yrs.	Rank
<u>Average</u>				
Arig 8*	905	Italy	32.3	1
Flyn 37	903	U.S.A.	30.7	2
Cebada Lupe	785	Spain	30.3	3
Arrivat	962	Lebanon	30.1	4
Rabat*	071	Maroc	29.4	5
CPI 7737	770	Australia	28.5	6
Saida	765	Lebanon	28.0	7
Moreladore	786	Spain	28.0	8
Blanco Mariout	797	U.S.A.	27.5	9
Merzaga*	077	Maroc	27.0	10
Bolivia	764	Lebanon	27.0	11
Flynn 7009	794	U.S.A.	25.7	12

Data courtesy of the Moroccan Program (Mr. Momcilo Kuc).

*Varieties already released.

TABLE 4. Average yields of several varieties and lines developed in Morocco and grown at nine stations (rainfed) during five years (1967-72).

Name of the variety or cross	Pedigree number	Origin	Yield, q/ha 9 stations/ 5 Yrs. Average	Rank
MINERVA x 289	42/2	Morocco	35.1	1
KENIA x 289	5/135	Morocco	34.9	2
PROCTOR x 289	23/42	Morocco	34.8	3
AUORE x 289	8/41	Morocco	34.0	4
HAISSA II x 289	24/178	Morocco	33.7	5
WISA x 289	22/437	Morocco	33.5	6
BRASSERIE MAROC*	895	Morocco	33.3	7
STAMCA x 289	18/135	Morocco	33.2	8
GLOIRE DE VELAY x 289	38/8	Morocco	33.0	9
AUORE x 289	8/83	Morocco	32.9	10
PROCTOR x 289	23/420	Morocco	32.3	11
ESPERANCE*	289	Morocco	30.1	12

Data from the Moroccan Program (Mr. Momcilo Kuc).

*Varieties already released. (Two-row)

A small program for testing a limited amount of introduced material was initiated in 1969-70, where CIMMYT, ALAD, FAO and USDA collaborated with the Moroccan Institute for Agricultural Research. Most of the introductions tested during the first two years (1969-70, 1970-71) were very susceptible to rusts and Heminthosporium. Some of the most promising varieties are shown on Table 5.

Hybrid barley seed facilitated by a private British company is currently being tested, as well as some drought-resistant varieties.

TABLE 5. Yields of several varieties grown in Morocco under dryland and irrigated conditions during the 1971-72 cycle (Regional Barley Yield Trial).

Name of the variety	Yield, Kg/ha	
	Dryland Sidi Kacem	Irrigated Marrakech
Svalof Hellas	2567	3112
W W Cilla	2540	3158
W I - 2197	2507	3620
Svalof Mari*	504	4466
Svalof Kristina	2361	3700
Giza 120	1732	3587
Rabat 071 (local var.)	965	2245

*This variety was very early and had 100% bird damage at Sidi Kacem.

CONCLUSIONS

As already stated, barley is the most important cereal in Morocco. This fact becomes more important when one considers the conditions under which barley has to strive in order to produce relatively good yields. This situation offers an excellent opportunity for improvement and shows also a great potential.

Drought resistance studies could yield great benefits for a large population. Dry-land farming practices are essential for the Moroccan conditions.

BARLEY PROTECTION

Enrique Rodriguez

In spite of the good characters with which nature has provided barley, the plant has been "blessed" with a multitude of disease problems. It is probably, among the cereals, one of the most "appealing dishes" to many pathogens. Ranging from the viruses seen only under electron microscope through the microscopic bacteria and fungi and extending to the macroscopic fruiting bodies of the ergot, diseases of all types get their "bite" on some part or the entire barley plant. Among the most common diseases in barley, we can mention the following:

1. Rhynchosporium scald. This is probably the most widely distributed foliar disease in barley. It occurs under a wide range of conditions of temperature and humidity. The causal organism is Rhynchosporium secalis.
2. Spot blotch. It is also a foliar disease, and can be a serious problem in humid and semihumid areas where barley is cultivated. The causal organism is Helminthosporium sativum.
3. Net blotch. This disease is prevalent in areas where cool temperatures persist during the growing period of the plant. The causal organism is Helminthosporium teres.
4. Helminthosporium stripe. This disease is also widespread in many regions where barley is grown. The causal organism is Helminthosporium gramineum.
5. Powdery mildew. This disease occurs in areas where cool, humid and cloudy weather persists during the growing period of the crop. The causal organism is Erysiphe graminis.
6. Loose smut. This disease is widely distributed in both high and low altitudes of the barley growing areas. It is a floral infective pathogen and many of the varieties that open their glumes during the anthesis are susceptible. The causal organism of this disease is Ustilago nuda.
7. Covered smut. This disease is more restricted to high altitudes with cool climates where the growing vegetative period of the plant is extended. Since the primary infection of this organism takes places in the seedling stage, this gives the fungus a chance to grow along with the growing point. The causal organism of this disease is Ustilago hordei.
8. Stem rust. This disease is caused by the same organism that causes stem rust in wheat, although in many cases the races attacking barley seem to be more specific to this crop. The disease can become of relatively little importance in varieties with a short growing cycle which can escape the attack of the fungus. The causal organism is Puccinia graminis var. hordei or va. tritici or even var. secalis.

9. Leaf rust. This disease is present in areas of mild climate, but it seldom causes severe losses to the crop. The causal organism of this disease is Puccinia hordei.

10. Stripe rust. Of the 3 rusts attacking barley, stripe rust is probably the one that is more widely distributed. Unlike the stripe rust in wheat which needs special conditions for its development (that is low temperatures and humidity), stripe rust in barley seems to have more elasticity in its adaptation to different environmental conditions. The causal organism of this disease is Puccinia striiformis.

11. Other diseases. Some other diseases such as Septoria leaf blotch, barley yellow dwarf, downy mildew, bacterial blight, etc., which are sometimes classified as minor diseases can also become a major problem, providing the conditions are appropriate for their development.

It is difficult to get an overall estimation of disease losses in barley, and we can only say that they vary from season to season and from country to country. In areas where barley is cultivated for the commercial brewing industry, records indicate that losses range between 10% and 15%. However, these estimations cannot be extrapolated to areas where barley is grown as a basic crop for food purposes. In these areas our information about such losses is meager, but one can assume that they exist and that some reduction in yield is experienced.

The barley breeding program initiated by CIMMYT aims to produce varieties with high yield, good agronomic type, good adaptation, drought resistance, high nutritional value, and a broad spectrum of resistance to at least the most common important diseases. In its initial stages the program has been mainly concerned with the gathering of material that can serve as a basis for building a wide germplasm base which will serve as the backbone of our breeding program.

There is no doubt that among this material we have presently available, we have sources of resistance to the principal diseases. Unfortunately, the genes conferring this resistance are scattered through many varieties and will have to be brought together into the desired agronomic type. Scattered as they are, resistance to certain leaf diseases, for example, is covered by the susceptibility to one or more of the other pathogens under natural infection in the field. The concentration of these genes for resistance will involve multiple crossing among the different genotypes, complemented with a very exhaustive screening process that will allow us to select the resistant types.

We are very fortunate in having a site at El Batan where we can depend upon natural epidemics of any one of the major barley diseases to provide good screening of our breeding material. This preliminary screening complemented with others made in sites carefully chosen in different parts of the world will indeed greatly help us select genotypes with a greater depth of disease resistance. Since our program will be devoted, to a large extent, to developing lines for areas of low rainfall, it is likely that under these conditions some diseases (especially foliar diseases) may be of relatively lesser importance.

The question arises whether we should breed for disease resistance for those areas or concentrate more on the incorporation of other characters.

In the general sense, there is little doubt that we will have to breed lines with disease resistance. Even for dry areas, certain diseases do not require high humidity conditions in order to thrive (for example, smuts). Also, weather conditions under some of the so-called "low rainfall regimes" are very unpredictable and can vary greatly in amount of rainfall from year to year and, as a consequence, enhance the development of disease epidemics. Thus, incorporating genes for disease resistance will serve as a control measure against these unpredictable situations and provide greater yield stability.

QUALITY IN BARLEY

Evangelina Villegas

Our barley breeding program, as Dr. Rodriguez has said, is very new at CIMMYT and, consequently, our work on quality here is in its infancy. Fortunately, we are lucky. We have in our hands now material that has very good quality. I must make clear that when I talk of quality in barley I am referring to nutritional quality. We are not interested in malting because we have at present many programs around the world devoting time to developing such varieties. In Mexico, INIA is developing new malting barleys.

As Dr. Rodriguez mentioned, we are now only at the F2 generation of the first materials. The first thing we did was to evaluate the materials donated by different breeders all over the world. We are fortunate in that the Swedish group at Svaloff identified one line of the barley collection which they were evaluating which was high in lysine. After going through only about 2,000 lines they found this line which is high in both protein and lysine. This has been named "hiproly". It has one gene "lys" which increases the level of lysine in the protein irrespective of the protein percentage.

In general, we have observed that in all cereals, except for the mutant opaque-2 in maize, there is an inverse relationship between the level of protein and the percentage lysine in the protein. It is also known that lysine is the principal limiting amino acid in cereal grains. I would like to mention that Dr. Lynn Bates is in the audience today. He is one of the scientists who discovered the opaque-2 gene in maize.

The work on opaque-2 maize was important because this finding aroused the interest of all breeders in improving the nutritional quality in the cereals. As Dr. Varughese said this afternoon, yield is very important but when we have the tools to improve both yield and quality simultaneously, we must do both. We now have those tools. In the past, the problem was that our facilities were limited for the study of quality. However, now we have both the facilities and the trained personnel.

It was said that we should not place a high priority on industrial quality because the technology can be modified. While this is true, breeding good industrial quality into the varieties will save a good deal of money and effort. I refer here to the development of varieties for specific end-products, such as bread in the case of wheat.

The opaque-2 and floury-2 genes which modify the endosperm of maize were identified 10 years ago. In barley, the gene lys was identified in 1969. This hiproly line was about 16 percent higher than normal in lysine. Recently, in 1971 another line was identified. This was a mutant known as 1508 from the variety Bomi in Sweden. It gives 45 percent more lysine in the protein, so it is very good. This has been tested by bioassay test to see if it was actually high in nutrition. It was demonstrated that the lysine is available to the animal and does provide better nutrition.

The Risø group in Denmark has also identified six new mutants

which were higher than the control in lysine. This means that it is possible to get improvement directly by mutation in the material we are handling in our program.

We started using this material at the beginning of our CIMMYT program. The breeders are attempting to incorporate these quality characters in a better phenotype because hiproly has a very poor phenotype. It is quite sterile but we are only interested in moving over the high quality genes to good agronomic types. This hiproly line is a hulless barley. In the program we are using both types. We intend to work with both types. Since it will be used for food and feed both types can be used. We will choose those which show better adaptation irrespective of their hulled or hulless character.

The selected lines being used are being screened for quality by a very simple method. This is the dye-binding capacity method --called the Udy method in the United States. With this method it is easy to detect small differences in lysine content because the test is based on the reaction with the basic amino acids of the protein in the diet. Lysine is among the basic amino acids. The method was used long ago to evaluate level of protein but we now know it is not too useful in evaluation for total protein in these varieties which are quite divergent from normal in their basic amino acid level. After we determine the DBC (dye binding capacity) in the sample, we find the total protein in the sample of the selected lines. Then again we determine the DBC and evaluate quality.

This type of test will allow us to screen a very large number of samples and have a very aggressive breeding program.

I should mention that we also try to do a biological assay as well as a chemical assay of the material. We have not done any of this with barley because it is such a new program. We do have an animal nutrition laboratory under the direction of Dr. Reinald Bauer. When you visit his laboratory, he will explain what we are attempting to do in the way of biological assay.

To summarize, we have only begun the barley program but we are in a good position. From the 1,000 lines we have evaluated, we found the range of protein was 12-21 percent, a very wide variability, with an average protein level of 16 percent. The lysine content varies from 2.8-4.5 percent. We find the average level in barley as a whole was 3.9 percent. This is a very good level in any cereal.

DISCUSSION

Paarlberg

Dr. Villegas, you mentioned mutation work being conducted in Sweden on barley. Are you doing any mutation work here at El Batán?

Villegas

No. We would rather look for natural mutants, but if something good arises from artificial mutation, we will use it.

Ramirez

Don't you feel that you should look into the possibility of getting induced mutants? We in Chile have been able to get new genes for resistance to powdery mildew by this method. This may be necessary to get resistance to all of these pathogen races in many locations. Secondly, and also from the standpoint of use, the data presented by Dr. Acosta showed that in the barley international trial, three of the top yielders were mutants from Svalof, Sweden. It seems to me that you should take a good look at the mutant material available from these countries.

Anderson

I feel that Dr. Ramirez has a point here when we consider that barley is a diploid crop and mutations are revealed easily. In wheat it is another question when ploidy is at the tetraploid or hexaploid level. Maybe we should investigate this area for specific purposes when the need arises.

Kohli

Dr. Ramirez, we did make use of Svalof Mari, Svalof Christivie and several mutants from Svalof showing high protein and high lysine derived from Dr. Munk's material. What we are finding though is a high degree of sterility in this latter group. We are trying to overcome this. Similarly, we are employing Hiproly as a male parent and introducing it to our crossing program.

Hafiz

It is encouraging to know that work has been started by CIMMYT on barley improvement. As you have seen, there is a real need for barley in North Africa and the Middle East where it is a very important, though neglected, crop. For a long time, little work has been done. Wheat always seemed more important but as things are at present, wheat has been pushed into marginal areas which should have barley. If we can find better varieties, barley will yield more and it will be a better economic crop for the farmers to grow. Secondly, the need for animal products will increase and it is estimated that by 1985, the need will have increased by 200% to 300%. Barley is one of the most important feed crops which will help to combine crop and animal husbandry. Thirdly, many countries are producing beer and they are getting malt at a high cost from other countries so that improvement in barley type can help save some of this money. We, in our program, started two years ago to distribute a regional barley yield trial from which Dr. Acosta's results were derived. Two Swedish varieties and one or two Australian varieties gave good results. We would like to solicit from any of you good varieties for inclusion in this nursery.

Eslick

The two mutants from Svalof referred to here are probably day length insensitive and are early types. Thus, they could be expected

to do well in Morocco. Probably the Australian material has Prior in their parentage which also would make them day length insensitive. Actually, this is quite widespread in barley germ plasm.

In terms of mutation work, the Swedish group has the very extensive European collection of mutants which have been picked up. I am sure these are available to this or any group that wants to try to exploit them. I don't really see any good reason to get into this aspect even though the mutants are easily picked up.

Kohli

Have there been any dwarf barley types identified that have lodging resistance, or for that matter, lodging resistance in any height class?

McCuistion

Yes, we received from India a number of mutant lines derived from different degrees of irradiation in 1968-69. In Tunisia, they grew like a tree. They were very strong and they could not be broken over, but they have no yield. There is resistance to lodging. We conserved the seed, but without breeding work they have little promise.

Wright

In Turkey, at the Eskesehir Station, from a very few irradiated lines, a very dwarf, two-rowed barley was developed. This has not been widely tested, but it looks excellent. It is very short and has good straw.

Anderson

There is one other line which has straw strength which is not dwarf. I saw it in the South Korean program and it originated in Japan. This variety is called Hagenamuchi, which roughly translated means "steel" in English.

AGRONOMIC RESEARCH

Richard Bradfield, Chairman

I have known Dr. Borlaug for a long time and I know that he is very conscious of the importance of the environment as well as germ plasm in crop improvement. He was always seeking to improve the environmental conditions under which his crops were grown.

The work I will describe was sponsored by the Rockefeller Foundation and conducted at the International Rice Research Institute in the Philippines.

One reads a lot about the world food problem. If you glance at a globe and consider that broad belt extending from the Equator to 30 N and 30 S, you will find that in this belt (tropics and subtropics) lie most of the developing nations and hungry people of the world. This is significant. It has given many people the impression that the food potential of this region must be very low. One of the things motivating me in this postretirement position was to test this theory, which I did over about 8 1/2 years. I wanted to see what could be done on this food problem in this particular area of the tropics.

The environment lies at a latitude of 14 N, about midway in the belt I mentioned above. The altitude is about 60 feet, rainfall is 80 inches per year and humidity is high. Rainfall is distributed through the rainy season, beginning in May and ending in December. The dry season occupies the rest of the year. This presents management problems on the heavy soils. The soils at Los Baños are of volcanic origin only a mile from Mt. McKeeley, whose flora has been studied very thoroughly. At the beginning of the century, it was reported that the flora represents as many species as found in the continental U.S.A. Although this wealth of material exists on the mountain, the lowland crop is continuous rice in a monoculture. Malnutrition, deficiency of vitamin A and protein in particular, results in all the combinations of diseases brought on by these conditions (undersize and death rate of 50% before the age of six).

Under these circumstances, what are the problems? The first problem is to supply the base cereal that provides most of the calories, in this case rice. IRRI was doing this job, so I decided to take on the problem of producing in rotation with rice other crops to give vitamins and proteins and provide a little extra income for the peasant who earns US\$200-500 per year.

In looking over the plants which could solve these problems, different people would select different crops. Firstly, I would like to discuss a principle. If we want to use the growth season efficiently for food crop production, we must use sunshine to full efficiency. How can we shorten parts of the growth cycle? One method is the transplanting technique from a bed to the field after a month. This reduced the period of the crop in the field. Earlier maturing varieties could be used. I will speak of yields in a different sense than that in which we normally think. We must do this when dealing with food production in the tropics. In the temperate regions, we say that a given crop yields so much per year. This has little significance in the tropics when you are growing 4 or 5 crops. What we need to know is what is the production

per day on the land, and we must maximize the number of days the land is in production per year. We have succeeded in growing crops 440 days per year by overlapping planting with harvest. This is the sum of the times the different crops are in the ground. With earlier varieties, this might be increased.

Another way to gain time is sow the succeeding crop before harvesting the growing crop so that at harvest the new crop is 3 to 4 weeks old.

On the volcano, Mt. McKeeley, dark green plants cover it throughout the year. In the dry period a few leaves are shed. The yield of this rain forest is as high as anywhere in the world. There are leaves for sunlight to give you the maximum possible photosynthesis. If we are to aim at this objective in multiple cropping, we must emulate nature. The rain forest production is practically straight line, except for the dry season. Thus, we must try to remove the Sigmoid curve type of crop development by cutting off the early and late slow growth portions as much as possible in relation to each individual crop by inserting other crops so that the total growth on the land approaches the continuous straight line of the rain forest. We can not get the line straight, but can approximate it.

In a typical cropping pattern, the first crop is rice planted between two ridges followed by sweet potatoes sown on the ridges, sowing about one month before rice is harvested. After sweet potatoes are dug, new beds one meter apart are made to plant soybeans. When soybeans are a month old, we sow sweet corn in the furrows at one-meter intervals. As corn is cultivated, ridges are made against the corn and against the bed. At tasseling time, we plant between cornstalks another crop of soybeans to be harvested as a green vegetable. About one month before the soybeans are ready to be harvested green, we sow a crop of rice between the rows of soybeans. This is one cropping sequence. Rice is 120 days, sweet potatoes, 114 days, soybeans (dry), 85, sweet corn, 66, and soybeans (green), 60, or a total of 445 days. Gross income is US\$3,150 per hectare annually.

You can use many other rotations. This is a sample. For example, cabbages, tomatoes or other vegetables may be put in the rotation. One rotation I especially wish to mention is one involving sorghum. Sorghum follows rice planted on ridges before harvest. The first crop was cut in December, a ratoon crop was harvested in March and the second ratoon was harvested in late May. That is three harvests of sorghum, each averaging about 6 tons per hectare and a 5-ton crop of rice in a little less than 12 months. This totals about 22 or 23 tons of cereal grains.

According to some people, I had the weediest corn they ever saw. Sweet corn in the furrow and soybeans on the ridges were sown the same day. Corn grows fast in the early stages and the leaf surface is above the level of the sweet potatoes, so there is no interference between the two crops. They do compete for nutrients and water. Thus, we supply water enough for the two crops and fertilize both crops according to their needs. Yield of sweet corn is between 95% and 100% of what it would be if sown alone. This comes off at 60 days when the sweet potatoes are just getting a good start. The ground is covered and leaf surface is about at a maximum. The sweet corn is harvested and stalks removed.

From 60 to 114 days the sweet potatoes grow without competition and we get a 90% crop. This is a combination of about 180% of a normal yield in the same time in which a sweet potato crop would be grown.

Many people say that they do not like sweet potatoes in the Philippines, but in our experience, this is not true. A small sweet potato will supply the needs of a child for vitamin A for a full week. The soybeans provide the protein. The byproducts will feed a dairy cow or some goats to supply the milk or other animal protein that the children need.

Thus, by using the surface we have fully throughout the year the potential of the tropics becomes very great indeed. The question we need to answer is: in how many areas in the tropics are these things happening? I am convinced it is applicable to a huge proportion of the tropical areas.

MOISTURE UTILIZATION AND CONSERVATION IN A FALLOW-WHEAT ROTATION

W. L. Nelson

In agricultural production under rainfed conditions, the efficient utilization of available water helps determine the production potential. There is no simple solution to maximum utilization of the rainfall. It is complicated by rainfall pattern, soil depth and structure, fertility practices, variety responses, weed control, timely land preparation and seeding, and the vagrancies of climatic conditions. Good management for the optimum efficiency of water utilization must take into consideration these factors. Good management factors are designed to minimize losses under the extreme of adverse climatic variations and maximize the production under average or better than average climatic conditions.

This discussion will be limited to the regions having a Mediterranean pattern of rainfall, which extends basically from October through June with very dry summers. The evapotranspiration losses are less under these conditions than under a summer rainfall pattern. More efficient storage and utilization of rainfall is possible with the winter rainfall pattern.

Two major factors determining agricultural practices under these conditions are total annual rainfall and the soil depth. Where rainfall is seldom less than 400 mm and averages 450 to 600 mm, there is adequate moisture for annual cropping rotations. There is enough moisture for rotations, for weed control and for relatively high levels of nitrogen application for high production, even in soils of less than one meter in depth. Where rainfall averages 300 to 400 mm and varies from 200 to 500 mm, summer fallow on soils of 1 to 2 meters in depth may be the most efficient method of moisture utilization. On the shallow soils, even with this low rainfall, annual cropping with legume rotation appears to have the best potential of moisture utilization and total production of cereals and livestock.

Alternate Fallow Systems

The term "alternate fallow" has been applied to a system of alternate cropping where only one seeded crop is harvested every two years. The crop most often grown in this system is a cereal crop. In most of North Africa, the idle or fallow year is devoted to pasture from the crop volunteer and native plants, mostly unpalatable weeds. When fallow is practiced in the strictest sense, all plant growth is controlled by tillage and other methods, which will be designated as "clean fallow" in this discussion. The pasture fallow system actually approaches annual cropping. In this system, we do not get the benefits of increased available nitrogen and water storage that normally occur with good clean fallow. The volunteer plant growth uses available nitrogen that could be accumulated. The only benefit of this system is the animal production during the pasture cycle. Since a large portion of the volunteer growth is unpalatable weeds, it is an inefficient method of animal pasture production. The pasture must be balanced against the reduction in crop potential by the loss of available water and fertility that would be available with clean fallow.

Effects of Clean Fallow on Wheat Production

The effects of clean fallow under the Mediterranean rainfall pattern is well illustrated by data from Dry Land Research Unit, Washington State University, Lind, Washington. The data are given in Figure 1. This gives a direct comparison of the same wheat variety grown under conditions where disease was not a limiting yield factor. The yield progress was due primarily to improvements in clean fallow management, equipment and moisture conservation.

In the first period illustrated, 1916-27, the rainfall averaged 25 mm less, but this alone cannot account for the low yield. During this period, the common practice was to leave a weed fallow. Initial spring tillage often was completed in June, allowing weed growth before and after plowing to use most of the water that could have been stored. There are fine sandy loam soils averaging more than 1 1/2 meters in depth. Although the native fertility was relatively high during this period, in years of good spring rainfall, yields were reduced by the loss of nitrogen to the weed growth in the fallow year. The winter wheat was seeded late, after October or November rains, and made very little growth before winter temperatures stopped further development. These conditions are similar to the problems encountered under the pasture fallow system of North Africa today.

The period not illustrated, 1928-49, was one of extreme climatic variations. During the first part of the period, average rainfall was less than 200 mm, while it averaged 350 mm in the last part of the period. During this period there was a complete change over from animal power to tractor power accompanied by new and improved equipment.

The second period illustrated shows the results of improved clean fallow management, adapted equipment and fertilizer practices. The improved practices included early initial tillage, timely weed control by tillage, and nitrogen fertilization. The most important factor was the early seeding. The date of seeding was moved up from late October and November, to late August and early September. This was possible with the development of deep seeding equipment that permitted seeding in moisture stored by the clean fallow tillage. The improvement in diesel power equipment and timely tillage made it possible to save adequate moisture within 10 to 15 cm of the soil surface for seed germination. The wheat developed a well-tillered plant with an extensive crown root system before the winter stopped growth. Development in the spring was more rapid. The wheat matured earlier and was able to use the stored moisture more efficiently by making a greater proportion of its early growth during the cold spring. Moisture measurements of moisture utilization by the wheat during the growing season showed that early seeded wheat used as much as 35 mm less moisture in producing 20% more yield than late-sown wheat (1).

The yield difference cannot be attributed to the increased use of nitrogen fertilizer alone. Data comparing fertilizer and date of seeding response showed that late-seeded wheat used less nitrogen for maximum yield. However, the maximum yield for late-seeded wheat was 8 to 10 quintals per hectare less than the maximum yield of early seeded wheat at a higher optimum level of nitrogen fertilizer (2). The net result of the improved management illustrated in the second period of

FIGURE 1 : YIELDS OF "TURKEY RED" WHEAT VARIETY SHOWING
EFFECT OF IMPROVED AGRONOMIC AND TILLAGE
PRACTICES DURING 50 YEARS OF CONTINUOUS RESEARCH

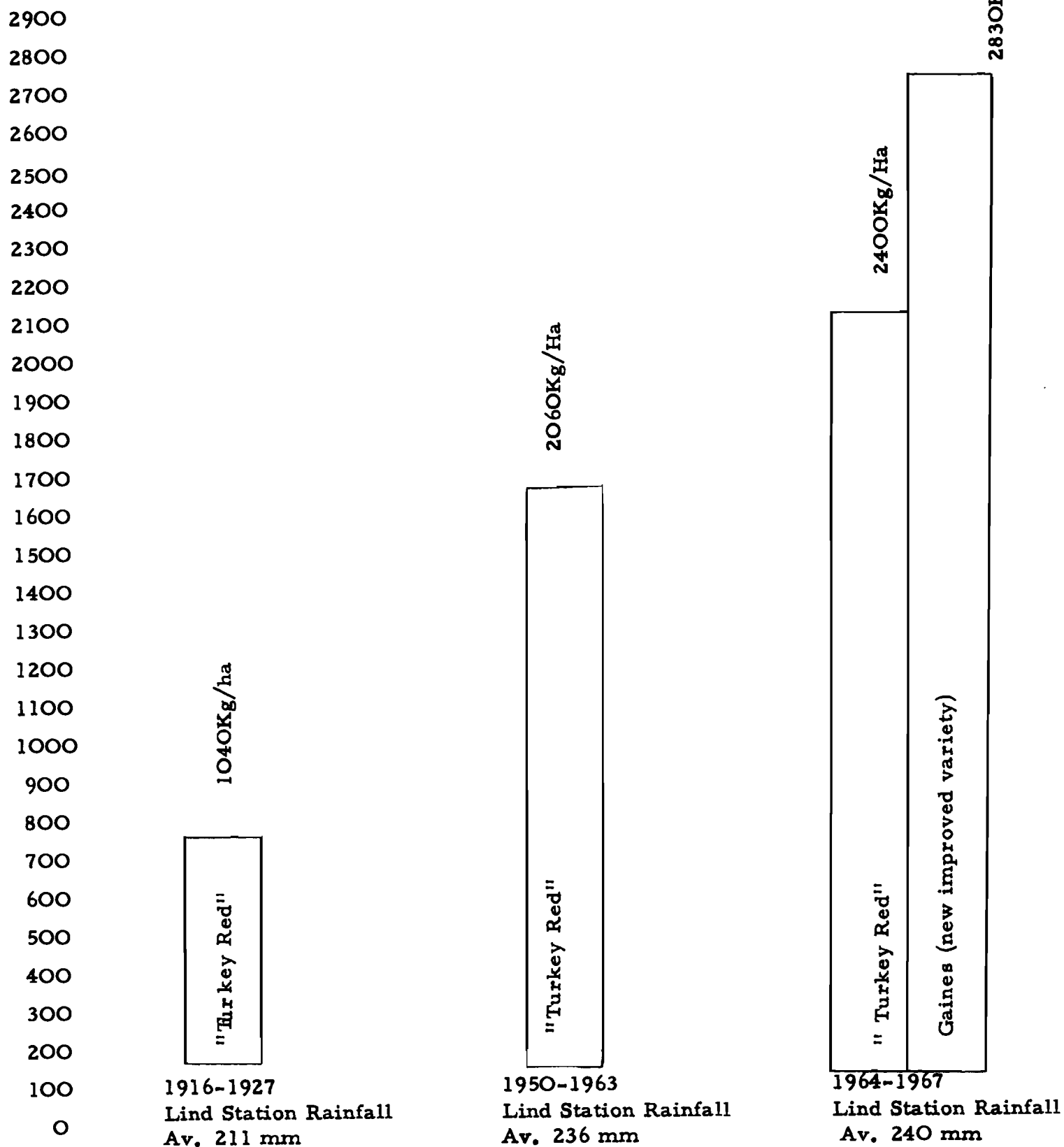


Figure 1 was improved moisture storage and more efficient utilization of the available moisture with a corresponding increase in nitrogen fertilizer response. This resulted in a 98% increase in yield of wheat.

The third part of Figure 1 illustrated an important factor in the production of wheat in the lower rainfall areas. The influence of the variety is important in the total yield with good management. New varieties do yield more and offer protection against catastrophic losses due to disease. High-yielding varieties increased the yield by over 4 quintals/hectare.

To get optimum yield from a good clean fallow management, we need yield responsive varieties. The data reported in Figure 1 was obtained under experimental conditions using standard farm equipment and is comparable to the results obtained under actual farm conditions. These are average figures over a period of years and influenced by the year-to-year variations in yield. An example of the advantage of yield responsive varieties under optimum conditions is illustrated by farmer yields in 1972 in eastern Washington in the 300 mm rainfall region. Yields of adapted yield responsive varieties were 4 to 5 tons per hectare for farm averages on 500 to 800 hectares where good clean fallow and fertilizer programs were followed. Rainfall was only slightly above normal but a 50% increase in spring rainfall with cool spring and summer temperatures resulted in optimum yield. Even with good fallow management, the yield responsive varieties will give maximum yield under the exceptionally favorable climatic conditions, as well as showing a yield advantage under normal or adverse conditions.

In Tunisia, the yield response from stored moisture was demonstrated in two separate situations. In 1968-69, 155 mm of water by sprinkler irrigation was applied to the soil before seeding. This moisture penetrated, with the 185 mm of rainfall during the crop season, to a depth of one meter. The yield of Inia 66 was 4 tons per hectare as compared to 1 ton per hectare for the same variety without the supplemental irrigation (3). In the irrigated wheat, the maximum penetration of water into the profile was about 30 cm and heavy drought stress was evident in February and March during the tillering and shooting stage of growth. Although the preirrigated wheat was subjected to the same drought period, the good root development and available stored moisture allowed normal plant development without stress during this period. Under fall irrigation, the maximum yield of Inia 66 was 5.9 tons per hectare.

The second illustration of the importance of stored moisture occurred in wheat varietal demonstrations at Pont Fahs, 50 km south of Tunis on the same farm in adjacent fields. In 1968-69, the rainfall totaled 200 mm with 185 mm of precipitation from December through May. The deepest penetration of moisture was 25-30 cm in the soil. In 1969-70, rainfall at this location totaled 813 mm, but only 157 mm was recorded in the period December through May. Over 640 mm of rainfall occurred in September and October. This completely saturated the soil to a depth in excess of 1 meter. Yields during the first season for Inia 66 were 5.7 quintals/hectare and 48 quintals/hectare in the second

season. The major production difference in the two seasons was the subsoil moisture available to the wheat, as adequate fertilizer and weed control management were carried out in each season.

In both of these situations, an important factor was the seeding condition where subsoil moisture was present. This allowed emergence at the optimum date of seeding. Plant development was normal with early development of crown roots and good penetration of the roots. The plants were able to use the moisture from a full one meter profile.

When the moisture penetration was only 25 to 30 cm, the wheat did not have moisture reserves to withstand drought stresses, besides limiting total production because of limited moisture. Emergence was in late December or early January. This limited good early root and crown development. Without moisture reserves, it is necessary to have very timely rainfall to realize a good yield.

One of the most important factors of good clean fallow is the stabilizing effect it has on yearly fluctuations in rainfall. Often the two-year total of rainfall is near normal, but the yearly rainfall may fluctuate tremendously. Crop season rainfall totals of 223 mm in 1968-69 and 868 mm in 1969-70 at Pont du Fahs, Tunisia illustrated some of the extremes that occurred. However, the two-year total was less than 150 mm from the normal two years average total. The crop variation was 6 to 48 quintals/hectare. Good clean fallow management can carry over moisture in the fallow year to help equalize the variations of yearly rainfall.

Criteria for Clean Fallow

Regions that can benefit most from a clean fallow system should have these minimum conditions:

1. 250 to 400 mm of average rainfall per year.
2. A soil depth of about 1 meter or more above an impervious layer.
3. Relatively moderate summer temperatures. Temperatures above 40° Centigrade will reduce the potential for moisture conservation.
4. Friable soils not subject to wind erosion, or adequate straw cover on wind erodable soils.

Production of cereals with less than 250 mm average rainfall per year may not be economically feasible. Unless the rainfall is well distributed and falls in a pattern conducive to storage, it is questionable that it can be effectively stored and used in a fallow system. Under the optimum water storage conditions in winter rainfall areas, 30% to 50% of the rainfall can be carried over for the next crop year. Often in the regions of low rainfall we have much less than optimum conditions for water conservation by subsoil storage. High summer temperatures, low intensity of rainfall, or periods of high intensity and rapid run off, or a highly variable rainfall pattern often are associated with these lower rainfall regions. These factors tend to decrease the efficiency of water conservation in the fallow year.

Optimum rainfall for clean fallow is 300-400 mm fairly well concentrated from November through March. When rainfall exceeds 400 mm, annual cropping may be a better choice for the Mediterranean region, especially with the emphasis placed on livestock production.

The depth of soil is perhaps as important as the amount and pattern of rainfall. With less than a meter of soil depth, there is not a sufficient reservoir for the storage of water to get efficient usage under clean fallow. The amount of water that can be held in a meter of soil varies with soil water holding capacity. Average amounts will vary from 150 to 200 mm per meter. In general, sandy soils have the least water holding capacity and the loam and clay soils, the higher capacity. Most of the surface 15 to 20 cm is of little use for water storage due to surface evaporation. The effective reservoir for water storage is only 80 to 85 cm of the first meter depth. On the average, the first meter of soil will hold less than 200 mm of available water at field capacity. For short periods of time, water can be held above field capacity. The speed of equilibrium depends again upon soil type and texture and the freedom of movement of water within the profile.

The ideal soil for clean fallow would have a depth equal or greater than the effective root zone of the cereal crop produced. In light sandy soils, this depth may exceed two meters, while in a heavy clay soil, one meter would more normally be the effective root zone. Management will influence the effective root zone.

Those management factors that stimulate early crown and secondary root growth generally increase the effective root zone under low rainfall conditions. Timely seeding and emergences of the plant with proper fertility levels for early growth are two of the most important management factors that influence root development.

Maximum yield of cereals with clean fallow depends upon the efficiency with which the available moisture is used, whether from stored moisture or current rainfall. Stored moisture influences the efficiency with which current moisture can be utilized. Stored moisture can carry the crop through drought periods with near normal development. Often a rainy period may follow a period of drought. A plant carried through a drought period by the stored moisture will utilize the subsequent current rainfall more efficiently. If it has not been under drought stress, it is in a more advanced stage of growth with a more fully developed yield potential than a plant which has suffered drought stress.

In addition to improved moisture utilization, cereals produced under conditions of good moisture reserve often utilize soil nutrients more efficiently. This may be associated with the movement of soluble nutrients with the free water in the soil profile. Often soluble nutrients will be moved to a depth of 1/2 meter or more as the free water moves down in the profile following heavy winter rainfall. If the crop has made early root development, these nutrients are still available to the plant. If root development was poor before the nutrients were moved deeper in the profile, then the development of the crop may be inhibited by a temporary shortage of nutrients before the roots penetrate to the nutrient zone. The yellow color of wheat developing under cool spring temperatures, even in well fertilized soil, often is caused by this type of temporary nutrient starvation. Early root development is stimulated by adequate stored moisture, which tends to increase the efficiency of nutrient use. If plant development is restricted by lack of available nutrients due to leaching into the subsoil, yields are often reduced with a quick onset of high temperatures which will reduce

tiller development and force formation of the spike.

Summer temperatures and the soil texture influence the conservation of water during the clean fallow. Loss through evaporation from the soil surface is influenced by air temperature. Upward movement of the soil moisture from unsaturated subsoil is influenced by the soil structure. Loss of water from the subsoil below the soil mulch is directly related to the temperature at the upper surface of the moist layer. Soil temperature and structure are factors which must be considered by the tillage program followed during the clean fallow year.

Effects of Tillage on Moisture Conservation

For maximum conservation of water during the clean fallow year, a very carefully controlled program of tillage must be followed. For maximum water conservation, tillage must control all weed or volunteer growth, leave the soil in condition for maximum water penetration, and protect against loss of water from subsoil through evaporation during periods of high air and soil temperature.

Conservation of moisture should start as soon as the crop is harvested. The stubble should be worked immediately as soon as the crop is harvested if active weed growth occurs. These weeds are removing deep soil moisture that may be used by the next crop. Weed control can be accomplished by tilling the soil to a depth of 10 to 15 cm. In light-textured soils, a sweep type of implement works very well providing the sweep blades are sufficiently overlapped. In heavy-textured soils, an offset disk may be necessary and often more than one operation will be required.

If there is little weed growth, there is no advantage in working the soil except to assist in the penetration of the winter moisture. If the soils are sealed tightly or are frozen during the winter rainfall or snowfall, then fall chiseling to a depth of 20 to 25 cm often increases the water intake. The depth of chiseling may be increased if the soil freezes below the 25 cm depth. Fall chiseling will be less effective in heavy clay soils that have natural fissures from soil contraction as they dry out. The soils tend to seal up with rainfall, and the effect of chiseling are lost. The best fall tillage for clay soils would be tillage that leaves the soil surface rough to hold free water until it has time to infiltrate before running off. Dry moldboard plowing, or shallow dry chiseling at a depth of 12-15 cm can accomplish this soil condition. In areas of snowfall, chiseling is recommended over moldboard plowing because it leaves the stubble upright to catch and hold snow. Since the fall tillage is primarily to prepare the soil for winter moisture intake, the implement used and the soil conditions obtained must be determined by the soil type, the type of rainfall or snowfall pattern expected the soil runoff potential and the wind erosion potential.

Remember that water intake by a soil is limited by the condition of the soil surface. All the water must penetrate through the surface layer of soil.

If the soil surface tends to seal rapidly, as a clay does, then penetration is limited as soon as the first few millimeters of the soil are saturated. The structure of unfrozen soil below the surface has

little effect on the rate of water intake after the surface becomes saturated. In this type of soil as well in frozen soil we must be concerned with holding the water in place either by a rough surface or some other physical structure change until the water has had time to penetrate to the subsoil.

The initial tillage following the winter moisture is basically to kill volunteer and weed growth and work the soil to a depth favorable for the formation of a soil mulch. The soil type again will be a factor in determining the implement to use and depth of tillage.

In highly wind erodable soils a subsurface tillage implement should be used to leave as much stubble on the surface as possible. Straw on the surface will help reduce evaporation and wind erosion. Loam and clay soils are less subject to wind erosion, and can be worked with a disk or mold board plow, depending upon soil type and amount of stubble to be worked into the soil. It may be advisable to leave part of the stubble on the surface to help protect against extreme wind erosion and help decrease water runoff from high intensity spring or summer rainfall.

Tillage has been shown to be highly effective in conserving moisture in the Pacific Northwest. The proper tillage develops soil mulch conditions that protect against the loss of stored moisture from the subsoil. Extensive studies by Papendick et. al. (5) have shown that very little stored moisture is lost from summer evaporation of a good soil and/or stubble mulch is developed by spring and summer weed control tillage. A relatively fine-textured soil mulch of 10 to 12 cm was effective in preventing subsoil loss and in maintaining moisture within 12 cm of the surface for seed germination. In this region, spring tillage in late February and March with a disk or sweep implement followed soon by rod weeding or subsurface packing with a skew treader developed an effective soil mulch in light-textured sandy loam soils. Subsequent tillage with the rod weeder to control weeds was all the tillage necessary.

One of the key factors in preventing loss of stored moisture from the subsoil during summer is the establishment by tillage of a fairly fine-textured soil mulch 10 to 15 cm in depth. The depth of the mulch necessary is determined partly by soil type and partly by summer temperatures. Where summer temperatures seldom reach 40°C, a soil mulch of 10 to 12 cm in loam soils should be sufficient. Clay soils may require a 12 to 15 cm mulch because of the difficulty in breaking soil particle size down fine enough for a good insulating mulch. As the summer temperatures increase above 40°C, a soil mulch of 15 cm is probably the minimum that will be very effective against loss of subsoil moisture.

An important part of the tillage program is the tillage for weed control. This must be accomplished as soon as any weed growth begins to develop. These weeds will remove the deeper moisture even though a good soil mulch has been formed. The weed growth is also greater when a good mulch is formed. The mulch tends to hold the moisture closer to the surface, favoring germination of weeds and their rapid development.

It will be necessary to till for weed control more often under

a good clean fallow program than under the late-plowed pasture fallow program. Under this system the late plowing leaves the soil rough. The soil dries out completely to well below the plowed layer with a high loss of any residual moisture. Very little plant growth occurs during the summer, except for deep rooted perennial weeds.

Under the clean fallow system, the extra tillage and preparation of the soil mulch leaves the soil in good condition for seeding. Very little extra preparation is necessary for seeding. Under the pasture fallow system, the land must be worked two or three times with a disk to prepare even a passable seed bed in the clay soils. The additional tillage for weed control is offset to a large extent by the reduction in fall tillage for seed bed preparation. The work load on a farm is better distributed with a clean fallow system. Much of the land preparation is completed before fall seeding and it reduces the heavy work load at seeding time.

With good summer fallow tillage, it is possible, in some soil types and with relatively mild summer temperatures, to conserve moisture in the seed zone for seeding in September before fall rains. In regions where winter temperatures require a winter type wheat, this is very important. It allows for good root and crown development before the onset of winter. The wheat develops more rapidly in the spring and may mature ahead of high summer temperatures.

In much of North Africa, conserving moisture in the seeding zone is not of major importance. Since the winters are mild and spring types can be seeded, the optimum seeding date is later, mid-November to January. Normally, rainfall occurs in ample time for emergence at these dates.

However, holding the moisture within 20 to 25 cm of the surface is very important. A rainy period with 25 to 50 mm of rain will supply enough moisture to penetrate the reserve subsoil moisture. This assures a good crown development and early root growth even if a droughty period follows emergence. If the soil is dried out to below 50 cm, as is the case with rough-plowed pasture fallow, it will take 100 mm of effective rainfall in one period to penetrate to this depth. The chance of getting this amount of rainfall is very much reduced as compared to the chance of a 25 to 50 cm rainfall in one rainy period in most of the 300 to 400 mm rainfall regions.

The Effect of Tillage Implements for Clean Fallow

The choice of the proper implement is important in a good clean fallow system. An implement should be chosen to fit the soil type and the tillage that is to be performed. A tillage operation may be influenced by the previous equipment used and a different choice of equipment for the next operation may be required. Preparation of the soil for fall rainfall may influence the selection of the implement used for spring tillage. Weed growth before the first spring tillage may require a choice of a different implement than if little or no weed growth was present. The choice of the implement must be made within equipment availability. Fortunately, several tillage implements can be used to accomplish each of the operations necessary for good clean fallow. When replacing equipment or purchasing new equipment to begin a clean fallow

program, the soil type should be considered to obtain the best-suited implements.

The following implement chart gives a general rating of equipment that can be used for most of the tillage operations required for clean fallow. Experience with the soil type, wind and water erosion hazards, and the timing of the operation to the proper moisture condition of the soil for tillage implements are important to obtain the proper soil condition. Working the soil too wet or too dry will influence the choice of implements later, and make the establishment of a good soil mulch more difficult.

As noted in the chart, as soil texture becomes more coarse, the implements used have less action on the soil. Clay soils require much more action by the implement to break the soil down into finer particles necessary for an effective insulating soil mulch. Loams and sandy loams are much more friable and implements must be chosen that do not break the soil too finely, causing excess wind erosion. A rod weeder will work well in a loam or sandy soil. It is less effective in clay soils. However, when used with or following sweep implements, the rod weeder will penetrate and work satisfactorily. Often the use of a spike tooth harrow behind tillage operation in clay soils will maintain a satisfactory soil mulch condition.

The initial spring tillage in a clean fallow system is perhaps the most important tillage operation. The depth of tillage should be no more than 3 to 5 cm deeper than the depth of the final mulch. The second tillage should follow the first before there is much soil moisture loss and while the soil is still friable and easily worked into finer particles. The second tillage and subsequent tillage operation should be 2 to 5 cm less in depth than the original tillage. The optimum soil conditions for a good soil mulch appears to be a relatively fine-particled soil 10 to 15 cm in depth. Just below the mulch it is necessary to have a more compacted layer that is in good contact with the moist subsoil. This allows the transfer of moisture from the subsoil to keep the layer moist. The mulch above the compacted layer remains dry and acts as an insulating blanket to lower the temperature of the soil below the mulch. It also helps hold down the evaporation through the mulch as all loss through the mulch is in the vapor form. Since the water has to vaporize before passing from the moist subsoil, the loss is directly proportional to the heat energy available for vaporization.

With a good soil mulch, the total loss of water from the subsoil is small. Less than 10% of the stored moisture was lost in tests with fine sandy loam soils in the Pacific Northwest. The loss may be higher in clay soils where the upward movement of water is greater than in sandy loam soils. Also, the insulating effect of the clay soils by the more porous structure of the less finely divided particles is less.

In light-textured soils, a mulch of this type can be obtained by initial tillage with a sweep, offset disk or one-way disk plow to a depth of 15 to 18 cm. This is followed by another tillage operation using a tandem disk, skew treader or rod weeder, at a depth of not more than 12 to 15 cm. Rod weeding for weed control is usually all that is necessary after these two operations. The choice of the initial implement is affected by the stubble.

IMPLEMENT CHART

<u>TILLAGE OPERATION</u>	<u>SOIL TYPE</u>		
	<u>CLAY</u>	<u>LOAM</u>	<u>SANDY</u>
Fall soil preparation (Rough texture)	Chisel Mold board plow Disk plow	Chisel Mold board	Chisel
Initial fallow tillage (Spring plowing)	Offset disk Moldboard Disk plow	Offset disk Mold board Sweep plow One way disk	Sweep Offset disk One way disk
Second tillage Preparation of soil mulch	Offset disk Tandem disk Skew treader	Tandem disk Rod weeder Skew treader	Rod weeder Skew treader
Weeding operations	(1) Sweep (1) Tandem disk (1) Duck foot cultivator Sweep and rod weeder	(1) Sweep Rod weeder	Rod weeder

(1) A spike tooth harrow can be used to help break down the soil to keep a good mulch behind these implements during weeding operations.

Heavy stubble requires an implement that will work some of it into the soil and break it down. The offset disk or one-way disk is more effective than the sweep for this operation. A skew treader or tandem disk also aids in controlling heavy stubble in the second operation. Following a heavy summer rain, it may be necessary to till the soil with a duck foot cultivator to get good penetration with the rod weeder for weed control.

The initial tillage for clay soils can be done with an offset disk, mold board plow or a disk plow. It should be followed with a disk or skew treader soon before the soil dries and while it has the proper moisture to break down readily. Tillage should not be deep, 15 to 18 cm. Deep tillage will cause excessive loss of moisture and make it difficult to obtain a moist compacted layer above the subsoil. A spike tooth harrow used behind the tillage implements in clay soils aids in the mulch formation. The offset disk tends to break the soil down better than the mold board plow or disk plow. A sweep, or duck foot cultivator followed by a spike tooth harrow is effective for weed control. The rod weeder can be used if a good mulch is formed. However, after one or two rod weedings or after a summer rain, the rod weeder will not penetrate in clay soils. It will be necessary to use a sweep or duck foot cultivator for good weed control and reestablishment of a soil mulch.

Stubble can be of value for moisture conservation if handled properly. To be of use it must be worked in the surface or left on the surface. If it is plowed down deep, it tends to break the seal with reserve moisture and increases the depth of the drying zone. When worked into the surface or left as a mulch on the surface, it protects the soil against wind erosion and is effective in breaking up hard rain to prevent the sealing effect on the soil surface often accompanying this type of rainfall. It will help maintain the normal filtration rate and decrease soil losses from water erosion. Heavy straw mulches will lower the soil temperature and slow down evaporation losses from the subsoil. The amount of straw mulch that can be tolerated is determined by the seeding equipment. Shovel or hoe drills, with wide spacing (35 cm or more) between hoes, will handle more stubble than disk drills. The stubble should be broken down into lengths of less than 25 cm to facilitate seeding. Wide row spacings are necessary for heavy stubble mulches.

Summary

In the Mediterranean type of climate where 80% to 90% of the rainfall occurs during October through May, as much as 50% of the rainfall may be conserved during the fallow year for use in the crop year with well-managed clean fallow. This type of management will be effective on soils with a meter or more depth of effective root zone and in regions with 250 to 400 mm of annual rainfall.

Good tillage management will aid in the intake of rainfall and help conserve the moisture after it has penetrated below the tillage zone of 12 to 18 cm. Tillage that forms a soil mulch of fairly fine soil particles above a slightly compacted layer in firm contact with the subsoil has been most effective in maintaining soil moisture. Tests under

these conditions in the Pacific Northwest have shown that the major water loss occurred during the winter due to surface evaporation before the water had a chance to penetrate below the tillage zone.

Control of all weed and volunteer growth is necessary for good moisture conservation in clean fallow. Any plant growth will rapidly deplete subsoil moisture regardless of the other tillage management.

Good tillage management for moisture conservation is less dependent upon a particular tillage implement than the timely use of a suitable implement. Overall management is the key to success and this involves proper timing of each tillage operation to obtain the right soil condition and to prevent moisture losses due to delayed tillage.

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CULTURAL PRACTICES TO MAXIMIZE YIELDS UNDER RAINFED AND IRRIGATED CONDITIONS

Bill C. Wright

Research on Plant Nutrient Needs

Where wheat is grown under irrigated or high rainfall conditions there is little need to carry out further research on plant nutrient needs until a significant change has been made in the varieties available. Some may disagree with this statement but I believe I can argue the point.

Dwarf varieties are now being grown on large areas in countries from Mexico, through the Middle East, to Pakistan and India as well as Latin America. There has been a tremendous increase in fertilizer use in these countries as a direct result of the introduction of these dwarf varieties and there has been considerable research to establish the most economical fertilizer rate for these new varieties. If we compare the recommended rates of nitrogen for dwarf wheat under irrigation or adequate rainfall in some of these countries, we find that the recommended rates are surprisingly uniform. Since these recommendations were derived from fertilizer trials aimed at establishing the highest economical level of nitrogen use, it leads me to conclude that the present varieties cannot economically utilize more than 100-120 kg N/ha. This conclusion is supported by observations in the field by numerous wheat scientists. This is true in many different countries under varying soil conditions and with different varieties; however, nearly all the varieties are dwarf and nearly all have a Mexican genetic background. It appears to me that the variety limits yield and not the lack of additional fertilizer. The variety may limit the yield potential because it lodges, because it is susceptible to disease or insects, or because of the inherent yielding ability of the variety itself.

In the Mid-East Region, I submit that there is not a single well-adapted, high-yielding variety available today for areas with adequate moisture. Susceptibility to insects and diseases, stripe rust and Septoria in particular, length of the maturity period, and lodging under high fertility are very serious problems from which no variety is free.

Another point concerns the plant configuration of the present varieties. With corn and rice it has been demonstrated clearly that upright leaves permit a greater interception of incident sunlight and can lead to higher photosynthetic levels which, in turn, permits higher yields. Is the wheat plant different from other species? If not, are varieties with upright leaves being produced?

The isolation of the so-called triple-gene dwarfs has touched off a series of investigations by agronomists. The nonlodging character of these varieties may permit higher levels of fertilizer use. Their dwarfness may permit closer spacing which could lead to a higher number of spikes/m², thus leading to higher yields. It is my impression, however, that the triple-gene dwarf varieties now available do not have a yield potential significantly higher than the older double-gene dwarf varieties and, in this situation, there have been no startling increases in yields

from higher fertilizer use and closer spacings.

My conclusion at this point is that we really do not need to emphasize further research in the fertilizer needs of wheat under adequate moisture conditions until significant changes have been made in the varieties available. These changes might be a different plant configuration or some other genetic change which leads to a higher innate yield potential.

The situation where wheat is grown under conditions of limited moisture is quite different. Under these conditions the varieties being grown usually yield below their yield potential and, in a general sense, the variety is not the factor which limits yields. It is also true that lack of nitrogen does not limit yields in many instances. In Turkey, under a wheat-fallow rotation, data show that as much as 50-70 kg N/ha may accumulate in the top 150 cm of the soil profile as nitrate nitrogen. If we assume that each kilogram of this N will produce 20 kg grain (a very conservative estimate at this level of N) we can calculate that the available N in the soil can produce 1.0-1.4 tons grain per hectare. I believe this explains why there has been no response to nitrogen fertilizers in the Central Plateau in fertilizer trials conducted in the past. The highest average yield in these experiments was about 1.6 t/ha, a yield for which there was sufficient available N in the soil.

Here it should be noted that many wheat soils are deficient in phosphorus and, even though reasonable quantities of available soil N may be present, this nitrogen cannot be utilized until phosphorus is added. The soils of Turkey are good examples of this kind of fertilizer interaction. Since the phosphorus status of a soil is specific for each location, it is necessary that research trials be conducted in all wheat growing areas to determine their phosphate status.

In areas of low rainfall the limiting factor is obviously moisture. It is clear that yields in these areas can be increased only by increasing the efficiency of moisture use or by increasing the fraction of the rainfall which is available to the crop. The efficiency of moisture utilization by a plant perhaps may be manipulated genetically; however, my understanding of the physiological processes related to drought tolerance leads me to conclude that there is little chance for a wheat breeder to produce a variety which has a significantly improved drought tolerance. It may be possible to breed varieties that have deeper root systems, thereby allowing them to exploit more soil moisture and it may be possible to breed very short duration varieties which could escape drought; but these short-duration types would be useful only in certain specific geographical areas.

An improved fallow management system in which a good mulch is established, field operations are timely, and weeds are eliminated will retain a larger fraction of the rainfall in the soil for future use by the crop. If the system is efficient enough, moisture will be maintained within a few centimeters of the soil surface so that seeds can be placed in residual moisture with a deep-furrow drill and germination can take place irrespective of rainfall. When that is possible, the plants can establish their crown root system and tiller to some extent before cold weather forces them into a dormant state. The roots of these plants

are in a position to fully exploit the soil profile for moisture; moreover, these partially tillered plants are able to utilize rainfall in the spring much more efficiently than younger plants. Therefore, if it is possible to establish the wheat seedlings early in the season, the yield potential is increased and the demand for fertilizer nutrients is also increased. Soils that show no response to nitrogen when the yield level is 1-1.5 t/ha may show a pronounced response to N when the yield level is raised to 3 t/ha. When the yield potential is elevated, the quantities of fertilizer nutrients required by the crop will change, and it may be possible that some nutrients which were adequate at lower yield levels will become limiting at the higher yield levels.

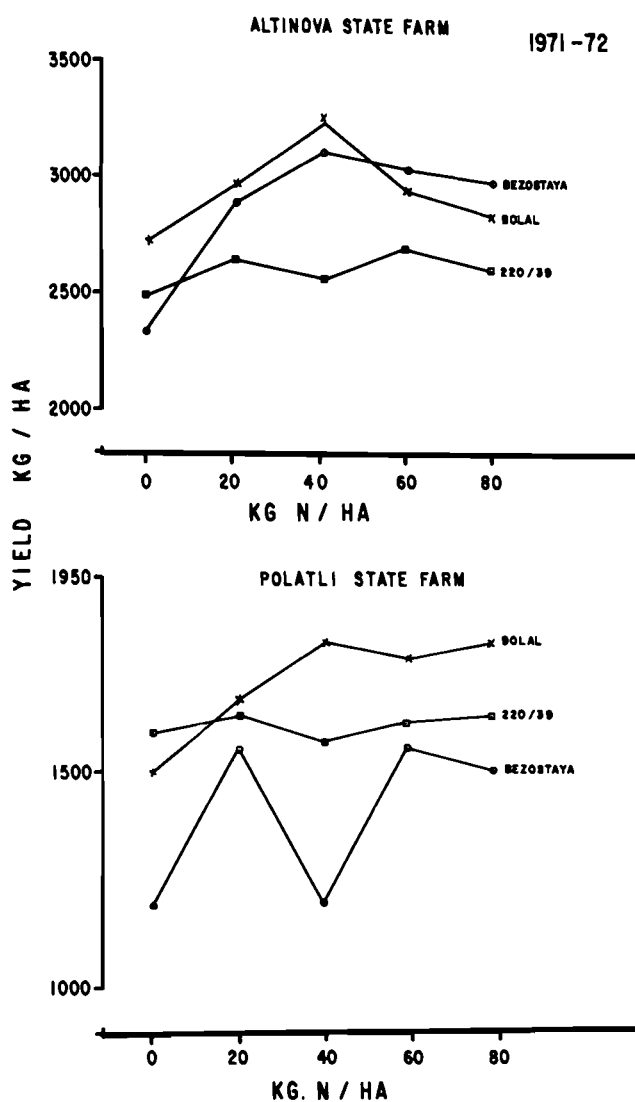
The Pacific Northwest of the United States is one region which has developed an efficient cultural system with the result that yields and fertilizer use have increased under unchanged rainfall conditions. The trends in yield per hectare near Lind, Washington, over a long period of years illustrate the effect of a good management system. In the early part of this period (1916-1927) with an inadequate management system yields of the old variety "Turkey Red" were about 1.0 t/ha and fertilizer use was nil. Later, (1950-63) when a management system had been developed which permitted good moisture conservation and early planting, yields with the same variety went to about 2.0 t/ha. After the management system had been improved further and the yield potential raised (1964-67), nitrogen fertilizer gave good increases, and yields were pushed to about 2.4 t/ha. When a well-adapted, high-yielding variety was added to this system yield climbed to about 2.8 t/ha.

The point I wish to make is that for much of the wheat area where rainfall is low, research on fertilizer use must first be preceded by research to increase moisture use efficiency which will elevate the yield potential. After this has been done, research on fertilizer use must be carried out using the new cultural techniques. In actuality the research to establish a management system and the experiments to determine fertilizer needs should be carried out concurrently. Fertilizer needs probably will increase in direct proportion to the increase in yield potential of the crop. Under poor management and low yields fertilizer requirements will be low whereas under intensive management and high yields fertilizer requirements will be high. It is my belief that in the 1970's we should direct our main research efforts at developing suitable fallow management systems for low rainfall areas, complemented by a modicum of research to establish fertilizer needs with these improved systems.

SUMMARY OF APPROXIMATE FERTILIZER RECOMMENDATIONS FOR DWARF WHEAT
(IRRIGATED OR ADEQUATE RAINFALL)

Country	N	kg/ha		K
		P		
INDIA	120	22		0
NEPAL	100	26		25
PAKISTAN	120	26		0
AFGHANISTAN	133	35		0
IRAN	110	22		0
TURKEY	140	30		0
EGYPT	96	0		0
SUDAN	83	0		0
TUNISIA	100	20		0
MOROCCO	100	20		0
MEXICO	140	30		0

EFFECT OF NITROGEN RATES ON YIELD OF 3 WHEAT VARIETIES AT TWO LOCATIONS IN THE CENTRAL PLATEAU OF TURKEY



WHEAT IN ROTATION WITH LEGUMES

John Doolette

The land use system that alternates crop with a pasture substantially composed of a forage legume has brought about a revolution in the agriculture of temperate Australia and it is not unreasonable to expect it to do the same in many other similar environments of the world.

CONCEPT

The main feature of the system is that a free-seeding self-regenerating annual forage legume is grown in rotation with cereal crops. The variety of legume and the length of the pasture and crop phases vary according to environmental and financial considerations but broadly it is intended that the legume pasture phase should: provide soil nitrogen, improve physical fertility and help control some weeds by competition and diseases by breaking the continuum of host plants.

Although it is not necessary for success or for financial justification, it is recognised that considerable forage is made available and this may be converted to animal products. So that in areas where livestock production is important to the economy the system is increasingly attractive.

IMPORTANT PRINCIPLES

1. Annual forage legumes produce dense stands of herbage and roots when properly fertilised, and well managed, and are easy to establish and to manipulate in rotation.
2. The nitrogen fixing ability of the legume assumes that inoculation and nodulation with rhizobia is satisfactory.
3. Nitrogen accumulation as a result of symbiosis depends on root growth but for practical purposes can be "correlated with" top production (stems and leaves). It will approach an equilibrium value with time.
4. The production of adequate seed, a large percentage of which is "hard" and will not germinate in the autumn after production, is the mechanism by which the legume regenerates itself after a short cropping phase.
5. There is evidence to show that under a wide range of conditions the system works best on a ratio of 1 crop — 1 year of pasture although obviously the quality of the environment determines whether there will be a potential for more crops or a need for more years of legume.

BENEFITS

1. Soil Fertility Improvement

While there isn't a satisfactory single index of soil fertility, it is reasonable to use organic matter content or soil N as an indicator. In terms of N buildup there is adequate evidence of the benefits of the system. Accession rates ranging from 38-170 kg of N/ha/yr have been

measured with the majority in the range of 45-80.

2. Yield Improvement

Soil fertility has no value except in the extent to which it is converted to crop yield or animal production. The consequence of the fertility improvement and nitrogen buildup in particular has been a notable rise in wheat yield which can be demonstrated in many ways.

3. Increased Crop Intensity

It is not sufficient to consider crop yield alone without considering the frequency of crop. If the frequency is reduced, then nothing is gained. As fertility increases the soil shows a capability to carry successive crops after pasture, so that the number of crops within any period of years becomes greater than the 50% of the fallow-wheat rotation or the 33% of the fallow-wheat-nothing rotation. In areas with annual average rainfall around 450 mm it is not uncommon to get 2 crops in 3 years or 2,3 or 4 successive crops after a 2- or 3-year ley period. This increased intensity can be important where climate sets a limit on yield.

4. Reduction of Bare Fallow

Fallow no longer becomes necessary to mineralise sufficient organic matter to supply the nitrogen needs. In fact, bare fallow has declined significantly in Australia. In some areas fallowing may still be necessary to conserve sufficient moisture. Other experiments have cast doubt on the usefulness of fallowing and shown that weed control in the crop is more important.

5. Improved Moisture Relations

Physical structural improvements have allowed more efficient use of limited rainfall, and soil improved by pasture has given yields better than impoverished soils with heavy fertiliser applications.

THE EXTENT OF THE AREA WHERE THE SYSTEM IS FEASIBLE

Technical Feasibility

The experience so far has been confined to temperate rainfed wheat lands with annual forage legumes of typically Mediterranean habit, germinating with the autumn rains, growing under favorable conditions until seed is set in the spring and summer period and surviving the summer as seed. So that a successful variety is one able to produce a heavy crop of seed which is protected against germination until growing conditions are suitable.

For the species of Trifolium and Medicago now in use there are definite climatic limits defined in terms of seed production. Donald defined 3 boundaries:

- a. An arid boundary beyond which soil moisture deficiency or atmospheric aridity cause flower abortion,
- b. A warm boundary beyond which the plants experience insufficient cold

to allow flower initiation to occur, and
c. A cold boundary beyond which frosts during flowering reduce or suppress seed production or where low temperatures may limit flower induction.

There has been an extension of the arid boundary as new early maturing lines have been introduced. Generally, at the low elevations in Australia the boundary follows the 250 mm isohyet although it is probably better defined in terms of influential rainfall period and the reliability of this. Very often as mean annual rainfall is reduced reliability is reduced and variability increased. Medicagos in general are more adapted than Trifolium species in the lower range of this spectrum.

Flower initiation depends on day length and temperature and is accelerated by low temperature, but lengthening of the photoperiod shortens the necessary cold period. In practice, the 12-13°C winter isotherm or 27-28° latitude S represents the warm boundary at low elevation. The cold boundary can be related to mean winter minima and altitude. An altitude of 1000 metres around 30-31°S makes little difference, whereas 650 metres at 35°S showed a depression in seed yield, which is most likely due to low temperatures.

Thus, undoubtedly there are 3 constraints to the successful commercial growth of existing cultivars. Defining them geographically is complicated by elevation. Any regions between the latitudes 38-45° could well be examined. This includes the Mediterranean basin to a line across the South of Europe excluding the Anatolian plateau, parts of South America, South Africa and Australia. Locations in much lower latitudes but a high altitude could be considered. It is important to get a more precise idea of these boundaries and a proposition appears in Appendix 1.

Within these areas there is room for more adaptable varieties just as there are soil-climate interactions which also alter the broad lines.

Economic Feasibility

This consideration is much more complicated and can be considered in terms of soil features, extent and reliability of rainfall and the relative importance of income sources. Ultimately, it is necessary to reach this decision in the specific location and after a consideration of these matters, but some of the considerations which would be likely follow.

With respect to soil features, depth and water storage capacity would be important. In a relatively low rainfall area where there is deep soil with good water storage capacity, substantial yield advantages may arise from water stored by summer fallow and this system could be preferred. Where the rainfall pattern is variable and drought frequency high it is difficult to get consistent results. Where rainfall is high (greater than 500 mm) and reliable, especially if soils are deep and fertile, there could well be more lucrative alternatives. The question of source becomes obvious if there are alternative crops which exceed the return likely from the grazing animal.

The programme in Tunisia is based on two assumptions:

- a. that the system was technically feasible and socially possible in a large part of the cereal zone, and
- b. that the system was good for Tunisia in that the dominant forms of agricultural production in this zone could be produced better within a crop-pasture system than in a crop-fallow system.

There was sufficient justification to make these assumptions in Tunisia because a careful evaluation of environmental features had been made and because wheat and meat are important commodities. While the assumptions are justified in Tunisia, they may not be elsewhere unless the same examinations are made.

Appendix I. PROJECT TO DEFINE WHEAT GROWING AREAS WHERE ANNUAL FORAGE LEGUMES ARE LIKELY TO GROW SATISFACTORILY

A programme to grow a tester set of annual forage legumes is envisaged. Sites would be selected throughout the rainfed wheat regions of the world regardless of the parameters discussed above. For practical purposes the set would probably best be planted at sites where an international wheat nursery is located.

The set would comprise approximately 15 entries with sufficient seed to plant approximately 25 sq. metres at a higher seeding rate than would normally be used in the establishment of a pasture in an area where it was possible to succeed. To avoid inoculation and establishment problems, the seed would be pre-inoculated with the correct bacteria and lime coated to form a pellet. The seed samples would be vacuum packed and the set of packets packed for transport in a simple polystyrene container. The planting procedures would be extremely simple and could be done by hand or machine. The only fertiliser requirement would be phosphate.

Very simple observations would be sought and relating to establishment, flowering date, seed yield and re-establishment pattern.

This simple nursery would immediately add to the information concerning areas where the system is technically feasible.

Appendix II. HARD SEED COAT

Seed coat impermeability is the most important of the dormancy mechanisms controlling the germination of annual forage legumes. The impermeable seeds are most commonly called "hard seed".

In practice impermeable seeds do not absorb water and hence do not germinate. Softening of hard seeds is brought about in natural conditions by the daily alternating temperature cycles whereas in artificial conditions it can be brought about by several means of which scarification is the commonest. The rate of softening varies between genera, species, varieties and with environmental temperatures. Medicago species generally soften at a much slower rate than Trifolium species and compared with other legumes can be regarded as being extremely hardseeded. Low seed moisture content and its relation to low relative humidity is important in the development of impermeability and so also is the adequacy of soil moisture as the plants mature.

Hardseeded characteristic is important for the proper manipulation of the legume-crop rotation system to prevent total germination with out of season rain in the summer, and to allow regeneration after the cropping phase.

TILLAGE AND OTHER AGRONOMIC PRACTICES IN THE WHEAT-FALLOW CROPPING SYSTEM

Floyd E. Bolton

Tillage and Moisture Conservation

Quite often when the climatic conditions of the Central Plateau of Turkey are discussed the question of water for irrigation is posed. This question can be answered by saying there is little or no possibility for additional water, except perhaps in limited areas, leaving several million hectares still dependent upon rainfall.

When the fallow-wheat cropping system is described wherein half of the land is idle for about a 14-month period, a second question usually arises concerning annual cropping versus fallow-wheat cropping. There are several areas of the world where an annual crop of wheat is produced on 400 mm or less annual rainfall, for example, Australia, but good distribution of rainfall during the critical growth periods is a prerequisite. In parts of the Pacific Northwest of the U.S. where annual rainfall ranges between 400-450 mm, a wheat-green pea-fallow sequence is used which produces two crops in three years. However, in this instance special harvesting, processing and marketing procedures for the green pea crop have been developed. Developing countries at present are primarily concerned with basic food crops and cannot afford the resources for speciality crops.

In regard to wheat production in the Central Plateau, the data in Fig. 1 show the general situation that confronts efforts to produce an annual wheat crop. Consumptive use data collected in the past indicate a water use in the range of 380-520 mm. The data in Fig. 1 show a C.U. of 345 mm for the average yield of 2.2 ton/ha, which is the present yield level in the fallow-wheat system. Under local climatic conditions in a 400 mm annual rainfall situation only about 260 mm of water are available to the crop. Present data indicate that this amount of water would produce 500 kg/hectare or less. Using these same data it is estimated that at least 530 mm or more is required before annual cropping would produce the same yield level of 1.2 tons/hectare now obtained under a fallow-wheat cropping system. To obtain a yield of 2.5 tons/hectare under an annual cropping system it would require about 630 mm annual rainfall. Since most of the wheat producing area of Turkey receives 450 mm or less annual rainfall, it is obvious that an annual cropping system faces a serious moisture deficiency.

The only alternative then appears to be the present fallow-wheat cropping system. The fallow-wheat system is often criticized because of the inefficiency of moisture stored during the fallow period. Fallow efficiencies generally range between 15% and 30% of the annual rainfall. However, the data in Fig. 2 show that if the water is used efficiently, the potential yield level is quite satisfactory. Past research in the Pacific Northwest of the U.S. has shown that approximately 100 mm of available water is required to grow and maintain the wheat plant. After this maintenance level is satisfied, each additional 10 mm of available water has the potential to produce 150 kg/ha of grain. Using these data, 300 mm of available water will produce about 3 tons per hectare grain. The data in Fig. 2 demonstrate that about 432 mm of water are required to produce 3 tons per hectare of grain, indicating the water use efficiency in the Central Plateau of Turkey is somewhat below that

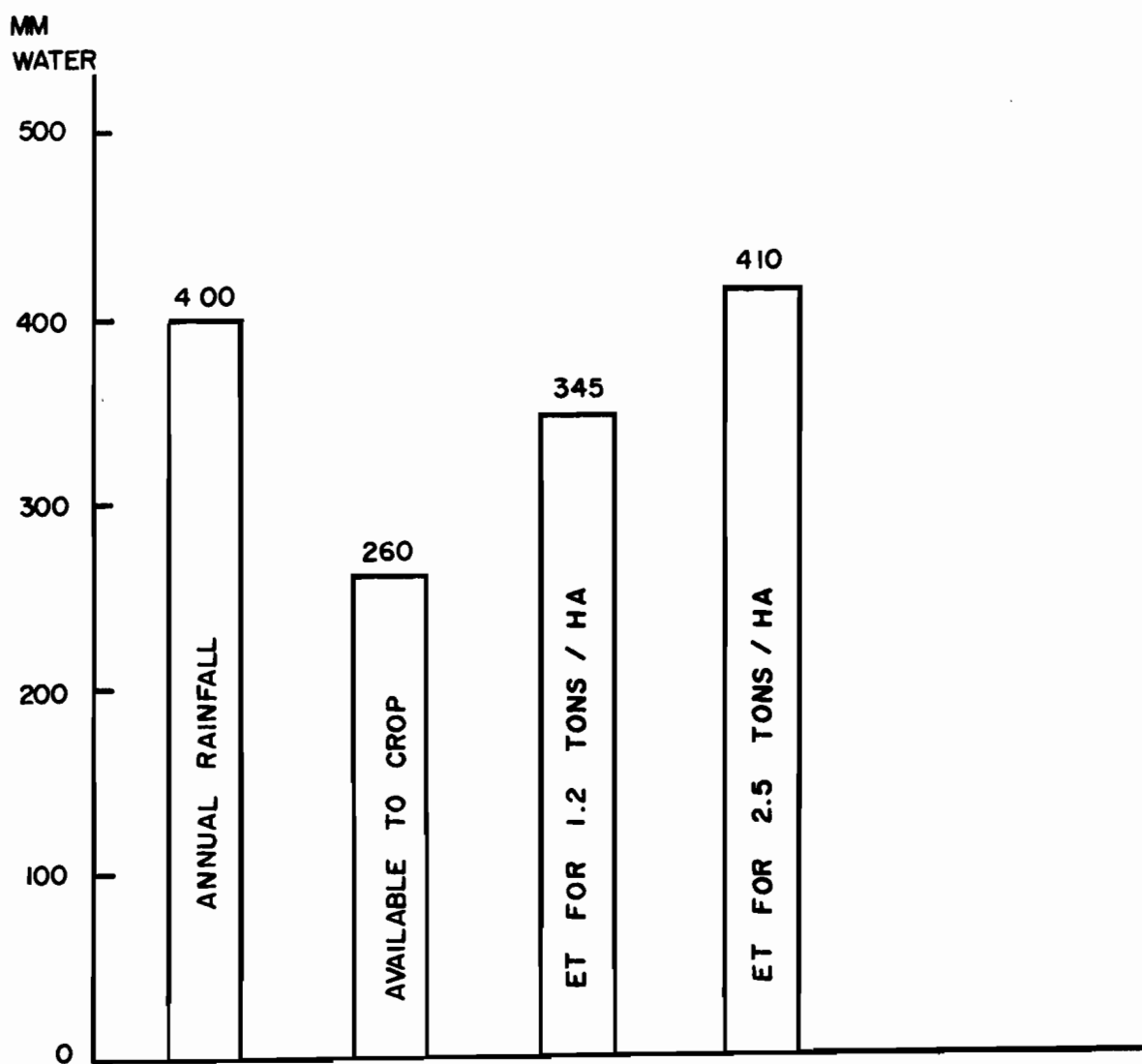


FIG.1 ANNUAL CROPPING - WATER SUPPLY AND YIELD
POTENTIAL IN CENTRAL PLATEAU OF TURKEY

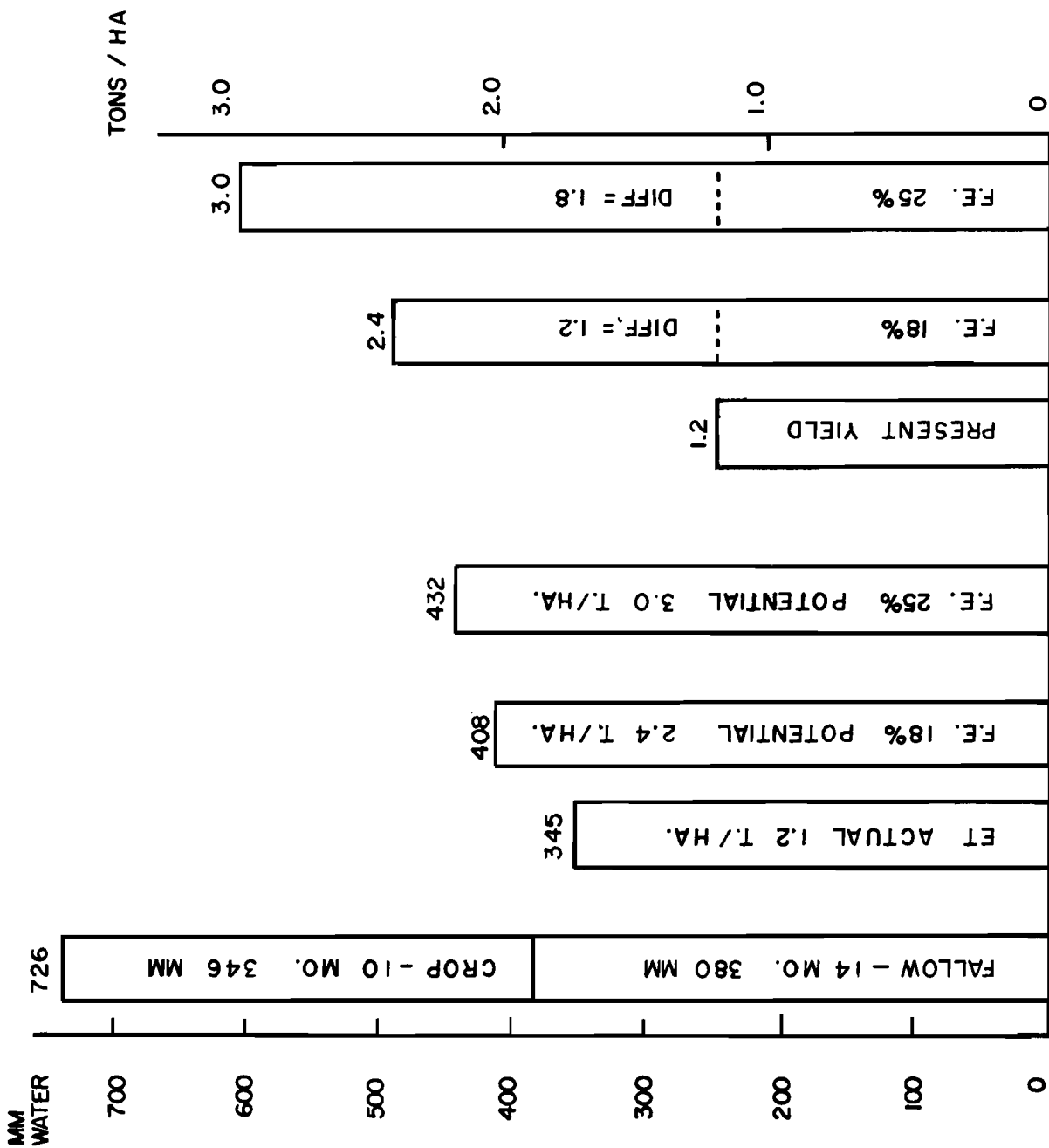


FIG. 2 FALLOW - WHEAT SYSTEM - WATER SUPPLY AND YIELD POTENTIAL IN CENTRAL PLATEAU OF TURKEY

achieved in the Pacific Northwest of the U.S.

The main significance of these data is that the potential yield level is much greater than is presently being achieved. In fact, on the basis of available water, there is a potential yield level of 2.4 tons per hectare under the present tillage system, which has an average fallow efficiency of 18%. This is double the present yield level and indicates that the present water use efficiency is very low. An increase of the fallow efficiency of only 7% (F.E. 25%) is sufficient to produce 3 tons/ha of grain.

The various tillage trials conducted over the past two fallow-wheat cycles (1969-71 and 1970-72) have demonstrated the possibility of improving the fallow efficiency. A successful fallow management system not only increases moisture conservation in the soil profile but also maintains the moisture close enough to the surface to permit seeding into the residual moisture. This would permit stand establishment independent of fall rains and before cold weather forced the plants into a dormant state. In field research in Turkey the tillage combinations which were successful in this regard gave excellent results with yields ranging from 3 to 4 tons/ha.

Several tillage combinations appear to be successful in the fallow management phase, but it must be recognized that only two fallow-wheat cycles have been studied. At this point it seems likely that several different combinations could be used to achieve the same soil surface condition. There are some special problems posed by the high clay content of the Anatolian Plateau soils which are likely to require tillage practices differing from the standard practices used in other fallow-wheat areas of the U.S.

In general the tillage research trials during the fallow period have shown that:

1. Fall tillage such as chiseling (25-30 cm deep) or subsoiling (50 cm deep) have not shown any consistent advantage over no tillage in the fall.
2. In the initial spring tillage the moldboard plow and offset disk plow show an advantage over the sweep plow which may be due to better control of cheatgrass (Bromus spp.) and slightly deeper tillage depth of the former two implements.
3. The sweep-harrow combination and sweep with a rodweeder attachment have consistently given better results than the rodweeder alone when used for summer weed control and maintenance of the soil mulch.
4. In those treatments where moisture was not sufficient, but a good seedbed existed, the first significant rainfall was enough for germination and emergence. This finding demonstrates that even though surface moisture is not sufficient for germination, a good seedbed with moisture at 20 cm is superior to the traditional, cloddy seedbed in which moisture is found at 30 to 40 cm.

5. From the results above it appears that the moldboard plow, sweep plow and spike-tooth harrow used in proper manner and sequence would do a satisfactory job of soil management in most of the Central Plateau.

AGRONOMIC PRACTICES IN THE WHEAT-FALLOW CROPPING SYSTEM

Although tillage practices for maximum moisture conservation have given a yield potential of 3 tons/hectare based on water availability, the job is only half finished. The next step is to maximize the water efficiency of both the stored moisture and the rainfall during the crop growth period. A series of agronomic trials were conducted in sites adjacent to the tillage trials at each location during the fallow-crop period of 1970-72. The trial land was prepared using the best treatments from the adjacent tillage trials, and would be equal to the better soil management treatments with respect to moisture availability and soil surface conditions. The data from these trials are being used to determine the best crop management practices to give maximum utilization of the available moisture.

Date and Rate of Seeding Trials

With resent cultural practices, the cold and relatively dry fall conditions make germination, emergence, and stand establishment, before the winter season very difficult if not impossible. In some years, fall rains occur early enough for stand establishment in October but this situation is very unpredictable.

The present practice is to plant in mid-October if fall rains have produced enough moisture for germination or to delay until late October or early November and seed into dry soil hoping for rains to begin soon. In many instances, the first fall rains are used to make final seedbed preparations, further delaying the time of seeding. Earlier planting into residual moisture conserved from the fallow period appears to be a more dependable practice. The data in Fig. 3 show an average increase in yield due to early seeding (September) of 415 and 740 kg/ha over the medium (October) and later (November) seedings, respectively. The time from seeding to emergence is an important factor, particularly in the later dates of seeding. In these trials the average time from seeding to emergence was 9, 13, and 27 days for the September, October, and November seeding dates, respectively. Seeding rates affected yields less than seeding dates. The 60 kg/ha seeding rate was inferior to the 90, 120, 150 kg/ha rates; however, the 3 higher rates were about equal.

Nitrogen Fertilizer Trials

The lack of response to nitrogen fertilizers has been the most outstanding feature of trials conducted in the Central Plateau in past years. Possibly the reasons for this are (1) cultural practices limit the yield to a level where the nitrogen accumulated from the breakdown of organic matter during the fallow is sufficient to supply the crop needs and (2) in years when moisture conditions are good, the old varieties lack yield potential or lodging resistance and are unable to utilize the increased moisture supply. Some recent information indicates that nitrate accumulation from the fallow is sufficient to produce

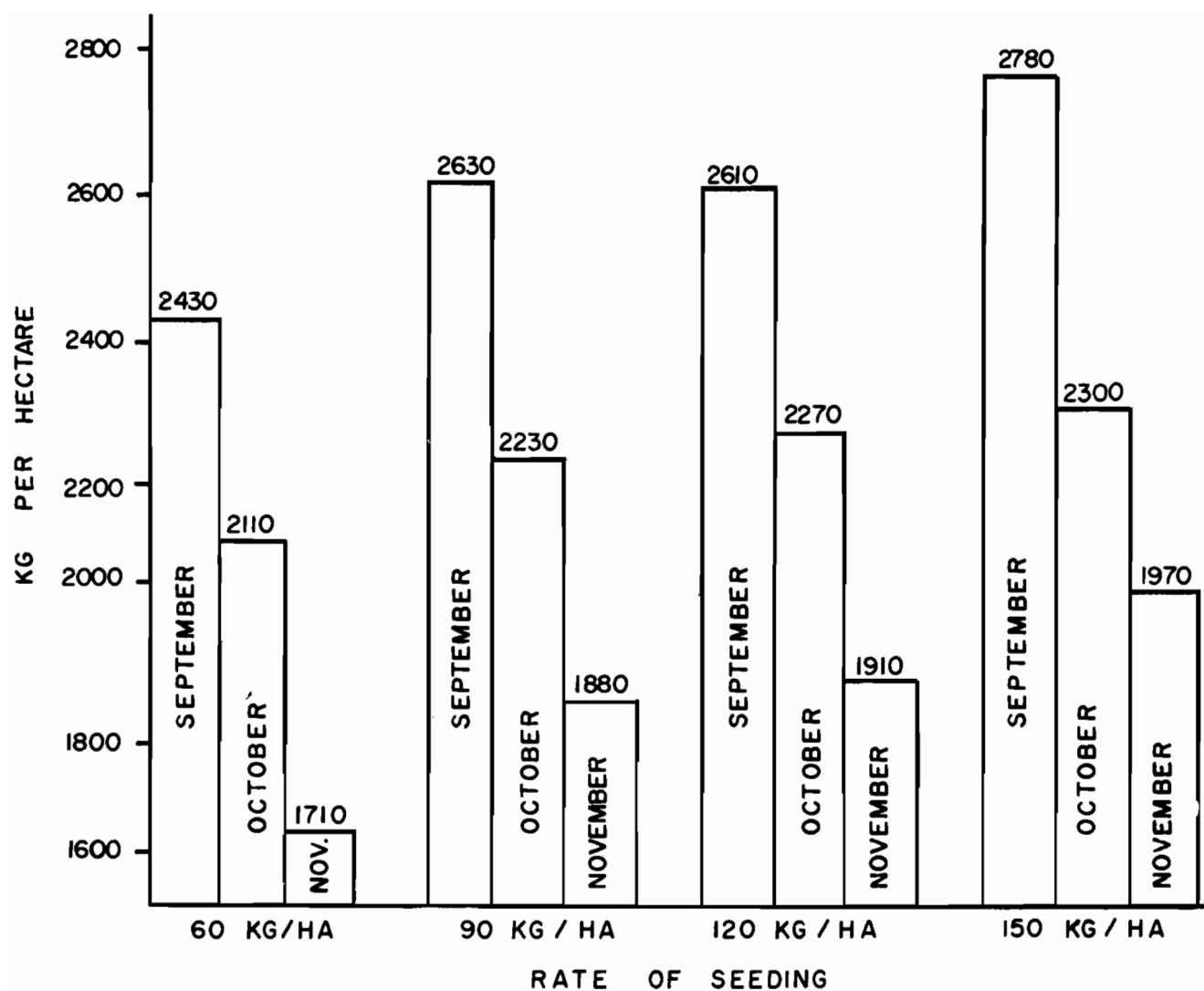


FIG. 3 EFFECT OF DATE AND RATE OF SEEDING ON GRAIN YIELDS AVERAGED OVER TWO LOCATIONS IN CENTRAL PLATEAU OF TURKEY. DATE OF SEEDING IS GIVEN ON EACH BAR.

1.5 to 2.0 tons per hectare. With the present yield level in that same range, no response to added nitrogen should be expected.

The data in Fig. 4 give the response to nitrogen at two yield levels. At Altinova, the improved varieties responded up to 40 kg/ha whereas 220/39, a tall local variety, did not. This variety lodged severely at nitrogen rates of 40 kg/ha and above. At Polatli where the yield level was low, there was little or no response to added nitrogen.

Fig. 5 gives the results of a time of nitrogen application trial which again shows a response up to 40 kg/ha of added nitrogen. Applying all of the nitrogen one month before seeding resulted in a slight decrease in yield compared to the split applications. These data may not be representative because the spring of 1972 was prolonged and wet, thereby giving an unusual advantage to the **spring** applied nitrogen. For example, at Polatli State Farm the rainfall in May and June totaled 163 mm compared to the long term average of 69 mm.

Weed Control Trials

Herbicides have been used in Turkey for weed control in wheat for the past 10 years or more. The phenoxy acids (2,4-D and 2,4,5-T) are used almost exclusively. These herbicides have done a creditable job wherever they have been applied; however, less than 20% of the wheat land is treated annually for control of weeds.

As has been the case in other areas there are problems which arise from the use of a single type of chemical over a period of time: (1) there are species which are not susceptible to the material from the beginning, and (2) as susceptible species are controlled other species, often more aggressive and difficult to control, begin to take over. The data in Fig. 6 show the advantage of weed control versus no-weed control and also the advantage of materials which control a wider spectrum of weed species.

Using only the phenoxy materials, better control of weeds could be achieved with more timely application. Quite often herbicides are applied only after the weed problem has become apparent and visible. The data presented below show the advantage of more timely application of the currently used herbicides:

<u>Material</u>	<u>Year</u>	<u>Date of Application</u>	<u>Yield, t/ha.</u>
Tribution	70	March 26	2.70
"	70	April 30	1.96
"	71	April 6	1.90
"	71	May 1	1.10

Even though the phenoxy materials require relatively warm temperatures to be completely effective, that is, complete kill of susceptible species, the early treatments effectively reduce competition through severe stunting or retardation. In areas where water availability is the primary limiting factor, this reduced competition becomes increasingly important.

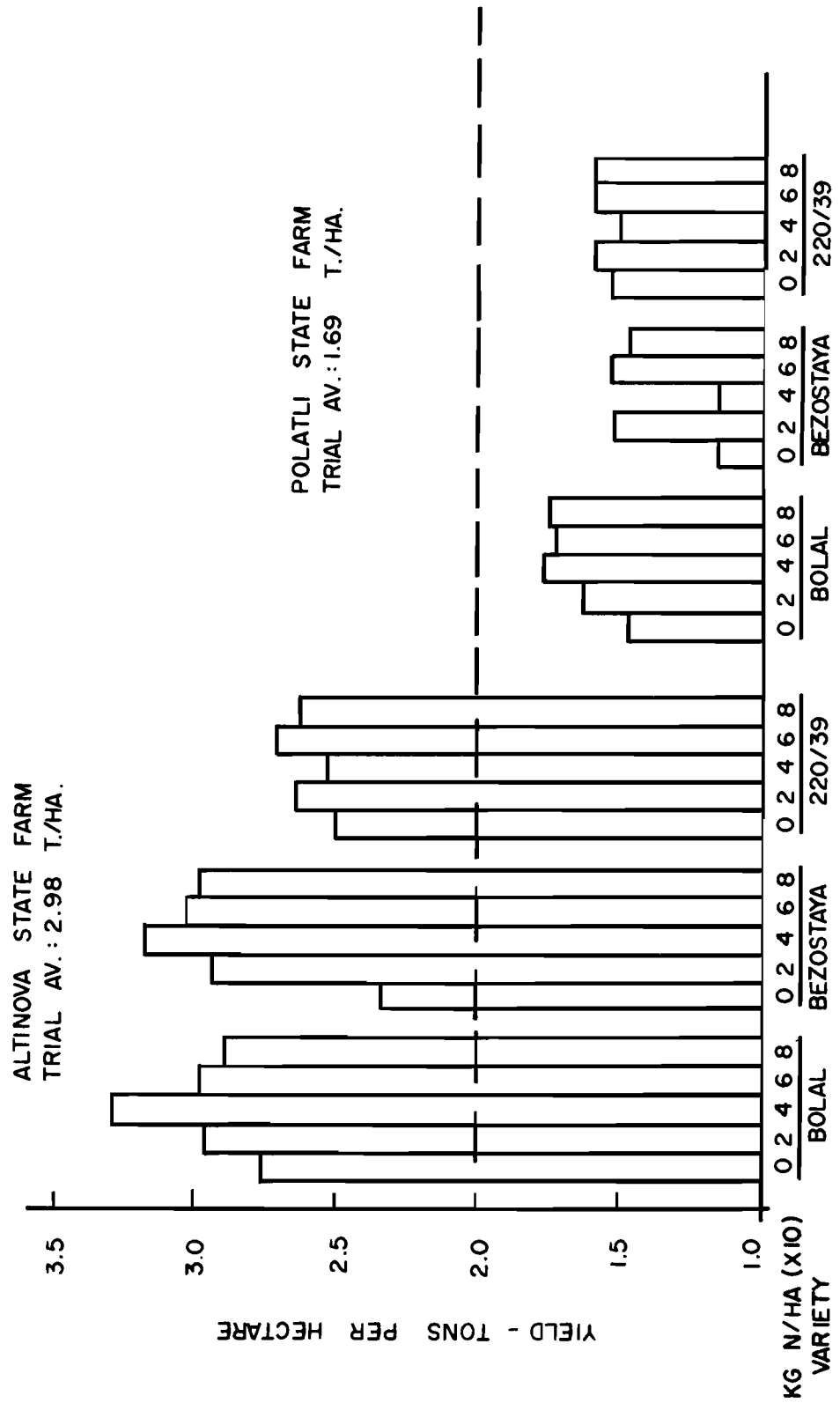


FIG. 4 EFFECT OF NITROGEN RATES X VARIETIES AT TWO LOCATIONS IN
CENTRAL PLATEAU OF TURKEY

FIG. 5 AVERAGE YIELDS IN A TIME AND RATE OF NITROGEN APPLICATION TRIAL.
AVERAGE OF 4 LOCATIONS IN THE CENTRAL PLATEAU OF TURKEY

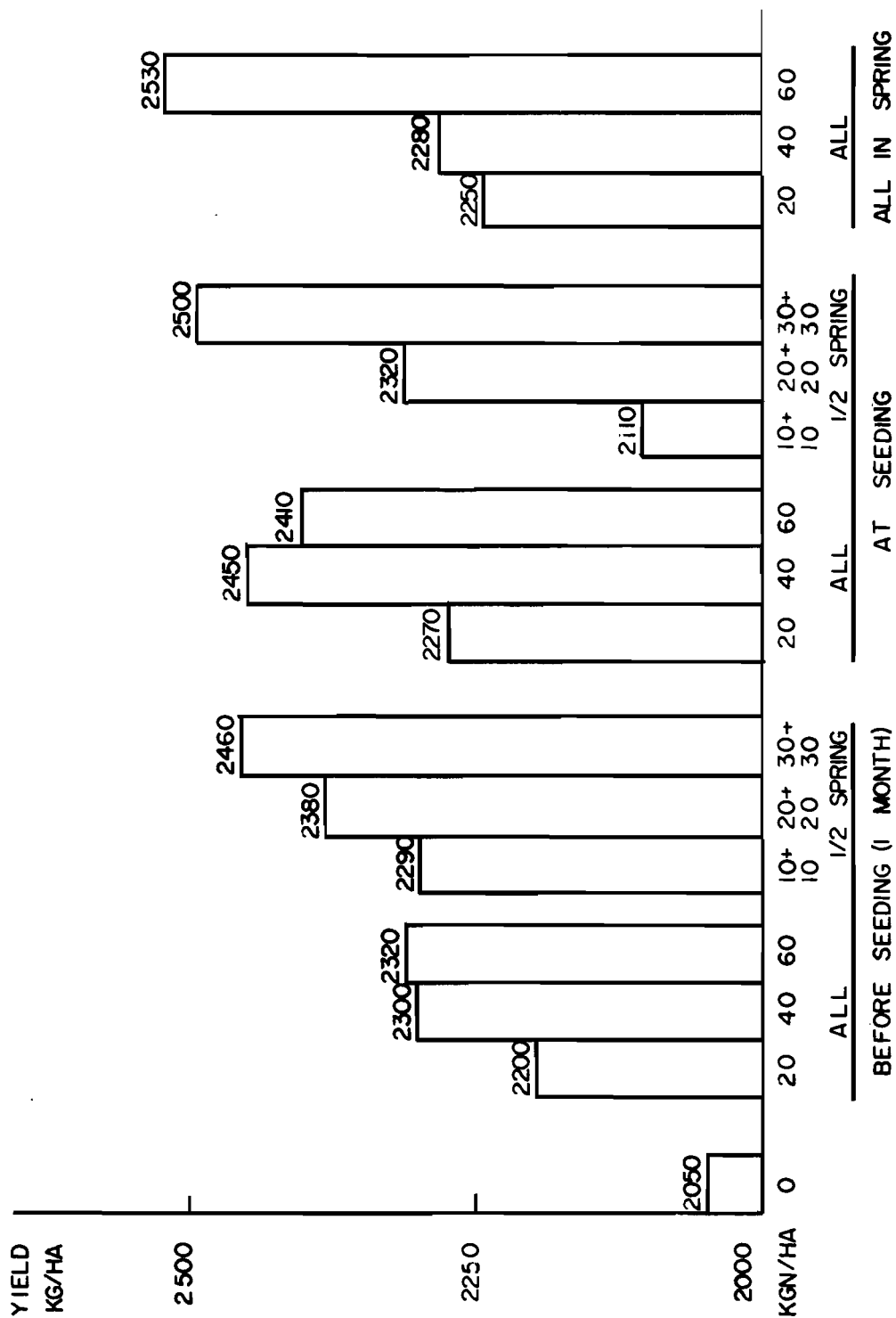
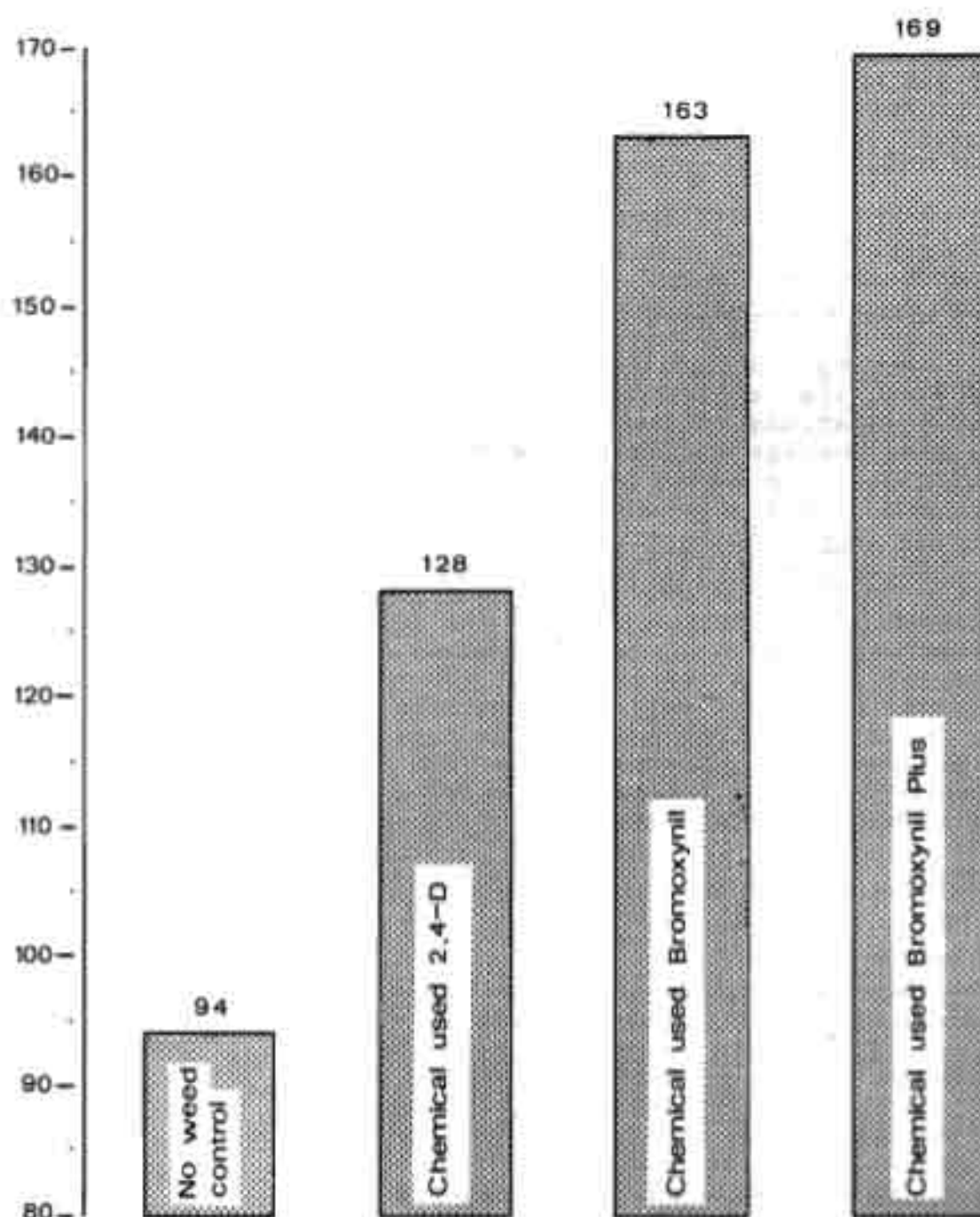


FIG. 6 USE OF HERBICIDES INCREASE WHEAT YIELDS IN TURKEY



SUMMARY

Since the availability of water is the primary factor limiting wheat yields in semi-arid areas, it is essential to gain maximum use efficiency of the limited resource.

Improved soil management to conserve moisture during the fallow and create conditions suitable for seeding at a optimum date appears to be the key to increasing and stabilizing yields. However, unless equal attention is given to the management of the crop itself, the initial effort may be wasted. The value of each individual input in a fallow-wheat production system is very difficult to determine. Often the various components complement each other and together give yield increases greater than the sum of the individual parts.

The production scheme shown in Fig. 7 is based on field research data; however, the values for each component are average yield increases found in separate trials. The potential yield level of 3.0 tons/hectare is based on the average moisture conditions found in Central Turkey. Within a given fallow-crop cycle the climatic conditions often vary widely. During the past four years, which covers two complete fallow-crop cycles, yields of 3.0 tons/hectare or more have been recorded at each of 4 locations in the various tillage or agronomic trials. In some cases, average yields of individual treatments have been up 4.0 tons/hectare. Our experience indicates that 3.0 tons/hectare under average conditions and perhaps at least 2.0 tons/hectare under adverse conditions appear to be attainable yield levels. It is not meant to imply that such a wheat-fallow system for the Central Plateau is now ready for implementation. These data represent only two sets of growing conditions. In addition, some of the equipment used is not locally available and would need to be imported or manufactured in Turkey. The data merely indicate the potential yield level under normal moisture conditions in a relatively confined area. Further testing under actual farmer field conditions needs to be done before reliable recommendations would be possible. However, these data indicate that substantial improvement over the present yield level is possible and within economic limits of many Turkish farmers.

DISCUSSION

Sadek

Our experiments show that the optimum level of fertilizer application for short, dwarf wheats is about 168 kg N/ha plus 54 kg P₂O₅/ha. This season we grew about 60,000 acres of the dwarfs with this recommendation on fertilizer rates.

Carter

In the wheat-fallow system, one precaution should be considered. In Montana we have many acres of saline-seep areas that developed after many years of practicing this system. You can do too good a job of preserving moisture, so you must take a look at the profile and see if there is an impervious layer underneath. If there is, the water will begin to move laterally, bringing the salt out on the surface. Several thousand acres have been ruined where the profile will not allow the

CENTRAL PLATEAU OF TURKEY
350-400 MM ANNUAL RAINFALL

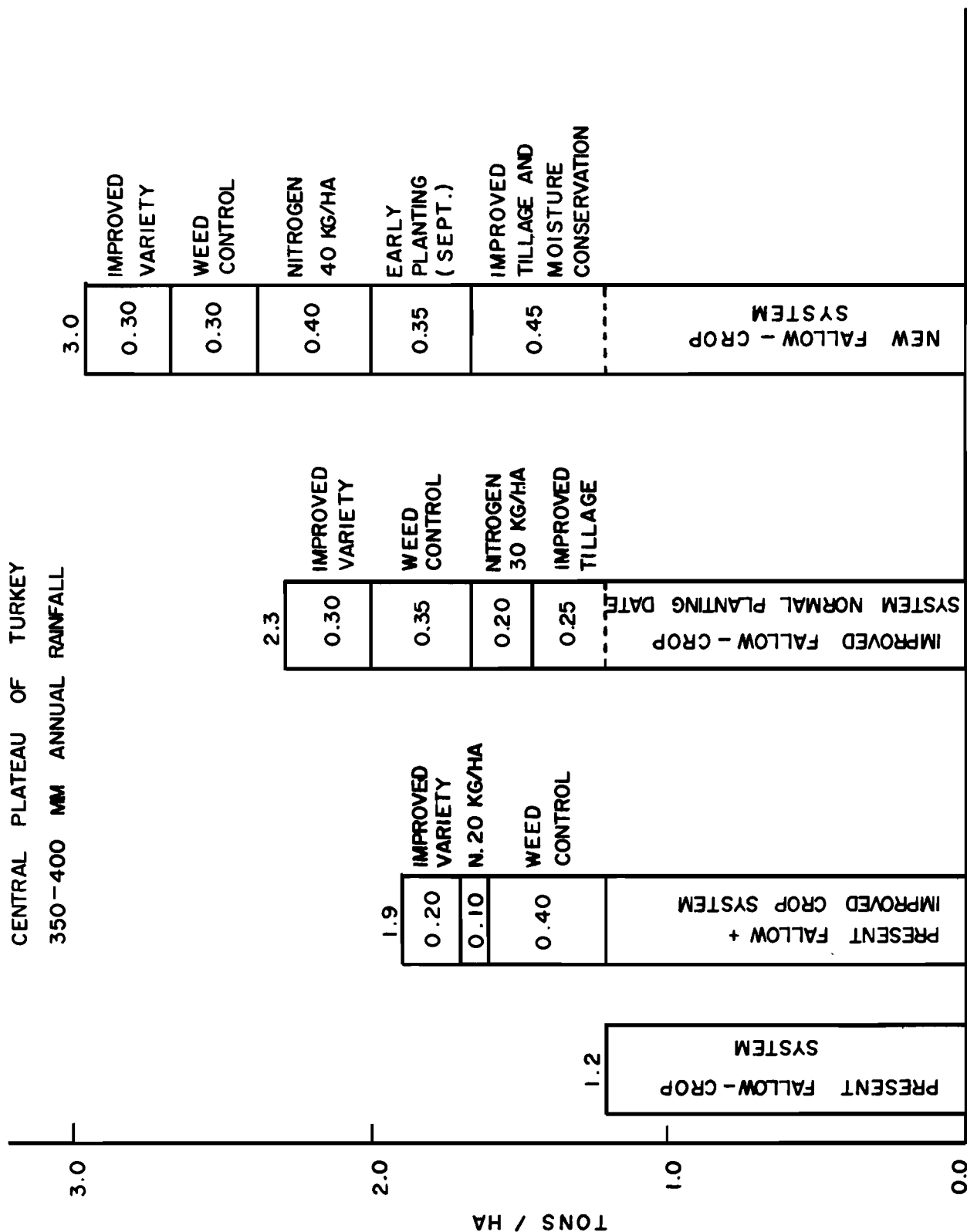


FIG. 7 TILLAGE AND AGRONOMIC PRACTICES FOR A WHEAT-FALLOW SYSTEM IN THE
CENTRAL PLATEAU OF TURKEY

accumulation of moisture in the subsoil. There are many areas where this is not a problem, but I feel you have to look at the full profile.

Nelson

In Montana, there is an entirely different moisture regime than that in North Africa. In Montana, rains are primarily in spring and summer, or a more even distribution of moisture. In North Africa, we do not get a large accumulation if we have an effective rooting zone to use this moisture. If above the impervious zone we have 1 to 2 1/2 meters of soil, the plants remove all the water. I suggest we do not use this system with less than one meter of soil.

Smith

In 1969 in Minnesota and North Dakota, there was little semi-dwarf wheat. However, we have been experiencing a revolution there, too. In 1972, about 75% of the wheat in Minnesota was dwarf. A large portion of this was Era, from the University of Minnesota, and also a variety released by a commercial seed company. In North Dakota, adjacent to Minnesota, dwarf wheats cover about 20% of the wheat area. Most of this is in the heavily producing area of the Red River Valley. The fertilizer usage has markedly increased. Some farmers are using 100 pounds N/acre whereas prior to the semidwarfs, about 50 pounds was maximum. Yields of 80 bushels are not uncommon with semidwarfs. Preliminary quality data show protein quality equal to conventional types. We felt there might be a quality reduction, but the increased use of N evidently has offset this.

Fischer

I feel that we will always deal with a water problem in Dr. Wright's part of the world. This will not be eliminated as a main limiting factor, yet N can also be a limiting factor in these situations. It seems to me that we pushed aside the work on nitrogen-water interaction--the sort of work that Ken Wilhelmi has been doing in the drier parts of Tunisia or Fran Bidinger in Morocco where they gauge the N recommendation in terms of the water available to the crop. This seems to me to be an important area.

Wright

I did not mean to imply that N is not a limiting factor in many situations, even under low moisture conditions. In the data from the Soil and Fertilizer Institute I mentioned, the range of values they obtained was about 10 kg N/ha at 150 mm of moisture up to 70 kg N/ha. Further, we would like to do in Turkey what has been done in the Pacific Northwest (U.S.A.), that is, develop a system for N recommendations based on the yielding capacity of the soil and the amount of moisture available to the soil. What they have done over a long period of years and with a mass of data is to work out a correlation between the yielding ability and depth of the soil by making N measurements throughout the rooting zone of the soil in the spring and also by making moisture measurements throughout the root zone in spring; they can then predict how much N should be added to give a specified yield. Thus, in one year you may add 40 kg N/ha and the next year, if it is dry, not add any N. The three pieces of data are needed, but we hope one day to be able to provide this service to the farmers.

DEVELOPING HERBICIDE PRACTICES FOR WHEAT IN TUNISIA

Torrey Lyons

Our weed control program in Tunisia is presented as a starting point for the discussion of the role of herbicides through the 1970's.

Weeds are a serious problem in Tunisia. There are at least 30 broadleaf species of economic importance. However, 3 grass weeds cause even greater losses. Wild oats is the most damaging, although rye grass appeared to be equally harmful last season due to the resulting increased lodging of the wheat. Canary grass is also damaging but the area of heavy infestation is limited.

Weed infestation tends to be high as a result of inadequate tillage. The most severe yield reductions occur where weeds survive the preplant tillage. However, even on well-managed farms, damaging weed infestations occur which require herbicide application for control.

Our weed control effort consists of demonstrating better tillage practices and a herbicide program which includes demonstration, and a program of experimentation. We enjoy cooperation with the two Tunisian agencies involved with weed control: the National Agricultural Research Institute of Tunisia (INRAT) and the Plant Protection Division (Défense des Cultures). We also work with the Belgian agricultural aid mission and agricultural chemical supplier.

Two years of experimentation with herbicide has been completed. Our objective has been to choose the most promising materials for evaluation and then concentrate on learning to make effective use of the few which appear to be best. Three types of trials have been conducted: wild oat control, broadleaf weed control, and a study of the most profitable use of 2,4-D.

For the experimentation we use a bicycle wheel sprayer with a 3-meter boom and a Wintersteiger harvester with a 1 1/2-meter cut. Trials are laid out with nontreated strips on each side of all treated plots to aid in weed control observations. Conditions at the time of each application are recorded and a composite soil sample from each trial site is collected. Analytical work is provided by the FAO soil laboratory.

RESULTS

Comment on wild oat herbicides evaluated

<u>Dicuran</u>	(80% wettable powder of chlorotoluron) 2.4 kg of active ingredient per hectare at the 3-leaf stage. Fair control of wild oats, rye grass and good control of most of the important broadleaf weed species; expensive; phytotoxicity is a problem.
<u>Dozanex</u>	(80% wettable powder of Metoxuron) 4 kg of active ingredient per hectare at the 3-leaf stage. Fair control of wild oats, rye grass and most of the important broadleaf species;

expensive; phytotoxicity is a problem.

Suffix (20% emulsifiable concentrate of Benzoyl-Prop. Ethyl) 1.25 kg of active ingredient per hectare at the 6-leaf stage of wheat and completion of tillering of the wild oats. Dependable control of wild oats; however, a second herbicide application may also be needed because only wild oats are controlled. Two, 4-D should not be applied within 10 days before or after the Suffix application. Suffix is expensive.

Avidex (46% Triallate) Not promising in our trials because of severe phytotoxicity, inconsistent control and the necessity of soil incorporation.

Carbine (11.8% Barban) Not promising in our trials because of phytotoxicity and the requirement of precise timing of the application.

Comment on broadleaf herbicides evaluated

2,4-D (64% emulsifiable concentrate of methoxy butanol low volatile ester) 0.55 kg of active ingredient equivalent per hectare at the start of jointing. The practice is established; cost is low and a broad spectrum of broadleaf weeds are controlled; however, phytotoxicity may be a problem if 2,4-D is applied before the jointing stage.

MCPA (47.3% equivalent emulsifiable concentrate of low volatile ester) 0.55 kg of active ingredient equivalent per hectare at the end of the tillering stage. Slightly less phytotoxic than 2,4-D with a similar range of broadleaf weed control; slightly more expensive.

Buctril (34% emulsifiable concentrate of Bromoxynil) 0.41 kg of active ingredient per hectare at the 4 1/2-leaf stage. Can be used earlier than 2,4-D but is often phytotoxic and some important broadleaf species are not controlled.

Bronate (21.9% Bromoxynil + 21.9% MCPA emulsifiable concentrate) 0.41 + 0.41 kg of active ingredients per hectare at the 4 1/2-leaf stage. Can be used earlier than 2,4-D and the spectrum of broadleaf weed control is as wide; may be phytotoxic

Tribunil (70% wettable powder of metabenzthiasuron) 1.95 kg of active ingredient per hectare at the 3-leaf stage. Can be used early without phytotoxicity; ryegrass partially controlled and herbicidal activity against a wide range of broadleaf species; however the control was not as dependable as 2,4-D.

Igran (80% wettable powder of Terbutryne) applied at the 3-leaf stage. Used for canary grass control; not promising because of phytotoxicity.

Karmex (80% wettable powder of diuron) applied at the 3-leaf stage. Used for oxalis control; not promising because of phytotoxicity

ECONOMIC RESULTS

In the trials of the past season yield increases from herbicide treatment tended to be small because weed competition was not great. This was the result of good stands of vigorous wheat, moderate weed infestations and ample moisture due to the near-perfect distribution of rainfall. At most sites moisture stress did not occur at any time, with or without control of weeds. With a minimum of yield benefit as a result of weed control, yield reduction as a result of phytotoxicity was often revealed.

Table 1. Average yield for three wild oat trials, 1971/72.

Product	Kg AI/ha	Stage	q/ha
Dicuran	2.4	1 leaf	27.6
Dicuran	2.4	3 leaves	28.9
Dicuran	2.4	4 1/2 leaves	28.8
Dicuran	2.4	6 leaves	27.3
Dozamex	3.2	3 leaves	26.5
Suffix	1.5	4 1/2 leaves	29.2
Suffix	1.5	6 leaves	29.0
Check			27.3

The most striking feature in this table is the economic loss. The cost of each treatment is 12 to 14 dinars per hectare, approximately 25 dollars, the value of 3 quintals of wheat. In no case was there a statistically significant yield increase which resulted in economic gain. However, there were statistically significant yield reductions.

Table 2. Wild oat trial, Ebba Ksour, 1970/71.

Product	Kg AI/ha	Stage	q/ha
Dicuran	2.4	1 1/4 leaves	21.1
Dicuran	2.4	3 leaves	22.4
Suffix	1.5	4 leaves	15.3
Suffix	1.5	6 leaves	18.9
Check			15.1

The results of this trial of the preceeding season illustrate the striking difference in the biological and economic results we may encounter from one year to the next under rainfed conditions. In this trial, high moisture stress developed as the grain was filling and there

were substantial yield increases. Average yield increases of this magnitude or more will be necessary to finance practices which cost the equivalent of 3 quintals of grain.

Table 3. Average yield, six broadleaf trials, 1971/72.

Product	Kg AI /ha	Stage	q/ha
Dicuran	2.4	3 leaves	37.8
Dozamex	3.2	3 leaves	38.5
2,4-D	0.55	6 leaves	37.1
MCPA	0.55	4 1/2 leaves	36.1
MCPA	0.55	6 leaves	38.6
Buctril	0.41	3 leaves	36.5
Buctril	0.41	4 1/2 leaves	37.8
Bronate	0.41 + 0.41	4 1/2 leaves	37.2
Tribunil	1.95	3 leaves	40.3
Check			37.9

Last season's broadleaf weed control trials also illustrate failure to achieve economic gains under conditions of minimum damage from weed competition and phytotoxicity of herbicide treatments. Significant yield reduction at the 5% level occurred at least once with each treatment except MCPA at the 6-leaf stage, Tribunil and Dozamex treatment often resulted in phytotoxicity symptoms.

Tribunil was the highest or second highest yielding treatment in each trial and always equal to or better than the check. In the ratings of species controlled and in general appearance of weed control it was inferior to all herbicides except Buctril. Was the relatively good yield performance the result of consistent phytotoxicity of the other treatments or of a beneficial growth regulator effect?

Study of 2,4-D Phytotoxicity

Because severe ear distortion has resulted from recommended applications of 2,4-D, trials were conducted to learn if yield effects may be involved. Methoxy butonol low volatile ester at 0.55 kilograms equivalent active ingredient per hectare was applied at 6 different stages of growth on 3 varieties. The varieties were Soltane or Zaafrane, Inia and Jori chosen to represent high, medium and low sensitivity to 2,4-D based on preceding observations of ear distortion. The stages of growth were (1) 3 leaf, first tillers beginning to appear above the soil surface, (2) 4 1/2 leaf, maximum rate of tiller production, (3) 6 leaf, tillering completed but joints not yet formed above the soil surface, (4) jointing, one or two joints above soil surface, (5) boot stage, and (6) flowering stage. A hand-weeded and a nonweeded check was used.

In the 3-leaf treatment "onion leaf" symptoms appeared in all varieties. Severe ear distortion appeared in Zaafrane or Soltane and

Inia, but none in Jori. In the 4 1/2-leaf treatment a small amount of onion leaf appeared in Zaafrane or Soltane, a trace in Inia and none in Jori. Again, severe ear distortion appeared in both Zaafrane or Soltane and Inia but none in Jori. In the 6-leaf treatment medium to severe ear distortion appeared in Zaafrane or Soltane, slight ear distortion in Inia and none in Jori. Normal plant morphology developed in the later treatments except for sterility and upright rather than pendant ears.

Table 4. Average yields in quintals per hectare of 3 trials of 3 varieties treated at different stages of growth with 2,4-D at 0.55 kg a.i. per ha, 1971-72.

Variety	Stage of growth when treated*					Hand-weeded check	Non-weeded check
	3 leaf	4 1/2 leaf	6 leaf	Joint	Boot		
Inia	33.1	38.2	39.0	40.2	37.7	42.3	41.2
Soltane or Zaafrane	33.2	36.7	35.4	39.1	35.2	37.9	39.2
Jori	30.3	31.4	32.3	33.7	29.6	32.5	31.9

*Flowering stage yields omitted due to spray timing problems.

For each variety the optimum time of treatment was the jointing stage. The pattern of response differs for each variety. For example, yield of Inia and of Jori at the 6-leaf stage was not much less than at the optimum stage, but yield of Soltane or Zaafrane was considerably less at the 6-leaf stage than at the optimum stage. This difference is of economic importance because the 6-leaf stage has been a recommended time of spraying. If this is the normal pattern of response of these varieties, 2,4-D should not be used until after the growing point is above the soil surface. This limits the period of time available for the application and results in mechanical damage to the wheat.

FUTURE PROGRAM

In Tunisia we will continue to promote improvement in cultural practices and herbicide practices with equal vigor. Our most urgent need is control of wild oats and rye grass and an early broadleaf herbicide application as effective as 2,4-D but not phytotoxic. Our program of experimentation with herbicides has shifted to one of both experimentation and demonstration. The four types of experiments are: (1) evaluation of the most promising herbicides, including both wild oat and broadleaf herbicides in the same trials, (2) checking important and potentially important varieties for sensitivity to herbicides we expect will be used commercially. This will be accomplished by crossing both replications of our variety demonstrations with strips of herbicide treatment, (3) demonstration of the proper timing of 2,4-D application, and (4) demonstration of herbicide treatments of greatest potential commercial value. The herbicide demonstration trials are laid out in 50-meter

plots adjacent to our variety demonstrations. In addition to their extension function, they will provide data on the economic value of the applications, phytotoxicity and weed control effectiveness.

In a new environment we cannot take for granted the biological results or the economic value of herbicide treatments. Whether new or established, they must be checked on the farms under the normal range of local conditions. Neither can we assume that the response of new varieties will be the same as that of preceding varieties. As needed information is developed emphasis should shift from experimentation to demonstration as rapidly as possible.

My prediction for the remaining 1970's is that herbicides will become more important in increasing world production of wheat. CIMMYT agronomists will become more involved with herbicides, and perhaps geneticists. With increasing demand for protection of the environment it may be more expedient to develop varieties adapted to approved chemicals than to depend on development and approval of new chemicals for use on new varieties.

THE ROLE OF INSECTICIDES, RODENTICIDES AND PESTICIDES IN MAXIMIZING YIELDS AND PROTECTING THE CROP IN THE FIELD AND THE GRAIN IN STORAGE

Gonzalo Granados

INTRODUCTION

Insects similar to the species we know now were already on the earth 300 million years ago.

Out of approximately 1.2 million species of animals described so far, 686,000 or about 60% of them correspond to insects.

The predominance of insects in the terrestrial habitat is due primarily to their tremendous diversity and to their extraordinary ability for adaptation and reproduction.

All organisms are subjected to pressures which are typical of the environment in which they live. These pressures, which are physical and biotic, together with the genetic composition of each species regulate the existence and abundance of a given species in a given area or crop.

The outbreak of a given species up to the level at which it can do damage of economic importance, in most cases, is brought about by the action of man either voluntarily or involuntarily.

These actions can be summarized in three points:

a. Modification of the environment by destruction of forests and grassland and many other habitats, replacing them by highly specialized habitats in which one or only a few species of plants either native or introduced, are cultivated (many times only one variety). The species favored by this modification and which in many cases were previously of no economic importance, increase its population density to such an extent as to constitute serious pests.

b. Introduction of insect species from other areas without taking along their natural enemies. If the physical resistance of the new environment is less than in the original one, this particular species will become established and will constitute a serious pest.

c. The third factor that can contribute substantially to the development of severe outbreaks of insects in many crops is the establishment of economic thresholds progressively lower with the aim of obtaining products free of insect injury and of high quality. This has forced the grower to use more and more all sorts of pesticides and has brought about alterations in the ecosystem which in many cases have given rise to more important problems than the ones that were supposed to be solved.

These will become more and more acute because of the tremendous human population explosion which requires more food. This will force the governments and, of course, the growers to seek means of increasing production per unit area. This means among other things that more pesticides will be used with the aim of maximizing yields and that less damage will be tolerated before control measures are applied.

The unwise use (voluntary or involuntary) of pesticides can bring about several new problems:

1. Development of strains of pests resistant to pesticides.

It looks like a paradox that there is a very close association between the efficiency (killing power) of the pesticide and the probabilities of developing an insecticide-resistant strain of the pest. The more efficient the pesticide, the higher are the chances of developing a resistant strain. This is because a highly effective pesticide exerts a tremendous selection pressure by which only the individuals that are able to detoxify, all or in part, the pesticide, will survive. These survivors will interbreed and in a few cycles the farmers are faced with a highly resistant pest population.

2. Build up of some pest species at which the pesticide application was not actually aimed but whose natural enemies were destroyed by the pesticide.

3. Reinfestation by the same pest against which the pesticide was aimed.

This could come about because the pesticide killed the natural enemies of the pest and thus was able to build up in large numbers before the natural enemies could do so.

4. Pollution of the environment.

Then, if the use of pesticides in agriculture has all those disadvantages, why are they used? The question could be raised, aren't there other methods of pest control that could be as efficient as chemical control and less hazardous?

The answer to the first part of the question is yes. There are other methods of pest control.

The second part of the question has to be answered with a yes and a no.

The other methods of pest control are:

1. Natural control
2. Cultural control
3. Biological control
4. Resistant varieties
5. Legal control

All of them have their limitations and disadvantages.

Natural control. This type of control was included in this discussion just to be thorough. This type of control can hardly be modified by man, because it refers to the action of physical factors of the environment (temperature, humidity, light, etc.) which in one way or another influence the growth and development of the pests. Perhaps in the case of stored grain insects and fungi, the environmental

factors can be manipulated at will.

Cultural control. It refers to all the manipulation in planting dates, crop rotation, fall plowing, spring plowing, irrigation techniques, etc., that can be done in order to avoid, escape or minimize plant damage by a given pest. This method also has limitations because, for example, in areas where crops are grown under rainfed conditions, little change in planting dates is possible because the farmer has to plant when the rains come. Also, in areas where killing frost occurs late in the fall and early in spring, little planting date manipulation is possible. Crop rotation sometimes can be done and sometimes not. Fall and/or spring plowing helps to reduce some pest populations but not always below the economic threshold.

Biological control. This type of pest control refers to the use and manipulations of the natural enemies (parasites and predators) of the pest. There are a number of cases in which biological control has been quite effective, but also there are many in which it has been a failure. Some times it has been so because of lack of synchronization. For example, there are some pests that can feed and reproduce at low temperatures of 5°C, and the natural enemies do not start development until the temperature reaches 18°C. Therefore, by the time the natural enemies are numerous enough to efficiently control the pest, it has already done considerable damage to the crop.

There are also many pests for which no parasite or predator is known, at least at the present time, that can maintain the pest population under economic levels under any set of environmental conditions.

The use of resistant varieties. This is a method of pest control that presents many advantages and few disadvantages.

One advantage is that resistant varieties are cheap (it is not cheap to develop resistant varieties but it is cheap for the farmer). Another advantage is that it is fairly permanent; there are examples of resistant varieties which were reported 100 or more years ago as resistant, and still retain it. A very interesting characteristic of resistant varieties is that when planted in a large acreage, they tend to reduce the population levels of the pest. This is not true when the mechanism responsible for resistance is tolerance.

One disadvantage of resistant varieties is that in most instances the resistant variety is not necessarily resistant to all the biotypes of the pest.

Another disadvantage and certainly the most serious one is that it takes a number of years (sometimes ten or more) to develop a resistant variety, and what is worse in many cases, even at the present time, there are not known sources of resistance for many pests of economic importance.

The legal control. Relates to government legislation in the form of quarantines enforced by state or national officers with the aim of preventing the importation of pests that may be harmful to the crops in a given state or nation. This sounds fine and has done lots of good, but what about the pests that have already been introduced?

Because of the previous stated, it becomes evident that no control method alone will or can solve all the pest problems in a permanent way. Then, it follows that whenever a control method fails to give the needed protection, the farmer faces a dilemma—he allows the pest to destroy his crop and lets his economy go to pieces or else he uses pesticides which are the only control method that he can practically use at will and that can lower the pest population to a subeconomic level almost overnight.

Then, and based on the previous stated, it can be postulated that agricultural chemicals, even with all their disadvantages, will be used extensively to protect the crops in the field and the grain in storage, and that this will continue for a long time in the foreseeable future. However, much more research should be directed towards solving the disadvantages that agricultural chemicals have at the present time. The best way of doing this is to seek means of fully developing the concept of integrated control, which calls for the development of selective pesticides and for in-depth study of the ecosystem.

A white grub, together with wireworms and false wireworms, are responsible for extensive damage to small grain root systems and in the case of false wireworms, to the seed germ before germination, mainly in the areas where small grains are grown under rainfed conditions. So far, no resistant varieties have been developed for these pests, and even though natural enemies help to reduce these insects populations, in many cases they reach population levels well above the economic thresholds. This is where the use of the proper insecticides, in this case Aldrin or Dieldrin at a rate of 1 to 2 Kg. AI/Ha., could make the difference between a good crop or a complete failure. These insecticides should be applied at planting time and their insecticidal action lasts up to 3 years.

Cutworms. The cutworm larvae injures young plants by cutting off new tillers and leaves at slightly below or above the surface of the soil. Cutworms feed at night or on cloudy days. They are most active during warm nights following warm afternoons. Cold weather prolongs the feeding period of the larvae and also prevents rapid growth of the plants. This results in considerable injury to the crop. So far, no resistant varieties have been found and, therefore, this insect has to be controlled with insecticides.

Cutworms can be controlled by spraying Dieldrin or Aldrin, 1/4 to 1/2 pound of actual insecticide per acre, or Toxaphene or DDT, 2 pounds of actual insecticide per acre.

Armyworms are really climbing cutworms that attack wheat about the time it is heading. They feed on the leaves, kernels and beards of the heads and often cut off the heads. Since larvae feed during the day as well as at night they may be observed on the wheat plant feeding in groups of several to a plant. Armyworms can be controlled with Dipterex, 1 Kg. AI/Ha.

Grasshoppers. There are a number of species of grasshoppers which can injure small grains. Grasshoppers damage wheat mainly by eating the leaves and stems. Also, as the head stalks emerge, they climb to the stalks and chew into and sever the stalks under the wheat head.

The severed heads fall to the ground and cannot be recovered. Occasionally, this type of damage is widespread with considerable losses. Sometimes, mainly after 2 or 3 dry years, they increase to tremendous numbers and only insecticides can control them. Grasshoppers can be controlled with the following insecticides used as sprays:

Aldrin	125 Gr. AI/Ha.
Dieldrin	65 Gr. AI/Ha.
Chlordane	1000 Gr. AI/Ha.

Hessian fly. The best-known damage done by the Hessian fly is the breaking over of culms somewhat before harvest time. Many culms infested by the larvae do not break over. However, heads carried on these culms yield 25 to 30 percent less than heads on uninfested culms. Also, the fly kills tillers and young plants, resulting in a reduced plant stand.

The problem is not so severe in the wheat growing areas of the U.S.A. because of the availability of resistant varieties. However, in the North African wheat growing areas, where all the known sources of resistance seem to be ineffective and where the fly-free date concept is not applicable, this insect has to be controlled with chemicals. So far, the insecticides among the many that have been tested that have shown to be effective are the organophosphate systemic insecticides: Phorate (formerly known as Thimet) and Di-Syston, at a rate of 1 kg. AI/ha. When these insecticides were applied together with the fertilizer at planting time, a 100% control was recorded 2.5 months later, and a yield increase of 18% was obtained as compared with the untreated check.

Cereal leaf beetle. Both adult and larvae of the cereal leaf beetle are injurious to small grains. There is a marked preference for hosts. Barley and oats are much more attacked than are wheat and grasses, while rye is a poor host.

The cereal leaf beetle prefers seedling plants and the younger growth on older plants. Both the adults and larvae are voracious feeders. The adults may consume up to 1,040 mg. of leaf tissue during the 40 or 50 days they live. This is the equivalent of 8.6 oat seedlings. One larva will consume 119 mg. (the weight of an entire one-leaf oat seedling) in its lifetime.

In population studies of this insect, as many as one million beetles per hectare have been counted. Considering that on the average a female lays 250 eggs, then a fair idea of the magnitude of the problem can be visualized.

Extensive screening in the United States, where the pest was recently introduced (around 1962) despite the quarantines, seems to indicate that there are sources of resistance to this pest, mainly in wheat, but for the time being this pest has to be controlled with insecticides.

So far, the most effective insecticides for cereal leaf beetle control are:

Carbaryl (Sevin)	1 Kg. AI/Ha. for adult control
Malathion	1 Kg. AI/Ha. for larvae control

Greenbug. This insect is the most important of several kinds of aphids which commonly infest small grains. What makes this insect so dangerous to small grains is its ability to reproduce at very low temperatures (at about 5°C), temperatures at which the natural enemies reproduce very slowly or not at all. Long periods of cool weather allow the greenbug to increase in enormous numbers, while its natural enemies increase very slowly. This relationship is no doubt responsible for the frequent outbreaks that have been recorded in the small grain growing areas in the United States. It is also very destructive because of the toxic materials that the insect injects into the plant when feeding which destroy the leaf tissue and because it transmits the Barley Yellow Dwarf virus. Progress has been made in the development of small grain varieties which are resistant to greenbug; but until they become available for farmers, the greenbug will have to be controlled with insecticides. Ethyl Parathion seems to be the most effective used at a rate of 375 cc. AI/Ha.

Rice weevil. Rice weevil together with the angumois grain moth (Sitotroga cerealella) are perhaps the most destructive insects in the world.

In many countries there is work under way towards the development of varieties resistant to stored grain insects. However, so far, no resistant variety is available. Therefore, these insects have to be controlled with insecticides either as fumigants or with seed protectants. Fairly good results have been obtained here in CIMMYT using Malathion (Phosphorous compd) or Bythion at a rate of 15 p.p.m.

RODENTICIDES

Rodents can cause heavy damage to crops in the field and to grains in storage. Sometimes rodents increase in tremendous numbers for an unknown reason and heavy damage to crops results.

In storage perhaps the best way of avoiding rodent damage is to make the warehouses rat proof.

In the field the best way of controlling them is by regional campaigns using one or several of the following rodenticides, in the form of baits:

Warfarin	1 x 4000
Thallium sulfate	2 x 200
Zinc sulfate	1 x 200
Strychnine	1 x 200

FUNGICIDES

In the past no attempts were made to control some diseases of small grains like rusts or Powdery mildew with fungicides even though there are on the market fungicides which are sulfur and zinc derivatives and have some action against these pathogens (mostly protectants). They are too expensive for the farmer to use.

Recently, several fungicides have appeared on the market which are systemic, can act as erradicants and also have a reasonable price.

All these factors may make them useful for farmers.

These fungicides are:

1. Oxycarboxin. Works as a protectant and erradicant against leaf and stem rust.
Can be used in soil application.
Does not work against powdery mildew.
2. Triarimol. Erradicant and protectant against rust and powdery mildew.
Used as spray to the foliage at a rate of 6 pounds per acre (6 Kg./Ha. AI).
3. Benumyl. Has good action against powdery mildew and leaf rust.
Does not work against stem rust.
4. Ethirimol. Controls powdery mildew, does not control rusts.
5. E-RH-124. Not commercial yet.
Promising as erradicant of leaf rust.
6. Vitavax. Gives good control of Sphacelotheca reiliana, head smut.
7. Mercurial fungicides used in the past as seed treatment to control smut and Bunt seem to be phased out because of pollution.

What the real role these new systemic fungicides will play in the future in small grains pest control is open to discussion and the wheat pathologists are the ones qualified to answer this.

DISCUSSION

Bolton

The most widely used herbicide throughout the wheat area is 2,4-D or a 2,4,5-T combination. The instructions on the label say that temperatures must be above 10°C before the chemical is effective. Then you should get good control of the susceptible species. However, sometimes when you wait for 10°C for 4 to 6 hours, you will have weeds above the wheat occasionally in the flowering stage. Some work done by Dr. Hepworth in Turkey and work at Oregon State University shows that these materials can be applied earlier in the spring and although there is not complete kill, the weed growth is stopped and it remains small and distorted, and the wheat will outdistance it, and a higher yield is obtained. Often when you measure weed control and it looks a little sloppy, you will say, "I did not get good weed control." However, we found that although you may have a few large weeds sticking up in the field and a few small ones under the canopy, I would rather have a less than perfect field of 2.5 to 3 tons than a clean field of less than 1.5 tons.

Reddan

Dr. Granados, what is the effectiveness of insecticides in the case when insects are mobile and can immigrate from other areas after the crop is sprayed? Sometimes insecticides may be quite ineffective when neighboring farmers do not apply the chemical. How much of a problem might this be with certain insect pests?

Granados

The chinch bug migrates from small grains to corn, for example. It might be necessary for legislation to be passed and enforced to have small grains producers control their insects so that the succeeding maize crop would not be attacked.

Börlaug

When you get a real infestation of greenbug in a region, you can kill all of them on your own field and three hours later be fully infested again. Unless you have regional control, you accomplish nothing except the satisfaction of killing the bugs in your own field, but the yield is just as miserable as if you had done nothing. In 1968, I went to Argentina where there was a loss of about 1.5 million tons to greenbug. About two years later another heavy loss was registered. When the whole predator system is thrown out of balance because of temperatures and the conditions are right for the increase of greenbug, it has to be considered as a regional problem or the money spent is wasted.

Floyd

Does anyone have anything to contribute on the solution of a major problem in North Africa--the control of birds, particularly sparrows?

Lindt

There is some work by the U.S. Fish and Wildlife Service. One of the chemicals, mesurool, is in an advanced stage of testing. I do not have complete information on this.

Ramirez

We have the same problem in Chile. We tried several chemicals. One of these was Abitol, a chemical put out in 1968 by Phillips Petroleum Company. It was particularly effective in controlling bird damage on sunflower, but not as effective in wheat because it has to be applied to some area that gets on the birds' feet. The cost of the chemical was very high at the time since it was being used mainly for bird control at airports. We also tried Arasan 40S. It is a well known fungicide. We tried this as a spray on the heads. We later found that this had an effect on the protein level of the wheat, so this did not work. We are now trying some substances on grain spread on the ground. Some compounds related to the quinines seem promising and we are looking for chemicals in the markets that carry these for spraying. Main damage is on the wheat after heading and we are still exploring the possibilities of different chemicals.

Quiñones

Some years ago there was a heavy infestation of sparrows in wheat in Sinaloa. We controlled them with an application of 3 kilograms of endrin when the wheat was headed. This, however, made the wheat unusable for human consumption. They were concentrated in one field, interestingly enough, which was earlier so we stopped them there and the rest of the wheat fields were saved.

Narvaez

Some sorghum varieties are really resistant to bird attack. Early wheat varieties are attacked invariably. However, this is apparent mainly in the small plots where the birds have a choice. Latter, when the crop is fully headed, there is plenty of food for the birds and there is no specific damage in any given plot. I don't know if chemicals are practical against birds. I think if we raise the yields high enough, we will have grain for both the birds and humans.

OPENING REMARKS ABOUT TRITICALE

L. H. Shebeski, Chairman

I would like to comment on a few remarks made by Dr. Borlaug yesterday. As I recall, he indicated that there were a number of unresolved problems with triticale, such as shrivelled grain and this was the important one. I felt that man, despite his scientific ingenuity, had not synthesized a species which matched what Mother Nature had evolved for us ages ago. I know that he had used the term "Neolithic Woman" rather than Mother Nature, but that doesn't suit my purpose nearly as well. For the sake of encouraging a lively discussion at the conclusion of the session, I have taken the liberty of interpreting Dr. Borlaug's remark as implying that Mother Nature, by combining the A, B and D genomes to evolve the bread wheats, provided man with a more productive crop species than he could hope to achieve when he replaced the D genone with the R genone of rye.

Before we give the nod to Mother Nature, may I respectfully suggest that in any comparison made between the bread wheats and triticale, we should recognize the obvious. The bread wheats used for comparison are the end result of thousands of years of selection and improvement by man and at least 70 years of intensive plant breeding on a massive global scale. The triticale varieties, by contrast, stem from a very limited breeding program starting a dozen years ago and using newly synthesized raw species which in themselves were of questionable value as parents.

I am convinced that there would be relatively little support for interest in triticale today if Dr. Borlaug had not looked at the new species, had the vision to see its potential and launched the CIMMYT program that will provide much of the information we will hear this afternoon.

HIGHLIGHTS OF THE CIMMYT TRITICALE PROGRAM (1965-72)

F. J. Zillinsky

The CIMMYT triticale program was started by Dr. Borlaug in 1965. It was organized as a cooperative program with the University of Manitoba and funded by the Rockefeller Foundation. The main objectives were to develop triticales into a commercial crop for the developing countries having protein of good nutritional quality.

At the University of Manitoba a triticale program was started by Professor L. Shebeski some 10 years earlier to develop a cereal crop competitive with other cereals in grain and forage production. This program provided the basic material for the CIMMYT program.

Several major hurdles had to be overcome in order to tailor the triticales for the low latitude areas where most of the developing countries are located. It was necessary to have day length insensitive types to reproduce under the short day lengths during the winter months. They had to have resistance to the severe rust infestations which occur in these regions and they had to be fertile.

The first major advance in the program came about with the isolation of the Armadillo strains in 1968 and 1969. The fertility, plant type, disease resistance and agronomic characteristics of these strains were so superior to the normal population that by 1970 all triticales in the program were converted to the Armadillo type. During this same period several other strains of triticales, ryes, and new amphiploids were developed. The most useful of these were Beaver, Badger and PM-13 among the hexaploid triticales, Maya I to IV as octaploid triticales, and Snoopy dwarf rye.

There were still many problems to be solved. Susceptibility to lodging, poor endosperm development, narrow adaptation, and several preharvest and postharvest problems were limiting yield potential. Several approaches were used to overcome lodging. Norin 10 dwarfing genes from the Mexican bread and durum wheats were used to reduce plant height. The rye genomes in Armadillo carried tall genes which marked the expression of dwarfing obtained from the Mexican wheats. Snoopy, a dwarf rye, was used to introduce dwarfing in the rye genome. The first strains selected for dwarf stature from this program were included in yield tests in 1972. There is a tendency for dwarf strains to be less fertile than the Armadillo parent. The best combination of fertility and short stature was found in the strain Cinnamon. Its resistance to lodging permits higher applications of nitrogen fertilizer under irrigation than any of the previous triticale strains. The second major hurdle, susceptibility to lodging, is well on the way towards being solved by these new strains.

In 1971 considerable emphasis was directed towards improving nutritional quality. Screening for better quality requires both chemical and biological evaluation. At the same time more effort was devoted to the improvement of seed type. Our efforts in screening for better seed type from hybrid populations or induced mutations have not resulted in

major improvement.

During 1971 the Canadian Government, through CIDA and IDRC, took over the funding of the triticales program. This permitted expansion of the program in Mexico and at the University of Manitoba. Staff expansion and diversification of program started in 1972. Two international screening nurseries were provided, one for irrigated areas and one for rainfed areas. Programs were set up in several developing countries with the financial assistance of the I.D.R.C. Staff increases at CIMMYT have permitted more attention to cytology, agronomy, wide crosses and winter triticales to increase genetic diversity and to improve nutritional quality.

During the past five years the improvement of triticales has been very rapid. It appears that only one of the major hurdles hindering progress towards using triticales as a commercial crop has not yielded to genetic manipulation--abnormal endosperm development. This problem appears to be related to the self-incompatibility mechanism in rye. Seed shrivelling occurs regularly following self-pollination in rye. Perhaps if self-pollination ryes could be found which do not produce shrivelled seed, the problem could be solved.

A LOOK AT YIELD TRENDS IN TRITICALE

E. N. Larter

During the last couple of days of our discussions, reference has been made to the term "yield components". Although over simplified and not universally accepted by plant physiologists, the term has proven valuable in helping us as plant breeders to break down that almost incomprehensible "thing" called yield and to reduce it to parameters which we can at least begin to understand and perhaps even to manipulate in the field. These parameters are, as you all know, number of seeds/spike, number of tillers/plant and seed weight.

Theoretically, the philosophy behind the practical usage of yield components as a plant breeding tool is that if we can successfully increase any one of the three parameters while holding the other two constant, yield/plant will increase as a result.

Although in actual practice this becomes a very difficult thing to demonstrate, there should be no argument that if we as plant breeders strive to "maximize" all three of these parameters, we certainly should be going in the right direction in breeding for yield.

What I would like to do in the few minutes that I have to introduce this topic of yield as it applies to triticale, is to have a brief look at the yield trends in our Canadian triticale program and to interpret them in terms of "components".

Our program began in 1954 with the first 6 to 7 years being devoted to the synthesis of new amphiploids, plus the introduction and evaluation of others introduced from various sources. The first large scale yield tests were initiated in 1961. Yield trends for the period 1961-1972 are shown in Fig. 1.

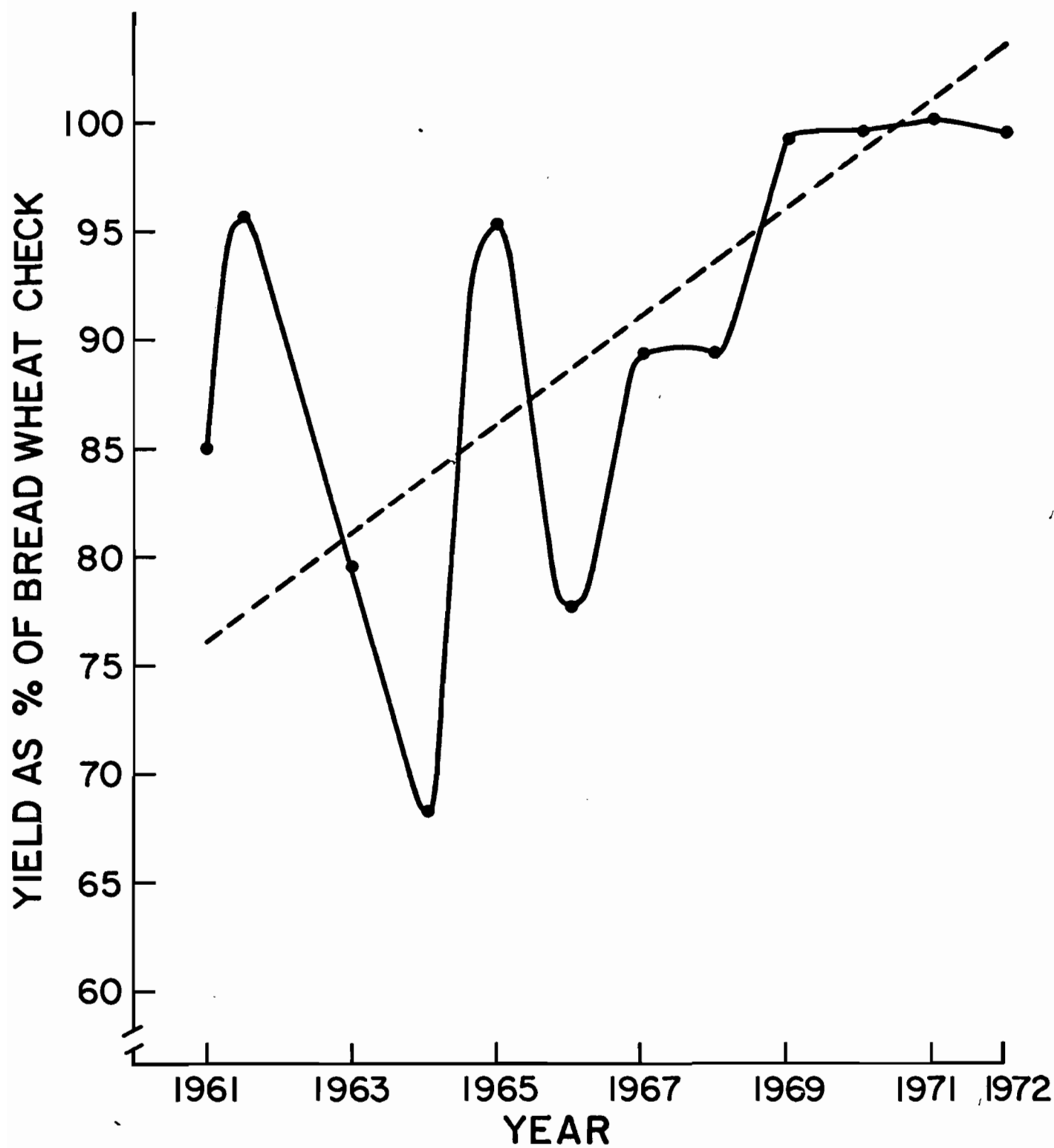


FIG. 1. Triticale yield trend compared to a breadwheat check (1961-72).

The graphs show the mean yields of advanced triticale lines tested each of the 12 years; the check material was a bread wheat variety which was standard throughout the whole period. Obviously, during the earlier period of development, extreme fluctuation occurred. This was a result of the general lack of adaptation of triticales at that time.

This was followed by a period of reduced fluctuation (improved adaptability through hybridization and reselection) accompanied by an improvement in fertility.

The increment in yield obtained in the 1968-69 period of testing was largely a result of the vastly improved fertility and general agronomic performance of hybrid lines of the type that ultimately gave rise to the variety "Rosner" in 1970. In addition, the introduction at this time of the CIMMYT high-fertility, day-neutral selection (the Armadillos), many of which were yield tested directly in our program, obviously had a very stabilizing and enhancing influence on yield.

The levelling off of yield in the past 3-4 years (Fig. 1) is the feature of this graph that deserves special comment. It should be emphasized of course that only mean yields are represented on the graph which themselves can be deceptive. In any particular year for example, lines with yields exceeding the mean by 20% to 30% were quite common. These stocks, needless to say, are used as parental material in the recycling hybridization program. However, in terms of yield parameters, what can we say regarding the possible factor contributing to what appears, tentatively at least, to be a plateau in mean yields?

It is generally known that triticale inherently exhibits some infertility, the amount depending upon its genetic background and growing conditions. In addition, our experience has shown that large spikes generally exhibit a higher percentage of sterile florets. Naturally, our selection program has always been directed toward retaining those segregates with a well-filled spike. By so doing, however, the trend has been to unintentionally reduce the mean spike size, approaching that of wheat with an accompanying reduction in the number of kernels per spike.



FIG. 2. Trend of triticaie spike size.

Fig. 2 shows the trend that has taken place with respect to spike size with improvement of triticaie in Canada. 2A is a typical spike of the triticales developed early in the program and which has undergone little if any intercrossing and selection for higher fertility. Fig. 1B is a spike from Rosner triticaie and represents a type that is intermediate in size and with higher fertility than 1A. Fig. 1C is Armadillo, a highly fertile type approximating wheat in spike size.

I believe that we should be exerting strong selection pressure on the retention of larger head size with increased fertility. Unfortunately, triticaie breeders have not been too successful in developing large-headed strains with high seed set. Although the underlying reason for this unfortunate relationship is not fully understood, I am suggesting that with selection pressure we should be able to improve fertility in these types. Even if we have to accept a lower percent fertility for the time being, the increase in the absolute number of seeds obtained on a larger spike would represent an overall improvement in yield.

Plant height is another characteristic which is closely associated with spike length. There are those who believe that with selection for a desired reduction in plant height, a concomitant decrease in spike size will also occur.



FIG. 3. An E.M.S.-induced dwarf of 6TA204.

As shown in Fig. 3, an E.M.S.-induced dwarf of 6TA204 produced by Dr. Sisodia, now in India, retained the long spike characteristic of its parent (Fig. 2A). The relationship between spike size and plant height does not appear to have to be a deterrent to the selection of short-strained, long-headed plant types.

How important in terms of yield is increased spike size in triticales? The following is a summary of data obtained by Dr. P. Gustafson during the time that he was at the University of California working with triticales.

TABLE 1. Fertility of three triticales and their yield in relation to three wheats.

	Seeds/spike	Seeds/spikelet	Yield (% of mean of 3 wheats)*
6TA 204	66	2.1	107
Armadillo	46	2.2	79
Rosner	45	2.0	73

*Wheat checks: Inia, Siete Cerros, Oviahic.

The significant aspect of these data is that if fertility of the three triticales, 6TA204, Rosner, and Armadillo (Fig. 2) is comparable, the yield increment shown for the larger spike type is directly related to the increased seed number. Under the conditions which these data were obtained, tiller number and kernel weights were not significantly different. Unfortunately, under our conditions in western Canada 6TA204 is not agronomically suitable per se, however, as a parent it is one of several that we could use as a source for increased spike size.

To this point I have dealt almost exclusively with increased spike size and fertility as a means for improving triticale yields. Naturally, there is also need to improve the tillering capacity of this species and to do this, I propose the use of bulk F2 populations, thinly planted for ease of selection in areas where they will be subjected to moisture stress. Too much of our triticale selection work is being done under near optimum moisture conditions. With triticale improvement now becoming international in scope, selection under a wide range of conditions will be possible.

The improvement of seed weight is also receiving our closest attention, both in the selection nursery and in the laboratory. Strains with good seed type have already been isolated and this character is being transferred to agronomically suitable backgrounds. Meanwhile in the laboratory, cytogenetical and biochemical studies are being conducted in an attempt to determine the underlying cause (s) of kernel shrivelling in triticale.

In summary, the mean yields of newly developed lines of triticale are significantly higher than those of a few years ago and the trend promises to continue upward. Entering the testing stages now is material which incorporates the new high-yielding feed wheats as parents. These triticales, in their early stages, have shown higher fertility and wider adaptation than the early triticales synthesized from the long established wheat varieties which had a rather narrow genetic base and limited adaptability. In addition it is proposed that with strong selection pressure for increased head length, fertility, and tiller number, yields of future triticales will be even further enhanced.

DISEASES OF TRITICALE

Santiago Fuentes Fuentes

Triticale is a man-made crop that has received increasing attention in the last decade. Our knowledge of diseases of triticale is rather scarce, it is still in the phase of identifying the casual agents for disease and in few cases there is search for sources of resistance as rapidly as possible.

Diseases reported in the literature appear in Table 1.

Table 1. Diseases of triticale as reported in the literature.

Common name	Causal agent	Reference
Downy mildew	<u>Sclerophthora macrospora</u>	Troutman and Matejka, 1972.
Ergot	<u>Claviceps purpurea</u>	Larter <u>et al.</u> , 1968. Platford and Bernier, 1970.
Leaf blotch	<u>Fusarium nivale</u>	Richardson and Zillinsky, 1972.
Leaf rust	<u>Puccinia recondita</u>	Chester, 1946; Larter <u>et al.</u> , 1968; Quiñones 1971; Rajaram, 1971.
Stem rust	<u>Puccinia graminis tritici</u>	López, 1971.
Bacterial blight	<u>Xanthomonas translucens</u>	CIMMYT's Annual Report, 1969-1970.
Head blight	<u>Fusarium</u> spp.	CIMMYT's Annual Report, 1971-1972.
Septoria blotch	<u>Septoria tritici</u>	CIMMYT's Annual Report, 1971-1972.

Ergot, the rusts and Fusarium blight were recognized early in the development of triticale. In the past two years the new additions to the list of diseases are: (a) Downy mildew recorded in commercial triticale crops of southwestern Arizona in the United States (8). Although rather widespread in the field, it caused minor damage to the crop. Symptoms were typical of the disease --enlarged heads and excessive proliferation of floral bracts. No grain was produced. (b) Fusarium nivale from the triticale nurseries of CIMMYT at Toluca, State of México (7). This was the first record of F. nivale in southern latitudes; symptoms consisted of water-soaked, greenish to grayish spots enlarging and covering most of the leaves. (c) Septoria tritici in CIMMYT's summer nurseries at Pátzcuaro, State of Michoacán, Mexico (1). Lesions resembled those of Septoria in bread wheats; nevertheless, the amount of apparent pycnia in triticale was quite small.

Bacterial stripe due to Xanthomonas translucens has had a peculiar history in Mexico. It was observed since 1968 in triticale, durums and rye, causing striping of the leaves with abundant exudate under humid conditions. In successive crop seasons the disease severely damaged the summer and winter triticale nurseries at Navojoa, Sonora State, and El Batan, Mexico. Estimated losses (9) are reported in Table 2.

Table 2. Effect of bacterial stripe on triticale (Navojoa, Sonora, México 1969-1970).

Test number	Yield, g/plot		Test weight, kg/hl	
	Mid variety in test	Infected triticale strains	Mid variety in test	Infected triticale strains
I	1153	860	71.9	69.7
III	913	801	71.5	65.9
V	940	533	70.5	61.2
VII	1005	643	69.0	67.6

Some Armadillo "s" lines and early sown materials were most affected in regard to test weight and yield. At this point, a screening of genotypes was made in order to incorporate resistance genes into the triticale materials. The disease, however, dissappeared gradually after 1970, and in the last summer season (1972) only traces were found in the nurseries.

A. López-Benítez of the triticale group at CIMMYT studied the nature of stem rust observed in triticales (2). Stem rust collections from wheat, rye and triticale were inoculated on the same hosts. The results are shown in Table 3.

Table 3. Stem rust of triticale (López-Benítez, 1971).

Rust collections	Reaction on		
	Triticale	Rye	Wheat
3 from wheat	Res-suscept	Res-suscept	Res-suscept
9 from rye	Resistant	Suscept	Resistant
1 from rye (#39)	Suscept	Suscept	Suscept
8 from triticale	Res-mod. res	Res-mod.res	Res - suscept
11 from triticale	Suscept	Suscept	Suscept

The 3 rust isolates from wheat and 8 from triticales giving resistant to susceptible reactions on the 3 hosts were assigned to Puccinia graminis tritici; those from rye attacking rye exclusively were Puccinia graminis secalis.

Isolate #39 from rye and 11 rust collections from triticales produced susceptible reactions in all three hosts; since the behavior of these isolates do not conform to any known rust, the author proposed a new forma specialis combination to name them: Puccinia graminis triticalis.

As mentioned before, Septoria tritici affected triticales in CIMMYT's summer nursery at Pátzcuaro. The reactions of some triticales lines shown in Table 4 are fairly similar to the genotypes included in the International Triticale Yield Nursery and the International Triticale Screening Nursery (1).

Table 4. Reaction of triticales lines to Septoria tritici as compared to durum and bread wheat (Pátzcuaro, Michoacán, México, summer 1972).

Genotypes	Septoria rating Scale 0-9
Maya II - Armadillo "s"	1R
Inia 66 - Guarda x Armadillo "s"	2R
Armadillo	2R
Inia 66 - Armadillo	2R
Badger - Calidad	4R
Armadillo "s" - Rye T33	2R
Inia 66 (bread wheat)	7S
Siete Cerros (bread wheat)	6S
Cocorit 71 (durum)	4MR-MS
Jori 69	4MR-MS

Even though triticales may be resistant under Mexican conditions, it is unknown whether this resistance will be maintained in other areas of the world such as North Africa and the Middle East. In these areas durums as well as bread wheats (both in the background of triticales) are heavily attacked by strains of Septoria, assumedly different in virulence to those present in Mexico..

Some resistance against ergot and leaf rust has been found in triticales.

Ergot, caused by Claviceps purpurea, remains the most important disease of triticales because of the toxic substances produced by its sclerotia. Platford and Bernier (3) from the University of Manitoba, Canada, tested the resistance of bread and durum wheats to ergot (Table 5).

Table 5. Reaction of wheat genotypes inoculated with one isolate of Claviceps purpurea from wheat.

Genotype	% florets with sclerotia	Size of sclerotia	Relative amount honey dew prod.
Manitou (bread wheat)	70	2	3
Kenya Farmer (Bread wheat)	26	1	1
Stewart 63 (durum)	78	3	4
Carleton (durum)	42	1	2

Kenya Farmer was clearly more resistant to the fungus than Manitou as indicated by fewer sclerotia, by smaller sclerotia and by a decreased quantity of honey dew exuded from the florets. In addition, Kenya Farmer offered similar results under field conditions. Hence, both varieties have been recommended as parents to induce resistance to ergot in triticales.

For his doctoral dissertation, Quiñones (5), at the University of Manitoba, studied the inheritance of resistance to Puccinia recondita in hexaploid triticales. Four isolates of leaf rust from wheat and one from rye were inoculated into the following hexaploids: 6A-190, Rosner, Armadillo, Bronco and Toluca 160. The results indicated that resistance in segregating populations was inherited by a single dominant gene carried by each one of the triticales used, and that "genes governing resistance to leaf rust were derived from the wheat parental species, and resistance carried by the rye parent was not expressed in the amphiploid triticales". Quiñones assigned the leaf rust symptoms observed in triticales to Puccinia recondita tritici.

Such a conclusion was supported also by evidence obtained by Rajaram (1) at CIMMYT in the last two years (Table 6).

Table 6. Pathogenicity of Puccinia recondita on triticales (Rajaram, 1972).

Rust isolates	Reaction on		
	Rye	Wheat	Triticale
Collections from rye <u>Puccinia recondita</u> f. sp. <u>secalis</u>	Suscept.	Immune	Immune
Collections from wheat <u>Puccinia recondita</u> f. sp. <u>tritici</u>	Mostly susc.	Suscept.	Suscept.

Furthermore, Rajaram (4) inoculated 125 hexaploid and octoploid triticales with isolates of Puccinia recondita. Thirty-three triticales were resistant at all stages of plant growth; 56 were susceptible at all stages also, and 19 lines gave susceptible reactions in the seedling stage in the greenhouse and resistant reactions in the adult plant stage both in greenhouse and under field conditions.

The response of some of these 19 lines against cultures #310 and #321 of leaf rust in the greenhouse is detailed in Table 7.

Table 7. Reaction of triticales lines to 2 isolates of Puccinia recondita (Rajaram et al., 1971).

Genotypes	Seedling reaction		Adult plant reaction	
	Cult. 310	Cult. 321	Cult. 310	Cult. 321
HEXAPLOID TRITICALES				
Armadillo "s"	4	3+	5MR	10MR
Bronco "s"	4	4	5MR	20MR
Grillo "s"	4	4	10MR	10MR
UM940-S	3	4	5MR	5MR
Tcl. My64 - UM940-S	3	3	20MR	20MR
UM940-S - Tcl. My64	3+	4	20MR	20MR
OCTOPLD TRITICALES				
Inia 66 - Guarda	3+	4	10MR	20MR
Penjamo 62 - Polko Rye	3+	3+	5MR	5MR

The susceptibility in the seedling stage and resistance in the adult plant stage are indicative of generalized resistance. This evidence offers new possibilities for a more stable type of resistance against leaf rust in hexaploid and octoploid triticales.

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QUALITY IN TRITICALES

Evangelina Villegas

Dr. Zillinsky and Dr. Larter have already mentioned that research on triticales has been conducted here at CIMMYT for several years in cooperation with the University of Manitoba. It was not until 1970 that work was undertaken on quality and nutrition of triticales. This program was financed by CIDA and IDRC in Canada. I know that the protein of triticales is also limited by the level of lysine in the protein. Therefore, we must improve the level of lysine in this crop. In the first analysis performed some years ago, we were excited to find that triticales were higher than wheat or rye in protein and that some lines were also high in lysine. Of course there was a wide range of variability.

We did not know, however, that as we began to improve the grain type, we would change the level of protein and the level of lysine. In the past two years, we have performed screening tests for protein and lysine on a very large number of lines. These tests were conducted simply. The protein content in 2,400 lines studied last year showed a range from 12.9% to 19.1% with an average of 13.4%. This contrasts with the first material evaluated which ranged from 11.0% to 21.9%. In general, we can say protein content has been decreasing as we have selected for yield and better grain type.

The lysine content of present material ranges from 2.6% to 3.9% with an average of 3.4%. In the earlier material, the average of lysine in protein was 3.7%. The screening method used is the DBC method I mentioned yesterday. This method is used to screen for total basic amino acids, but lysine is important in this. Thus, we screen first for high basic amino acids and among these lines we evaluate the lysine level.

Knowing the amount of lysine does not necessarily provide us with information on the nutritional value. We therefore, conducted some bioassay work using meadow voles and using the lines which had proven highest in amino acids. These lines, of course, were superior agronomic lines from the field. We found a wide variability among the voles which presents us with a problem. We no longer refer to results from the voles as a protein efficiency rating (PER) because we are not sure whether the voles are demonstrating this.

Occasionally, we found very low values for vole growth in certain triticale lines. It was hypothesized that these lines carried certain toxic compounds. Phenolic compounds such as the resorcinols were thought to be toxic agents since they were known to be toxic and present in rye. We did screening for these compounds but found that the values were essentially identical to those found in wheat. The values appear to lie between the values for wheat and rye, but closer to the wheat level. Therefore, we are not at all sure what compounds are responsible for toxicity.

The resorcinol in lines studied varied from .057 to 0.17. The bioassays are performed at a constant protein level (7%) for each diet. There was no correlation between resorcinol level and the vole index value. In certain cases, the animals did not eat and died without gaining weight.

In a cooperative experiment conducted with the group at Purdue University, we evaluated some of our triticales with other cereal grains. Normal maize, opaque-2 maize with a hard endosperm and opaque-2 maize with a soft endosperm were used in the test with three triticale samples and two wheats. Using rats, PER values were determined. The three triticales used were slightly superior to the wheat varieties in nutritional value.

Samples were also sent to Dr. Schenk at Pennsylvania State University who works with voles to get another determination. Opaque-2 maize was superior to normal maize. The three triticale strains gave about the same results as the wheat samples. At our laboratory we did not get a repeatable sample so we do not feel we can rely on the vole as a laboratory animal at this point. Probably, we may say that antimetabolites do exist in triticales. This must be checked and studied with other animals when the materials are available.

With regard to improvement of protein and lysine, we have wide diversity. Some materials, even at 17% protein, have 3.9% lysine. Unfortunately, we do not have sufficient material of this line to perform bioassays with different animals. Next year we hope to do these experiments.

We have also been looking at the possibility of using triticales for industrial purposes, not just for food as chapati or other preparations, but for bread. We have found that it will make bread without any blending with wheat flour. Sometime ago it was reported that triticale was unsuitable for bread and could be only used in very small proportion in a wheat flour bread--up to 10%. We know this is untrue. If we modify the fermentation period, we can make good bread. Again, however, if we reduce the protein percentage, this is unlikely to be true. In Dr. Amaya's first experiment, he got good loaf volume. But in the last year, the protein content was reduced. When we mill wheat the protein level of the flour is 1% to 1.5% lower the grain protein. For triticales, the reduction is about 3%. The loaf volume with the reduced protein of the newer types was disappointing.

In the CIMMYT material, the variability is sufficiently wide that if we do not discard the poorer grain types but keep them recrossed into the program, we will select better grain types with good protein and lysine levels. I am afraid that if we select only for grain type at this point, we will have values similar to wheat.

DISCUSSION

Zillinsky

I think it is very true that when we are selecting for a particular character like yield or seed type, we can change quality of the material. I believe Dr. Villegas left out one figure in the early part of her discussion. She mentions that the range was 10% to 21% protein in the original material. She did not mention the average, which I believe was 17%. The average dropped from 17% in 1967 to 13.4% in 1972. Thus, we are dropping on % protein as we increase the yield. We are still retaining the high-protein lines, but we have not concentrated on attempting to breed these back in as yet.

About the time the Armadillo, Badger, Beaver and Snoopy lines were coming out of the program, we did notice a tall plant promising as a possible forage triticale. We grew it in the next generation at Navajoa and it was one of the few lines not attacked by a heavy bacterial leaf infection. This aroused our interest, but it had such susceptibility to lodging under irrigation that it was flat just after heading. By coincidence, I was asked if I knew of something that might be suitable for growing on sand. We sent about three triticale selections--the one of these I spoke of, the forage type which we call PM 13, an Armadillo line and a population of wheat x triticale.

Wheat sown at the same time and under the same fertility looked very poor. The PM 13 line, however, looked excellent in plant growth. It is only about 60% fertile, except under good conditions where the percentage increases. We decided this might have something to offer in other countries and it was included as one of the entries in the ITYN a year ago. When the results came in, this line looked mediocre to poor at most locations, except at one location. Dr. Kiss in Hungary sowed the test in the fall instead of the spring by mistake. He used one of his better winter wheats as check. Practically everything in the nursery was killed except the winter wheat and PM 13. We do not know why this happened. This is a day length insensitive triticale. The yield of this line was more than double that of the bread wheat check. What do you do about oddities of this type? Why does a day length insensitive type produced here behave like a winter type in Hungary and outyield their winter wheat? These things do happen and we should remain alert, and whenever possible use them to our advantage.

Borlaug

I would like to comment on what has happened since you, Dean Shebeski, began to work with these plants. You can see that you have stirred up a lot interest around the world and I think you are on the verge of a real breakthrough in a manmade cereal, one which will serve human needs very well. We still do not know under what conditions it will do well or what uses may be made of it. In reflecting back on the first living triticale plant that I had ever seen, I had seen them in cytological laboratory collections as dried specimens before, but it wasn't until the First International Wheat Symposium that you held in Winnipeg in 1958, Dr. Da. Silva was there at the same time, that we saw your collection of the hexaploid triticales. Looking back to 1958 and what has happened since then, one has to be impressed. I think that now when so many people are involved and interested, we are likely to see continued progress in the next 3 to 5 years that is likely to break this crop into the open as an important cereal crop of the world. Just when this will happen one does not know. I am also very pleased that we are getting some competition into this game. You saw how these durum breeders were yesterday. Varughese and Quiñones were pushing the bread wheat people around pretty severely. Now the triticale people are going to do the same to the durum people. When we get this sort of competition, in a healthy way, we will make faster progress than if people go along complacently.

You have to remember also that durum wheats and their improvement are the basic building blocks on which you make new triticales. Thus, one complements the other. Now there is also interest in improving the other building block--the rye genome--modifying it for height, self-fertility

and other characters. There is a wide open field ahead.

There will now be big enough segregating populations growing in different parts of the world so that we will hopefully get a good return on the research effort going into the crop. When the populations were small and only a few people were working on the crop, it was less likely that this would happen.

Mother Nature is still pretty effective. Armadillo was the result of such a thing and it happened in a promiscuous sort of way. One night, probably about in 1966, and certainly at CIANO in the Yaqui Valley, a lot of these partially sterile triticales were being grown amidst quite a few hectares of segregating dwarf wheats of many kinds. We don't know exactly who did what to whom that particular night, but about three generations--a year and a half--later there were about seven plants that Dr. Zillinsky and Dr. Varughese found to be homozygous and about 20 others that were segregating. When I returned from a trip to India, I was not able to get out of the car when they grabbed me by the arm and dragged me down to see what was to become Armadillo. It happened in the dark of the night and the difference was that populations were big enough and there were enough people working so that it was spotted and found to be transferable. In the same package went fertility, partial light insensitivity and a dwarfing gene. It was a pretty good bull!

Shebeski

I think many of the tools that make it possible to start synthesizing species were only available about 1935 with the discovery of colchicine use. Now, plant scientists are moving into an entirely new field, i.e., synthesizing species at the cellular level. Protoplasts are being brought together. But this branch of science is still in its infancy. Following through on that, I must comment on Dr. Borlaug's last remark when he gave credit to Mother Nature for Armadillo. If the synthesized species was not there that was partially sterile, Mother Nature could not have done a thing, so it is really a combination of the two, man and Nature working together.

Rao

I would like to give you some information on the triticales work being conducted in India and also some of the discussion we had with Dr. Kiss of Hungary when he spent about a month in New Dehli last year. During the discussions, Dr. Kiss mentioned that in his triticales in Hungary, the new derivatives are giving yields equal to the bread wheats, and this is under marginal conditions. Of course, under high fertility, the wheat outyields the triticales. One interesting thing he reported was that bread made from triticales is better liked by the Hungarians than wheat bread. He feels that the Norin 10 genes are not good combiners whereas Tom Thumb is considerably better in the production of triticales dwarfs.

In India, one of my colleagues, Dr. Sisodia, mentioned by Dr. Larter, has a program at Indore. He showed us promising materials last year and some of these have amber grains, the type preferred by the Indian consumer. We had some all-India national trials of triticales and included triticales in our wheat trials. Because of the preliminary indications

that triticales carry high protein and lysine and our people suffer from protein deficiency, we felt there was a tremendous future for triticales in India. A number of trials were conducted at about 15 locations throughout the country. The results were not encouraging. On an average, they gave only 60% to 65% of the yield of Kalyansona. This year we discontinued these trials because we do not yet have the right genotypes to compete with wheat.

Last year under rainfed conditions we tried four crops--mustard, triticale, barley and wheat. Mustard was best because of its deep root system, evidently allowing it to exploit the water in the lower soil profile. The second best was barley, triticales were third, and wheat was last. This is only one year's experience.

Some of my colleagues tried boron spray on the triticales. This gave an increase of 5% to 10% over the untreated material. Still, the triticales are yielding well below Kalyansona. One thing that particularly impressed me in the triticales was the near immunity to powdery mildew. In our summer nurseries at Wellington and Lahaul Valley, we get severe powdery mildew and the triticales are essentially immune to this disease.

Borlaug

I would like to ask Dr. Larter what the regional yield tests showed in the last couple of years? You mentioned this in summarized form, but I was wondering how much variation you find between strains as compared with wheat?

Larter

Only three or four years ago, when Rosner triticale, the first commercial Canadian variety was being tested extensively, we found considerable variation from one area to another. I think we have a species which is still quite responsive to environmental conditions and I think we will have to live with this until we go through many more reselection cycles in order to stabilize yield through adaptability. We should not be startled by this variation in yield from place to place. The species is very new. Thus, we get more variation than in wheat. I expect this will be reduced when we are testing such highly fertile types as Armadillo. We haven't yet reached the stage where Armadillo is being put on a wide regional basis, but I am convinced that we will see this variability reduced substantially.

With triticale being a species compounded of two genera, I don't think we can predict what particular outcome or performance we may get until it is tested under a very wide range of conditions. I know that I speak for all triticale workers when I say that we are pleased indeed to see more and more countries with their diverse climates beginning to test triticale in a large way. We will not be able to do it with our narrow testing system. It must go into diverse areas where with large populations, and I am speaking of hectare size F₂ bulls where you have numbers and these are space planted so you can see individual plants and can select those you think are the kind that will carry the program into the future.

Wortman

The point was brought out that triticales are being used commercially in Canada. To what extent are they being used and for what purpose?

Larter

The one variety, Rosner, was released in 1970. At that time it was not utopian by any means, but it was a new species and we needed a yard stick by which to measure the triticales to come. Its yield was sufficient compared with wheat to justify its release and certification. It went out. The scale of production is not large--probably 2,000 acres (800, hectares) and it has stabilized. Much of this is grown under contract by distillers. They immediately found that it had a use in the distilling industry. It produces a product, we are told, that is different and I suppose in this industry something that is different will sell. So they are still under contract. The rest is being used as a livestock feed on a local basis.

Shebeski

I think Dr. Borlaug saw some of the contract growing on a field scale of a type that was precursor of the variety Rosner. It was one of the original synthesized species. It was interesting that yield trials across the country would be pretty low, but when grown in 160-acre fields, there were consistent yields of 45 to 50 bushels per acre on the better fields, which compared with the best wheat yields of that time. This was one of the reasons that right from the beginning we were confident that with work put on the species, using just the raw synthesized species, and no knowledge of what components to put together, we were getting that sort of yield and at that stage. The potential was there, I do feel, with the dwarfing gene, which most likely will be simply inherited and because it came by mutation one can expect that the long head type and short straw can be transferred to the highly fertile types and maintain the fertility by a backcross program. So, I can be very enthusiastic about a next major step.

Kohli

On the basis of the very narrow germ plasm we now have, we can't predict the adaptation we can find in the species. We still have a long way to go. We have, however, been sending from CIMMYT an International Triticale Yield Nursery (ITYN) and have received some results. The first ITYN results have been published, the second ITYN will be out soon and results of the third ITYN are being prepared.

In the first ITYN, we had 16 varieties and the test was grown at 39 locations worldwide. The second nursery again was comprised of 16 varieties, some of which were the same as those of the first test. This second ITYN was grown at about the same number of centers, but results were received from only 17. The third ITYN carried 25 varieties and was distributed to 50 cooperators. Results have been received from some 27 locations. From these results, it appears that when we weight the first five varieties and compare with the four checks (2 durum and 2 bread wheat), we find that in the first ITYN, a triticale variety appeared among the first five

places in yield 11% of the time. The same figure was 13% in the second ITYN and 16.5% of the times in the third ITYN. This is a modest advance, but there appears to be a trend line toward higher yield. We also calculated the percentage of times a triticale variety outyielded the best check in the individual locations. This also rose from less than 1.0% to 1.5% and in the third ITYN was 3.0%.

We are finding two types of adaptation. In the first and second ITYN, there were three Armadillo sibs, PM 130, PM 133 and PM 136, which had general adaptation in both years in the two sets. In the second ITYN we found certain varieties were specifically adapted to the cooler regions of Europe and North America. Another variety appeared specifically adapted to countries of South America--Chile, Brazil, Colombia, Ecuador and Peru. One variety was specifically adapted to regions where higher disease incidence was reported.

There seems, therefore, to be specific adaptation in certain varieties while in others general adaptation appears to be the rule. We are trying to identify these types and recross them into our better materials.

Borlaug

We have had for the past several years in the International Spring Wheat Yield Nursery, a feedback from any national program, any variety or advanced line which they would like to have included in this nursery in the next year. We get 200 grams of seed. This is multiplied in CIANO and insofar as possible these are included in the yield test. In one year, therefore, the scientist will have testing done around the world. It is now time to get the feedback in triticales to Dr. Zillinsky, since many people are now working with triticales. Up to now, the materials in your ITYN have been University of Manitoba or CIMMYT lines, I think. We should discuss this for durum and triticale tests and for a modification in the bread wheat nursery as well to get more feedback. These tests belong to the national programs, collectively, and we want to make them more effective to serve all.

Updhyaya

These triticales have been bred for irrigated conditions or areas of ensured rainfall. In India, we have large areas where there are no winter rains. For such areas we need triticales which are drought resistant. My feeling is that unless we use drought-resistant durums in making the amphyploids, it is unlikely that drought-resistant types will evolve.

Zillinsky

Last year was the first year that we divided the material into two lots, one set we felt might be suitable for dryland conditions. We did not worry that they might be tall for the irrigated areas, but they had to have good disease resistance and good fertility. These may not be good for your area, but we have had a very strong demand for this material from people in dry areas. In the coming year we are putting out twice as many nurseries for dryland areas as in the past. I suggest you get your name in early.

Borlaug

Since we are dealing with a very crude species, don't go into research on it with preconceived ideas. Remember that even with an old crop, Kalyansona or Siete Cerros were selected under irrigation, and they have walked out on drylands and many places people said it would never grow. We should test it under many conditions, certainly select enough plants and put them into tests under various conditions; one plant you probably thought should not be selected may surprise you.

Bronzi

What is the potential of triticale for forage in North Africa?

Anderson

Come back in one year and we will have some information.

Bronzi

Is it true that triticale is being used for forage in Texas?

Shebeski

We are dealing with a species that combines two species which are successful plants in about all parts of the world in the form of different varieties which are successful under different conditions. There is no reason that architectually, over time, we can not combine suitable components that represent the best of both species for any part of the world. Of course, it will have to counter the faults, I suppose, of both species at the same time.

Hafiz

What are the main objectives of this program? Are triticales to compete with the wheat crop or is it to be treated as an additional crop? Is it being prepared for marginal lands or where wheat is doing very well already?

Shebeski

The plant breeders' responsibility is to produce the best material possible. We should not worry about whether triticale will replace wheat or that durum wheat will replace bread wheat. If wheat can not compete with triticale in a particular area, then it should not and vice versa. In time you will have breeders breeding for the various kinds of uses for this species as you now find in the others.

IMPROVED SEED--AN ESSENTIAL INPUT FOR INCREASING PRODUCTION

Ahmet Demirlicakmak

INTRODUCTION

The main goal of agricultural activities is to gain more profit by applying the most qualified, advanced and effective methods. To increase agricultural income and farmers' living standard and to provide the food for increasing population, it is necessary to intensify the efforts on uses of agricultural potential and to increase yield per unit area.

In order to increase yield per unit area, sowing at the proper time must be done in a well-prepared seed bed with the appropriate equipment. To obtain maximum return, good seed and optimum rates of fertilizer must be used, combined with weed and pest control, and if possible, irrigation.

Unfortunately, in Turkey, the land generally is not as productive as desired and the complete impact of improved cultural practices is not realized. For this reason, good seed has more importance as an input. For example, certified seed by itself can increase the yield significantly because most of the farmers are still using wheat seed mixed with other cereal crops and with weeds. Experiments have shown that seeds with greater physical purity and biological value increased yield 12-15% in comparison with farmers' seed. If the genetic value of the seed is high, it is obvious that yield increases will be more.

During the First 5-Year Development Plan in Turkey, an intensive program to produce certified seed has been started. In the last few years of implementation, 70% of the yearly wheat seed requirement has been produced. Unfortunately, not all of this good seed was distributed to farmers and even all of that distributed was not planted. This is still a problem that must be solved. Presently, most farmers are still using their own seed and these, both physically and genetically, are not always good seed. Specifically, seeds are mixed with weeds and other crop seeds such as rye and are contaminated with diseases which reduce total production. Annual estimated losses in production due to loose smut (Ustilago tritici) and common bunt (Tilletia caries or T. foetida) is 3-5% and 5-10%, respectively. According to our specialists, losses due to weeds can be as much as 25-30%. This is the combined loss due to weeds planted and inherent weed seeds present in the field.

WHEAT PRODUCTION EFFORT

During the application of Turkey's development plan, technical and cultural measures have been taken for wheat production within the framework of an over all programme. The goal is to increase wheat production to a level where it will be sufficient to accomodate the needs of Turkey, taking into consideration the high rate of population growth. The program was constituted into three projects: research, extension, and seed production.

1. Research (Wheat Research and Training Project)

This project was established after an agreement was signed between the Turkish Government and the Rockefeller Foundation to increase yields per hectare of winter and spring type bread and durum wheats.

In the project there are 11 research stations in the major wheat growing areas of Turkey. There are three principal breeding stations, at Ankara and Eskisehir for winter wheat and at Izmir for spring wheat. The eight remaining stations are largely selecting and testing sites. There are two main wheat growing areas; the dry, cold winter wheat area of Central Plateau and Southeast Turkey and the warmer, wet spring wheat areas of the coasts. In these two regions research problems are different. In the winter wheat area there are several improved varieties which are yielding less than their potential, mainly because of lack of moisture. The most pressing problem in this area is to develop a set of tillage practices which will permit the early establishment of the seedling and the greatest conservation of rain falling on the fallow land. In the spring wheat areas the most pressing problem is the identification of varieties which have good resistance to diseases and which are long enough in duration to permit sowing in early November, yet which will not flower until April, after the danger of frosts has passed.

2. Extension (Increased Wheat Production Project)

The goal of this project to increase the productivity of wheat in dry land areas with the application of new techniques for soil and moisture conservation and other cultural practices. To achieve these goals a very active extension system is being developed.

According to the project, one million hectares of wheat in 20 low-rainfall provinces will be under control in the first year starting from 1973. This area will be increased to 1.5, 2.0, 3.0 and 4.0 million hectares in second, third, fourth and fifth years, respectively. In this area cultural management, such as timing of tillage operations, uses of tillage equipment, seeding rates, and seeding dates, will be controlled. Certified seed of high-yielding varieties and sufficient amounts of fertilizers will be provided and weed control will be carried out. One technician will be given 5000 hectares as a unit area to control.

Training activities in this project will take place in two steps. The first step is training of the technicians (specialists) and the second is the training of the farmers. The project involves first the training of national and provincial level wheat specialists. Afterwards these specialists will train county agents and village technicians, then these local agents will carry on the farmer training campaign.

The training of the national and provincial level wheat specialists will be both academic and field oriented. The field training program provides training and practice in each step involved in the establishment of adaptive research and demonstration plots with emphasis on moisture conservation practices, seed bed preparation, optimum fertilizer use, and weed control.

3. Seed Production (Seed Production and Distribution Project)

Turkey's total annual seed requirement is about 2 million tons, of which nearly 1.4 million tons is for wheat. Since wheat is a self-fertilized crop, seed can be renewed every five years. In this case, seed planted by the farmers needs to be replaced every five years with certified seeds. Therefore, the annual wheat seed requirement in Turkey is about 300,000 tons. On the basis of this judgement, the seed production and distribution project has been prepared in accordance with the present seed law and regulations. With the initiation of the program a large part of the required amount of seeds will be produced by the state farms and also by contracted farmers under the control of the state farms.

Consequently, these three projects and the complementary projects have been undertaken as a large program for increasing the productivity of wheat in Turkey.

PRESENT SITUATION OF SEED PRODUCTION

According to the seed law and regulations, seeds are produced under the following four categories: elite, original (foundation), registered, and certified. Elite seed is produced by breeders by selecting the best spikes or plants in a space-seeded plot at research stations. Original seed is also produced at the research stations or at the state farms under the control of breeders. This seed must possess varietal purity in a high degree, as well as excellent seed qualities. Registered seed is the first or second reproduction of the original seed. This seed is produced at the state farms. Certified seed is the seed distributed to the farmers and is produced by both the state farms and contracted farmers. According to the new regulation, it may also be produced by seed growers or cooperatives which are organized by the growers.

The Agricultural General Directorate has the responsibility of distributing the original, registered and certified seeds. This Directorate works in the closest coordination with the General Directorate of State Farms, the Agricultural Bank, and other governmental organizations.

In Turkey before 1940, the annual distribution of improved seed was about 200 tons. After the establishment of the state farms in the early 1940s, production of certified seed increased markedly. The state farms are responsible for producing certified seed of various crops, especially wheat. There are 21 state farms in Turkey, totaling 341,418 hectares. These farms have the capability of producing about 12,000 tons of certified seed each year. On the average the production per hectare on the state farms is about twice the national average.

Another source for producing certified seed is contracted farmers. These farmers are generally selected near the state farms and produce the seed under the control of state farm organizations. Seeds are purchased by the farms at a special price which is a little higher than the government's support price for wheat grain. With this system of contracted farmers it is possible to produce an additional 12,000 to 150,000 tons of certified seed.

Each state farm has a seed processing center in which seed processing

equipment and storage facilities are present. The seeds produced by the state farm, together with the seeds from contracted farmers, are collected at this center for cleaning, inspection, treating, and bagging. If the seed has qualified for certification (this is controlled by the seed certification laboratories), a portion of the seeds are cleaned, treated, and packed in 50 kg bags and stored until distribution.

The distribution of certified seed takes place 1-1.5 months before planting. Seeds are distributed according to a specific program which is prepared by the General Directorate of Agriculture. There is good coordination between governmental organizations (such as the Agricultural Supply Organization, Soil Product Office) regarding seed distribution. Agricultural Supply Organization is responsible for supplying fertilizer and agricultural equipments to the farmers, and Soil Product Office has the responsibility to purchase some agricultural products, including wheat with the government support price. Both organizations have branches with efficient facilities throughout the country. In this manner seeds are easily distributed to the farmers. The farmers get the seed either by paying cash or on a credit basis. Usually a very small amount of the seed is sold for cash; most is sold on credit.

Producing good seed has been very successful in this system and it is possible to produce large quantities of seed in one year. In addition, the seeds can be treated against some diseases, mainly bunt, which can cause very serious damage. These seeds are reasonably good quality as compared with the seed currently used by the farmers. For example, research carried on the seeds collected from Ankara province showed that the seeds used by the farmers for a long period have 220 weed and 255 other crop seeds (mainly rye and oat) per kilogram whereas the seed obtained from state farms have (as an average) 30 weed and only 4 other crop seeds.

In spite of this, distribution of the seed produced in large quantities by state farms has been disappointing. In the past more than 70% of the seeds required were produced, but the distribution, especially for the last two years, was much lower than the program goals. In the following table, quantities of wheat seed produced and distributed during 1963-1971 are shown.

QUANTITIES OF WHEAT SEED PRODUCED AND DISTRIBUTED DURING 1963-71 (TONS)

<u>Years</u>	<u>Production</u>	<u>Distribution</u>
1963	--	57,829
1964	--	57,185
1965	97,038	76,305
1966	106,927	126,310
1967	163,607	210,091
1968	186,467	186,467
1969	226,348	206,348
1970	325,000	94,015
1971	226,919	38,707

It can be seen easily that there are marked differences between the amounts distributed in 1970-71 and the previous years. The main reason for this is the lack of credit. There has not been enough credit available to the farmers for seed purchases. It is due to funds seperated for seed distribution was getting lower every year and money given to the farmers as a credit is not being returned back to the bank.

Even with the problems mentioned, the Turkish seed supply organization has the potential to produce large quantities of good quality wheat seed at reasonable prices. When new varieties are produced by the research project, these varieties can be multiplied and spread throughout the country in a short period of time.

DEVELOPING PROGRAMMES AND TRAINING PERSONNEL FOR SEED MULTIPLICATION AND DISTRIBUTION

Johnson E. Douglas

I Research and Seed Production

Wheat research and seed multiplication and distribution are a symbiotic relationship. They are a necessary and happy union. When both are successful, everyone wins.

International wheat research has made great strides and gained much recognition during the last few years. Success in seed multiplication and distribution has been much less spectacular in many countries. Increased cooperation internationally is just beginning to be emphasized in seed multiplication and distribution.

Even terminology has different meanings from country to country and area to area. It is for this reason that a listing of terms and definitions as applied in this paper is attached as Annex I.

II Objectives To Be Achieved

Recognizing the close relationship that must exist between wheat research programmes and seed multiplication and distribution efforts, it is appropriate to look at the objectives to be achieved. Through seed multiplication and distribution programmes, the following objectives should be achieved:

- A. Develop a means for providing the farmer with pure seed of good quality of the best variety available.
- B. Build a mechanism for rapidly introducing new varieties into the programme.
- C. Achieve a system of seed increase that is durable which will continue to grow and serve the seed supply objectives of the research programmes.

III Present Position

Countries differ widely in their capability for increasing and distributing good quality seed. Many European countries, the U.S.A. and Canada have gradually improved their seed multiplication and distribution programmes during the last 100 years. A private seed industry developed with the encouragement of governmental and semigovernmental agencies. The F.A.O. made a global seed survey during the 1968 to 1970 period (Feistrizier 1971). From this survey countries have been classified into three principal groups, namely:

Category A: Countries at a technically and/or economically advanced level; these probably need little or no further assistance.

Category B: Countries where improved varieties are available but seed supply is inadequate; these probably require assistance in seed industry development.

Category C: Countries where improved varieties are not yet available; these probably require assistance in the development and release of improved new varieties.

Table 1 shows a provisional review of this survey:

TABLE 1. Status Review.

Areas of the world	Number of countries	Percentage in each country		
		A	B	C
Developing world	73	8	85	7
Oceania, North America and Europe	24	79	21	None

Dr. W. P. Feistritzer, F.A.O. (1971), summarizes the position as follows:

"These figures show that existing methods for seed production, control, and distribution in most developing countries require considerable reorganization and intensification if improvement programmes are to be a lasting success".

During the 1950's and 1960's a number of agencies and countries have had "seed improvement programmes". The objectives of these programmes are good, but the successes versus failures have been somewhat disappointing. A few seed specialists have worked in different countries at the request of the host governments and sponsoring agencies for relatively short periods. Sometimes equipment has been installed and made operative. Other times the specialist has been transferred before the programme really got started.

Support from administrative heads in host countries is somewhat erratic. Interest in seed improvement is high for a while and then ebbs with a change of personnel. Countries often fail to develop long-term plans and programmes, but instead tend to rely more upon "crash programmes" to achieve short-term, immediate objectives. Crash programmes are frequently expensive and seldom result in the long term impact needed to have a sustained seed improvement effort.

The amount of "improved seed" multiplied in most developing countries is but a fraction of the seed needs of the country. This seed often comes from government farms and is distributed to cultivators on a subsidized basis (Proceedings, wheat seminar 1970). Government agencies and organizations usually have a number of responsibilities and find it difficult to meet the long-term objectives of the country in fulfilling even 5% of its seed needs. A seed increase programme of this kind is far short of a viable, sustaining seed industry which grows and develops with increased demand (Schoorel 1971).

Many areas are, undoubtedly, similar to India in the late 1950's.

Before the introduction of new varieties of wheat and rice and the hybrids of maize, sorghum and bajra, no organized seed industry was supplying cereal seed of any quantity. The government was distributing very limited supplies of improved varieties. No quality control system was operative on the seed supplied. No seed processing or drying equipment was used. It was generally believed that farmers would not pay more for good seeds and that farmers would change very slowly. The introduction of new varieties and hybrids during the last decade had an electrifying effect on the seed multiplication and distribution system.

By the end of 1972 India had the following: (1) the beginning of a viable seed industry composed of both private and semi-government enterprises; (2) seed drying and processing facilities; (3) hundreds of seed growers with interest in seeds; (4) an increasing number of seed dealers for merchandising seed; (5) at least one seed testing laboratory in every state; (6) a meaningful seed certification programme under way; (7) a seed law enforcement programme in the initial stages of being implemented applying emphasis on education and truthful labeling of seed above certain minimum limits; (8) over 1,000 persons who had been through some kind of special seed improvement training programme within the country; (9) an Indian Society of Seed Technology with a membership of approximately 400 persons; and (10) improved wheat varieties being used on approximately 35% of the wheat area. No one is satisfied or complacent about the position of the seed production and distribution in the country because it is recognized that even with approximately 25,000 acres of certified seed wheat production in 1971-72 the amount of certified seed available for planting in 1972 was less than 5% of the amount needed for the country.

IV Needs To Be Met

Recognizing the importance of the continued flow of new high yielding varieties from research programmes to farmers, the availability of good quality seed should not and cannot be left to chance. The farmers are going to continue to produce and save their own seed for many years to come. The "Green Revolution" has been sparked by farmer interest and farmer seed increase programmes. However, experiences in developed and in many developing countries suggest that a system built totally on the farmer's own methods of collecting and saving seed is far from adequate. Varieties become mixed, their identity is lost and one knows where to buy good seed of the once "improved variety".

As a wheat research scientist you could logically say, "Don't bother me with your problems; I am busy breeding new varieties". Obviously, your objective is not just to breed and test new varieties, but to assure that these new, high-yielding varieties are used by farmers. It is here that the symbiotic relationship between the wheat research scientist and the seed multiplier must be recognized. The wheat researcher is often the most knowledgeable wheat expert in the area. Thus, the responsibility of initiating good seed multiplication programmes often falls upon his shoulders initially. A wheat researcher cannot and should not allow himself to become totally immersed in seed production efforts. On the other hand, it is in his interest to assist in training local leadership in this vital area and to help build the system for moving the results from the research fields to the farmer.

Assuming the responsibility for building wheat seed multiplication

and distribution programmes is to be shared by the wheat researcher, the main aspects (Douglas 1969) of such a program should be identified. They include the following: (1) a strong research base on which production and distribution systems rest; (2) a means for making initial seed multiplications from material supplied by breeders; (3) commercial seed production, processing and distribution resulting in the development of an effective seed industry; (4) a dynamic extension and information programme to demonstrate and teach the value and proper use of new varieties; (5) a quality control programme to assure the farmer of good quality seed; (6) availability and/or training of personnel capable of developing and operating a seed programme; and (7) favourable economic, political and social conditions and policies within the country concerned.

In building a good wheat seed multiplication and distribution programme each of these components needs attention:

A. Modern Seed Production Rests on Strong Research

A strong research base and the flow of new superior varieties from it is essential in building a good wheat seed multiplication and distribution system. The farmer will use his traditional variety, save his own seed and have no need for outside seed sources unless better varieties and seed can be offered to him. The gains made in wheat research, the establishment of CIMMYT and the strengthening of many national programmes clearly indicates that a flood of new and better varieties will be coming forth during the next decade. Therefore, the seed multiplication and distribution systems will have a solid base upon which to grow.

B. Variety Release, Recommendation and Initial Seed Increases

Much debate and controversy centers around this aspect of the programme. It is the bridge between research activities and seed multiplication. At some point, the wheat research scientist needs to make a final judgement regarding varieties which he feels should be used by farmers. In other words, the variety is "released" from the research programme and recommended for use. In the early stages of many programmes a small amount of seed is made available to leading farmers for their own evaluations. This is sometimes connected with an actual attempt for seed increase. The timing of these actions is more critical in terms of seed multiplication and distribution than the procedure used. The Indian Seed Review Team Report (GOI 1968) developed a suggested schedule of events (Annex II) to stress their recommendations regarding the timing of release and recommendation, seed increase, publicity and commercial seed increase. This schedule outlines a rather formal and ideal situation. Nevertheless, it does illustrate the importance of proper timing and phasing of these activities.

If the farmer testing programme goes on for three or four years before a variety is officially recommended and the variety is good, the farmers will have multiplied substantial quantities and distributed it to their neighbours. This is not bad in the early stages of a seed multiplication programme. It helps to

identify those farmers who are not only interested in new varieties but also those with the capability for increasing and distributing seed. Ultimately, however, a seed multiplication programme needs to go beyond this. It is impossible to provide seed to all farmers who may want it in the first year of increase. The research programme can get into the awkward position of appearing to favour only a few farmers. Without any other checks in the system the seed multiplied by farmers can easily become mixed with other varieties either accidentally or otherwise. Without adequate follow-up and a means of verifying varietal purity, the identity of the new variety is rapidly lost and the farmer is back demanding fresh "breeder seed."

It is for these reasons that a plan for seed multiplication in the early stages needs to be developed to assure the proper identity of seed being distributed, to encourage key farmers and others to become recognized "seed multipliers" and to provide the research programme with an established pipeline to the farmer.

The major problem is trying to formalize the release, recommendation and initial seed increase programme centers around the tendency to delay release because of known and unknown uncertainties that may exist. The release and recommendation process can become so complex, confusing and restrictive that the purpose for which it was established is defeated. This can be especially true where traditional self-interest and well-known older varieties exist. Resentment builds up against the introduction of new material from the outside which may reflect upon past research efforts. Nevertheless, it is better for the modern wheat researcher and seed technologist to be involved in moulding a new system than to ignore and pretend that no problem exists.

The release and recommendation of a new variety should be based on some kind of a criteria or standard. Wheat research programmes would do well to develop a statement of policies in this regard without the pressures of a particular variety that may need to be released. Developing a general policy that would have applications not only to wheat but also to other crops could help avoid unnecessarily restrictive and arbitrary decisions at any particular time.

As a variety is ready for multiplication, the wheat research scientist should not only describe the variety in terms of agronomic performance but also from a morphological and physiological point of view so that it could continue to be identified properly in the seed increase programme.

Frequently, this is not done well because the breeder is familiar with the variety and does not recognize the importance of describing it in a way that other people can also identify it.

Another point of concern at this stage is the need to avoid prerelease or premature publicity on new varieties, especially

after farmers are awakened to the potential that can be gained through them. It is unwise to develop a clamour for seed when no seed exists. Therefore, regardless of how much publicity a breeding organization or institution may desire, it should restrict comments on new developments until these developments are at the stage of moving ahead to the farmer. Linked with this is the possibility of having a "prerelease" increase of seed so that a quantity of seed will be available for wide distribution and large scale multiplication when a decision to release and recommend the variety is taken. This can help to ease the pressure upon research organizations and seed supplying agencies. The phasing of seed availability with effective extension effort is most important.

The mechanism to be used for making the first increase of seed following the breeder's seed multiplication is a vital step. The breeder may choose to control this second stage increase himself; but many countries are finding it desirable to utilise another organization or at least develop a separate wing for handling this "Foundation or Basic Seed" increase. In public breeding programmes the amount of Breeder Seed available normally is too small to divide among a sizeable group of seed multiplying agencies. In a competitive situation where a broadbased seed industry is to be developed, it is unfair and unwise to turn the Breeder Seed over to a single agency for making all subsequent increases when the research has been supported by public funds. The initial increase from Breeder Seed can, however, be made by one organization for the common good. Therefore, a special "foundation seed stock organizations or unit" can be very useful. Wheat researchers need to plan with others involved in crops research programmes because such an agency could handle a number of crops. After the Foundation or Basic Seed has been multiplied, a clear allocation policy is needed to assure that the next stages of seed increase are made by recognized "seed multipliers".

The kind of a Foundation Seed structure and its method of operation could depend upon the seeds to be handled other than wheat, the amount of seed needed, whether or not its role is to be national or provincial and the land resources available to it. Foundation seed increases could be handled on a contractual basis with selected farmers. The agency could operate its own farm or farms. It could be associated with an agricultural research institute or university but operated as a separate entity.

Such a Foundation Seed organization can undertake other activities for stimulating the development of the total seed industry. However, its objectives must be clearly defined and its activities limited to those objectives. The risk with such an organization can be its monopolistic tendencies and the subsequent temptations to attempt to carry too many responsibilities which work against the long-range objective of developing a strong, vigorous seed industry. Obviously, such organizations must have very capable

leadership and a properly trained staff.

The National Seeds Corporation in India functions as a Foundation Seed agency and was formed in 1963 primarily to fulfill this role for hybrids.

C. Commercial Seed Production, Processing, Distribution and Marketing

1. Who should do it?

During the 1970's many countries will make decisions affecting the future course of their seed production, processing and distribution programs. One of the basic questions centers around "Who will be responsible for this activity? Should the government attempt to do this entire job? Can Government handle this aspect of the program effectively? If the government does not undertake this activity, who should be responsible?"

One of the conclusions drawn by the Indian Seed Review Team was as follows: "Government should take appropriate measures for the development of the seed enterprises working on commercial principles in competition to ensure the supply of high quality seed to farmers at reasonable prices....Government should, therefore, through a policy declaration earmark a major role, encourage the development of cooperative and private seed processing, marketing and distribution organizations. As these organizations develop, departmental (Department of Agriculture), agencies, now engaged in the production, purchase and sale of seeds, should reduce their activities in this direction."

Similarly, Dr. G. F. Sprague (1971) has stated, "I do not know of a single government controlled seed enterprise which has been highly successful. For this reason, I would strongly favour private or cooperative seed enterprises." An FAO Technical Meeting on Seed Production, Control and Distribution (FAO 1962) emphasized a similar point by stating: "It was felt that in the developing countries seed production and seed distribution should gradually be taken over by non-governmental agencies, such as seed cooperatives, seed growers' association and private firms, provided an adequate level of quality control could be maintained."

...There are many problems inherent in the development of a sound and successful private seed industry in tropical and sub-tropical countries, but this is a desirable goal. Such an industry should be based on the profit motive to the seed producer and distributor."

Recognizing the limitations of government seed enterprises one also has to be aware of the concern about the limitations of other types of enterprises in the past as Eisele points this out in a paper entitled "The Seedsman and the Scales". He indicates that when seed became a merchandize in the 17th and

18th centuries in Europe, two tendencies diametrically opposed to one another were apparent. He states: "On the one hand there were many people dealing in seed who wanted to earn as soon as possible much money, even though they sold goods which were not in conformity with the quality they declared. On the other hand there developed at the same time a trend..... by enterprise that wished to supply good seed which should, if possible, be of a better quality than declared"

(Eisele 1971). One of India's leading seedsmen has said: "Seed business is not an opportunist business. It is a business that is built upon quality and service year after year. The cost of the seed is insignificant compared to the total cost of production of a crop. While good seed can bring rich dividends to the farmer, bad seed can ruin his crop. Naturally the seedsman who does not keep quality shall not be in business. He can cheat for one season but next season he shall be in the soup."
(Barwale 1969)

The objective, therefore, in developing wheat seed production enterprises should be for governments to place their emphasis on quality control systems that will help protect the developing seed industry from its less scrupulous members and assure the cultivator of good quality seed. Governments need to help the development of good, viable seed enterprises. They do not need to dissipate their limited resources in an activity which can best be handled by a large number of small-scale enterprises consisting of their own farmers and small businessmen. By spreading the responsibility among a large number of enterprises, governments can be assured that the seed industry will become efficient, quality-oriented and not price seed at unrealistic levels.

2. Many growers and dealers involved

Although emphasis has been placed upon seed enterprises, it is recognized that such bodies would deal with a number of other people. Many seed growers can multiply seeds under contract for seed enterprises. Individual smaller growers may not have the interest or the capacity to process and market their own seed but would be very capable as seed multipliers. India has several thousand such growers supplying seeds to organizations for processing and further distribution. At one stage, many of these seed growers were supplying seeds to state governments, but the trend is currently very much away from the state government acting as the purchasing agent of their seeds. Some countries had special agencies such as Cereal Boards responsible for much wheat seed distribution.

Seed enterprises developed in the 1970's need to assume the responsibility for processing, treating, bagging, tagging and

storing the seed. The seed enterprise also should assume the risk of finding markets for the seed produced and for organizing a distribution and marketing system that will carry the seed to the farmer.

Most seed enterprises do not have the capability or desire to assume full responsibility for marketing all of their own seed directly themselves. For this reason, many dealers, such as marketing cooperatives, private shops and organizations, and leading farmers may become involved in selling seeds under special distribution arrangements with the seed enterprises (Douglas 1969). Organizations that succeed in the 70's will be those that can most successfully develop adequate distribution and marketing systems to assure that seeds produced and processed are sold profitably. Even semi-government operations in India, such as the Tarai Development Corporation and the National Seeds Corporation, are finding it desirable to organize their distribution systems through either sole distributors in specific areas or to arrange for retail dealers.

In some countries special provisions are made for "Cereal Boards" acting for government or the government to purchase most of the wheat seed from seed enterprises or seed multipliers. Although this procedure has some merit, especially in the introductory phases of a programme, the long-term objective should be for the seed enterprises to carry more and more of the direct responsibility for distributing and marketing their seed. As long as they are totally dependent upon a "Cereal Board" or government they fail to develop adequate strength of their own for marketing seed and fail to be as responsive to the market as they should be. When "seed multipliers" do not have their own identity in the market, they may feel less responsibility for the quality of seed being offered.

3. Needs of A Seed Enterprise

Traditionally the margins for seed enterprises handling wheat seed have been low. This results in the need for an enterprise to handle large volumes to have an economic operation. In many cases, however, seed enterprises should consider not only the sale and distribution of wheat seed but also other kinds of seeds and inputs that would complement their programme.

As was indicated earlier, farmer seed multiplication can be very useful in the initial stages of developing a programme and in identifying those individuals with capability for forming viable seed enterprises in the future. Many good farmers can become good seedsmen. On the other hand, definite limitations often exist. Because seed multiplication is often a secondary interest, the farmer may not place adequate attention on seed quality, on processing, treating and storing the seed adequately. He frequently does not have the marketing skills needed to effectively retail his seed. Farmers generally are very willing to wholesale seeds multiplied, but are not interested in distribution and marketing at the retail level. If a farmer seed multiplication programme is to be used extensively, attempts

should be made to develop complementary seed distribution and marketing organizations capable of effectively carrying out these operations.

Developing effective seed enterprises is not easy. Successful enterprises should include the following:

1. Strong local leadership and managerial ability
2. The availability of technical personnel for supervising, production, processing and marketing.
3. Seed processing equipment available.
4. Capital available for investment in processing facilities
5. Sources of credit to supplement the equity of the organization to purchase, process and hold the seed until it is sold.
6. Financial viability.
7. Suitable production areas.
8. Potential for growth and development of market outlets.
9. Other related interest that can complement the seed enterprise and help assure its success.

Although building successful seed enterprises is not easy, it is wrong to assume that it cannot be done. A few major private enterprises and semi-government organizations are operating in India and appear to have every chance of succeeding. They are building their own marketing systems. They have processing plants. They are utilizing a large number of seed growers and are selling good-quality seed.

Seed enterprises around the world have often started with meagre origins. Farmer-seedsmen with little more than a keen interest in good seed have developed vigorous enterprises. Seed villages offer a way to start small programmes. The emphasis needs to be on utilizing the best resources at hand and helping many enterprises grow as rapidly as possible. Seed enterprises need to consider the potential market in the region--not just within their own country. Similarly, governments should think and plan production programmes on a regional basis where the country's own potential market is limited.

The possibility of seed enterprises from outside the country making a significant contribution to the seed increase programme is often considered. Organizations considering collaboration are usually much more interested in the hybrids of maize and sorghum, vegetable seeds and forage seeds than wheat. Foreign companies normally would not be interested in developing a programme for wheat seed multiplication only. They might, however, make wheat seed multiplication and distribution a part of a larger programme involving other crops. The Indian Seed Review Team (GOI 1968) recommendation on this point was as follows:

"The Team is of the opinion that foreign collaboration with advanced countries would benefit (i) research in breeding programmes; (ii) processing techniques; and (iii) marketing

techniques. But the main attraction would be in the breeding and research programmes and the availability of breeding material. In certain crops where private research is very strong in foreign countries, foreign collaboration would be particularly useful. The terms of agreement should be liberal enough to attract foreign seed companies."

Each government should assess its position in this regard and clearly state its policies so that foreign firms can make judgements in regard to whether or not it will be worthwhile for them to undertake a programme in a specific country. Their choices among countries are great. They have limited qualified personnel for international programmes. Their funds are limited and, in some cases, they feel the risks are great. Therefore, countries and local seed enterprises expecting to use foreign expertise from private companies abroad need to carefully assess the kind of opportunities they are offering.

Because of limitations in this regard, it is clear that the bulk of the wheat seed multiplied in most countries will have to be done by indigenous enterprises. Nevertheless, the experiences of existing, more developed companies should be utilized to the maximum extent possible.

D. Dynamic Extension & Information Programme Needed

One of the key roles of government agencies in helping a viable seed industry evolve relates to their ability to provide good information on the variety of seed to plant, where it's available and the practices needed to maximize yields. Extension programmes should be free of supply responsibility of seed and other inputs in order to successfully carry out needed educational and demonstration work. Extension agencies often become involved in the supply of seeds in new programmes because no other means exist. However, their objective even in these cases should be to find and develop other means just as quickly as possible. As they assist seed enterprises to form and identify seed distribution points, a close relationship should continue to exist between the two. The extension staff needs to know where supplies are available, utilize seedsmen's assistance where possible in arranging for meetings and training programmes with farmers and in conducting demonstrations. In other words, many potential areas of cooperation exist between the extension staff and seed enterprises. Seed enterprises should do everything possible to build this bridge to assure that their efforts do complement local government agencies to the maximum extent possible.

E. Quality Control in Wheat Seed Multiplication and Distribution

Governments can be most effective and instrumental in assuring the proper development of a good-quality control programme. They should assure that a good seed certification system exists, that seed testing facilities are present and that at the appropriate time a seed law enforcement programme is brought

into being. Seed enterprises also need to provide a quality control system within their own organization. They cannot and should not rely totally on external assistance in this regard, but, instead should develop their own means of assuring that only good-quality seed is sold by them. It is not enough to just tag seed. The quality control programme within the organization must assure that the seed is as good as the tag indicates.

1. Seed Certification

Seed certification means different things to different people. However, its main purpose can be divided into three primary categories:

- a) A systematic increase of superior varieties.
- b) The identification of new varieties and their rapid spread as genetically pure seed.
- c) The continued supply of comparable material by the constant increase and maintenance of properly multiplied and identified varieties.

Such a programme should be voluntary and should put emphasis on those varieties which are most promising.

Many countries are in the process of initiating and building seed certification programmes. These programmes obviously have value not only for wheat but for many other kinds of seeds. If wheat is the primary crop, wheat could easily be the first crop brought under a seed certification programme. Those associated with wheat could assume leadership to assure that a sound programme is established. It is important that those involved in developing a program set clear, achievable objectives. Specifically, this could include the following seven points as stressed in a recent paper on seed certification (Douglas 1972):

- a) A clear separation must exist between agencies responsible for seed production, seed law enforcement and the authority charged with seed certification.
- b) The authority must have adequate flexibility to assure that timely and thorough inspections are made to assure that seeds have met predetermined genetic purity and other quality standards.
- c) The authority should be able to build and maintain a staff of "seed specialists" since seed certification is work that cannot be handled by many unqualified and untrained generalists.
- d) The program should be service-oriented so that it does win the interest, support, and confidence of seed growers, producers, processors, sellers, and buyers.
- e) It should assure that uniform standards and tagging exist throughout the country concerned and that the program operates in such a way that certified seed can move not only within the country but outside with ease.

- f) The authority should assure that a reputation is built and maintained for certified seed so that it is readily accepted by seedsmen and the public in general.
- g) The program should be built in such a way that it can be accepted internationally.

Points of emphasis normally included in seed certification standards are given in Table I. As stated in a technical guideline titled Control of Production and Distribution of Seeds (FAO 1969): "These standards should be set at such a level as to maintain proper seed supply and may be subject to amendment under exceptional circumstances."

TABLE I. Points of Emphasis Normally Included in Standards*.

Activity	Standard
Field Inspection	Varietal purity, isolation, seed-borne diseases, weeds.
Precontrol, and Postcontrol Tests	Varietal purity and seed-borne diseases.
Seed Quality Tests in the Laboratory	Varietal purity (as far as possible), analytical purity (Including particularly weed and other crop seeds), seed health, germination and moisture content.

*F.A.O. 1969

The seed certification standards developed and applied in any particular country should relate to the level of purity achievable in the country and the ability of the seed enterprises involved to produce seed of the desired quality. In other words, the standards should be realistic.

More attention is needed in the 1970's to developing standards for regions of the world where many factors are common. This will facilitate the establishment of programmes and the movement of seed within the region.

2. Seed Testing

As a part of the over-all quality control programme, many countries and seed enterprises will establish seed testing laboratories in the 1970's to measure the viability and purity of seeds. No meaningful quality control programme can function

without having seed testing as an integral component of it. Moisture tests, tetrazolium evaluations, seed health tests and special genetic purity tests may also be a part of a seed testing effort.

During the 1960's many countries have become a part of the International Seed Testing Association (ISTA). ISTA has put more emphasis on tropical and sub-tropical areas. These very desirable trends will, undoubtedly, continue. Countries need this link in order to help achieve uniformity in testing methods, to add credibility to tests on seeds for export and to keep abreast of the latest research in this discipline. Even more emphasis is needed to achieve good working relationships on a regional basis.

3. Seed Legislation

Seed legislation assumes many forms throughout the world. Individual governments have developed seed legislation to meet a number of different objectives (I.S.T.A. 1967). Seed certification, as indicated earlier, should be voluntary and developed to assure high genetic purity requirements are met. Therefore, it can be undertaken in any country without seed legislation. However, at some point, most countries ultimately feel a need to officially recognise their seed certifying authority or authorities through some form of seed legislation. This can be one aspect that many countries may want to consider during the 70's either individually or on a regional basis.

Recognising that all seeds cannot be certified, seed legislation that requires the truthful labeling of seed and, perhaps, seed above certain minimum limits of germination and purity can be extremely useful. Seed legislation has its greatest value where a large number of seed enterprises are being encouraged and the governments involved want to develop a good, broad-based seed industry. If all of the seed is to be distributed by government, it is doubtful that seed legislation either at the distribution point or for seed certification purposes would be of much value. Theoretically, quality control could be assured by administrative orders to government or semi-government officials in this situation.

Assuming a number of seed enterprises are being encouraged, careful framing and proper implementation of seed legislation should assist the development of a good seed industry and not create a government bureaucracy that will hamper its growth. New seed enterprises have enough problems in becoming established without unrealistic restrictions that will prevent their rapid growth. The objective in the 70's is to help the industry grow. Seed law enforcement officials should be operating with good seed quality control through education as their primary objective.

The ultimate purpose of seed legislation is to provide more good quality seed to cultivators (Douglas 1971). It will not result in dramatic changes in the quality of seed sold in one

season. If the program is implemented properly, gradual improvement will be made. It should free governments of much of the responsibility of the final steps of seed multiplication and sale. They can concentrate on quality control and devote their main resources to other problems of major importance to the country. Because of the need to move seeds between countries much more emphasis is needed in the 70's in achieving at least regional uniformity in the development of seed legislation.

F. TRAINING PERSONNEL

Seed production, processing, distribution, marketing, testing, certification and law enforcement all represent specialities. Most colleges and universities train graduates in genetics, plant breeding, agronomy and related subjects, but do not deal with the specifics of seed technology. For this reason, a developing seed improvement programme must be supported by specialized training to assure an adequate group of knowledgeable personnel. Training can be done within the country or on a regional basis. Benefits can also be derived from training in more advanced programmes for a few selected individuals. However, the main responsibility for training must be carried within the country or region concerned. The wheat research specialist can be instrumental in initiating effective training programmes. He certainly must be involved in assisting training programmes.

Depending upon the seed production programmes within a country, persons sent to CIMMYT or to more advanced programmes for training in crops research could also benefit by a limited special emphasis on seed multiplication and distribution needs. So often the leadership in wheat programmes are very capable as plant breeders and agronomists, but they have received very limited or no exposure to seed multiplication and seed distribution programmes. This has special relevance where a programme is just starting and the wheat researchers will need to assume a special leadership role in getting seeds multiplied initially.

Training has been one of the special emphases of the Indian Agricultural Programme of The Rockefeller Foundation. In cooperation with the National Seeds Corporation, the Indian Agricultural Research Institute, and various other foreign agencies in the country such as U.S.A.I.D., the Ford Foundation, F.A.O. and U.N.I.C.E.F. Fifty-one training courses have been offered during the last 10 years. The number of trainees from these programmes now exceeds 1,200. These people form the base upon which tomorrow's seed industry will be built. Table II summarizes the kinds of training carried out.

TABLE II. Coursewise Summary of the Trainees (July 1961-Feb. 1973).

S.No.	No. of series held	Kind of group	Total no. of trainees in a group
1)	28	Seed production, processing and certification	749
2)	9	Seed Testing	167
3)	7	Vegetable Seed Production	168
4)	2	Seed Development Officers	25
5)	1	Agricultural Engineers	8
6)	4	Seed Law Enforcement (Seed Inspectors)	109
Total	51	Grand Total	1,226

Training materials need to be adapted to the local country or regional situation. Some of these need to be translated into the major language in the area. In the early stages of the Indian programme, a Seed Testing Manual (Chalam, Singh, Douglas 1967) and a series of mimeographed publications were prepared on Seed Production, Seed Certification and Seed Processing and Storage (National Seeds Corporation and The Rockefeller Foundation, 1967). These have more recently been replaced by printed publications as follows:

- 1) Seed Storage and Packaging - Applications for India (Harrington and Douglas 1970)
- 2) Seed Processing (Gregg, Law, Viridi and Balis 1971)
- 3) Seed Marketing (Law, Gregg, Young and Chetty 1971)
- 4) Field Inspection Manual (Mehta, Gregg, Douglas et al 1972)
- 5) Indian Minimum Seed Certification Standards (Central Seed Committee, 1971)
- 6) Seed Processing Plant Operator's Handbook (Viridi, Gregg, Saakaran, 1972)
- 7) A Handbook for Seed Inspectors (Ministry of Agriculture, 1972)

The special emphasis in training programmes should be on "learn-by-doing" as much as possible. This means that seed testing and seed processing facilities need to be available. In the case of seed certification, training for wheat inspections should be conducted when wheat is in the field so that actual roguing and inspection procedures can be carried out by the trainees themselves.

G. Favourable Economic, Political and Social Conditions and Policies Needed.

Seed production and distribution need to be economically sound if a vigorous seed industry is to develop. This will hinge in part upon the economic advantages for producing wheat grain by the cultivator. If the farmer is not compensated adequately for the wheat he produces, his desire and ability to purchase wheat seed is very limited.

Seed enterprises, especially foreign enterprises, look critically at political stability in making judgements for their possible future in a country. Governments should be careful that seed production efforts are not entangled in political considerations within the country. Seed production programmes may need to meet long-term political objectives, but they should remain clear of operating to achieve short-term political expediencies. This has been a problem in some countries.

Basically, seed enterprises are small-scale industries and can benefit many seed growers, agricultural workers, seed retailers and ultimately the farmer. Therefore, for them to develop under a competitive situation is most desirable. Such an industry can meet social objectives in many countries without the programme being under direct government control and management. Unlike banks, steel and transportation, it normally does not and need not represent a few pockets of wealth, but rather would be a very diverse industry with opportunities for acceptable profit margins scattered throughout the economy. It must be recognized, however, that seed production and the enterprises related to it must deal with the more progressive farmers and the business community in order to achieve the high level of management efficiency and skill that is needed. Social objectives should not be carried to the point of insisting that every small tenant farmer attempt to be a seed producer. This is not feasible and does not recognize the requirements of the industry.

V. Organizing To Achieve Objectives

Although progress has been made in seed production and technology in many countries, much of the present effort is without clear long-range planning on the part of these countries and lacks coordination among donor agencies. Trained personnel are lacking and a seed industry needs to be built in many countries. Building a sound seed improvement programme requires a well-conceived plan and a continuous long-term input.

International agencies such as U.N.D.P., F.A.O., The Ford Foundation, The Rockefeller Foundation and various governments have supported seed improvement projects. These are usually on an individual country basis. Occasionally two or three organizations assist unrelated or similar projects within the same country. Many projects as well as the tours-of-duty of seed specialists are of a limited duration--three to four years.

Seed specialists in developed countries are usually experienced in only some of the sub-disciplines of seed technology--seed production, seed quality control, seed drying, processing and storage, seed business management or seed marketing. A team of three or four specialists could make the most effective contribution to developing seed projects.

The developing countries, the donor agencies and the seed specialists

would all benefit if a more rational coordinated approach could be developed. To provide a hub around which a good seed programme can evolve, it is proposed that key regional locations be developed from which a strong seed technology supported base can develop. Seed specialists working in and out of such locations can achieve desired seed programme objectives in countries throughout a region. Specific activities would include:

- 1) Provide consultancy services to governments and donor agencies.
- 2) Assist in individual programmes and projects.
- 3) Offer meaningful training to government and nongovernment personnel.
- 4) Function as a center of information for and about the region.

Donor agencies should assess their present seed improvement assistance and decide how their limited resources can be most effectively used to support such action. Country-oriented projects would still be needed, but they should relate well to the overall country plan and be complemented by the regional center (Douglas 1972).

VI. SUMMARY

The 1970's will be a challenging period for the development of sound seed production, processing and distribution programmes for wheat. The growth and development of such programmes should not be left to chance. They cannot be built in a day but need to be properly phased. Wheat researchers must be concerned about the development of this aspect of the programme if their "new models" are to perform and sparkle in farmers' fields. It is their responsibility to help train personnel and encourage adequate steps to develop strong seed enterprises. The development of a total seed industry must rest upon a strong wheat research base. Many seed enterprises of various sizes and organizational composition are needed. No one size or one organizational pattern will fit all situations. Enterprises dealing with wheat seed should also diversify and supply seeds of other kinds needed in the area. It is important that developing seed enterprises work closely with extension programmes and support them in the promotion of a "package of practices" that can result in the most profitable opportunities for the farmer.

Assuring that good-quality seed reaches the farmer is in the interest of both the seed enterprises and governments. Governments should assume leadership in assuring that a meaningful, voluntary, seed certification system is developed; that modern testing facilities are built and that a seed act is ultimately developed to support the programme. All of these measures should be framed and developed in a progressive, positive manner so that they do truly assist and encourage the development of a viable seed industry. In no way should they be designed to restrict or hamper the development of good seed enterprises. Annex II shows the main components and their relationships.

Trained personnel are needed at all levels. It is not enough to assume that a college graduate is well-informed on all aspects of seed technology. Although some training can be done within countries, more could be done regionally. In a few cases, training opportunities outside the region should also be used.

Both the production and sale of wheat seed by seed enterprises and of grain by farmers must be to their economic advantage if the programme is to grow. Political stability and an opportunity for a seed enterprise to develop free of political entanglement is necessary. The seed industry can contribute to the long-term social objectives of helping a large number of people, including farmers, to have a more satisfying life.

It must be recognized that all components discussed cannot be built in a year. Priorities should be set and the long-term programme phased to achieve the desired objectives. The establishment of key regional locations from which a continuing consultancy and training effort can be mounted would be extremely useful in many areas. It is difficult to provide first class opportunities within each country for this kind of programme development. Time, money and specialists available do not justify undertaking special seed projects country by country.

Our ultimate goal in the 1970's should be more, better quality wheat seed of first rate varieties to more farmers.

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ANNEX I

DEFINITIONS OF TERMS

Terms used in seed programmes carry slightly different meanings in different parts of the world. For the purpose of this paper the following are definitions of terms used:

Variety Recommendation

The process of encouraging the use by farmers of a variety or hybrid (cultivar) which has been found, usually by a special committee or research group, to have certain desirable qualities. Often related to such a recommendation is a systematic seed increase through seed certification as suggested in this paper.

Seed Quality Control

Any method to help assure that good quality seed reaches the buyer. An internal quality control programme may be developed by a seed enterprise to assure that good quality seed is distributed. External quality control programmes relate to measures applied by agencies outside the seed enterprise to assist in assuring that good seed reaches the seed buyer.

Seed Legislation

Legal documents prepared by governments for the purpose of providing an enforceable external quality control programme on seeds. Such legislation usually provides a legal base for a voluntary seed certification activity or a mandatory truth-in-labeling program or both. Prior to adoption by the authoritative governmental body it is called a Seed Bill. After adoption it becomes a Seed Act.

Seed Certification

A system used to keep pedigree records for crop varieties and to make available sources of genetically pure seed and propagating materials for general distribution. Seed increased through this programme is multiplied through a series of steps identified as Breeder Seed, Basic Seed and Certified Seed. All steps must be inspected in the field and in a seed testing laboratory before a certificate or tag is issued showing complete "certification".

Breeder Seed

Breeder Seed is seed or vegetative propagating material directly controlled by the originating, or in certain cases the sponsoring plant breeder or institution and which provides the source for the initial and recurring increase of Basic Seed.

Basic Seed

Basic Seed is seed stocks that are so handled as to most nearly maintain specific genetic identity and purity. It is the source of all Certified Seed classes.

Certified Seed

Certified Seed is the progeny of Basic Seed or of Seed certified earlier when it is so handled to maintain satisfactory genetic identity and purity and it has been approved and certified by the certifying authority.

Seed Law Enforcement

The means used by governments to assure that the provisions of their Seed Act are adhered to. Special emphasis is usually placed on assuring that all seed sold commercially, certified and non-certified, has been truthfully labeled and that the provisions related to certified seed are met at the time of sale.

Seed Certification Standards

Standards are criteria against which seed eligible for certification is measured. They should be officially recognized and are usually established by a committee. Such standards normally include factors related to genetic purity in the field and germination, physical purity and moisture content in the seed testing laboratory.

Seed Testing

The evaluation of seeds in a laboratory to assess their germination ability, physical purity and moisture content. These tests are usually done to determine if seeds have met seed certification standards, or if they have been properly labeled as required by the Seed Act. Tests may be done on a "service", non-official, basis for farmers as they evaluate their own seed and for seedsmen to assist their proper labeling of seed lots.

Seed Enterprise

Any government or non-government organization involved in the production, processing and/or marketing of seed.

Seed Industry

The entire complex of organizations and individuals associated with the seed programme in a country. A more restricted definition often used relates to all seed enterprises involved in the seed programme. The latter definition is applicable in this paper.

Seed Production

All aspects concerned with the growing of a seed crop.

Seed Processing

Those activities needed to maintain or improve seed quality from the field until the seed is bagged. These include threshing, shelling, extracting, drying, cleaning, grading, treating with an insecticide or fungicide or both and packaging.

Seed Distribution

The system and method used for moving seed to the buyer.

Seed Marketing

Those measures taken and activities used to sell and distribute seed to the consumer.

TESTING, MULTIPLICATION AND PUBLICITY FOR
NEW VARIETIES IN PUBLIC BREEDING PROGRAMMES

STEPS TO BE TAKEN	FIRST YEAR	SECOND YEAR	THIRD YEAR	FOURTH YEAR	FIFTH YEAR	SIXTH YEAR	SEVENTH YEAR
TRIALS	FINAL VARIETAL YIELD TRIALS ON RESEARCH FARMS AFTER PRELIMINARY TRIALS INDICATE SUPERIORITY						
TRIALS			TRIALS ON FARMER FIELDS				
BREEDERS MULTIPLICATION	BREEDER SEED ON RESEARCH STATION BY BREEDER						
REGISTRATION	APPLY FOR REGISTRATION *						
PRE-RELEASE MULTIPLICATION	FOUNDATION SEED INCREASED ON FARMS OF FOUNDATION SEED AGENCY						
RELEASE	RELEASE BY VARIETAL RELEASE COMMITTEE **						
POST-RELEASE MULTIPLICATION	CERTIFIED SEED MULTIPLIED BY SEED GROWERS OR SEED FIRMS						
SEED TO FARMERS	CERTIFIED SEED TO FARMERS FOR COMMERCIAL CROPPING						
PUBLICITY	NO PUBLICITY		PUBLICITY BEGINS		PUBLICITY INTENSIFIED		
EXTENSION EDUCATION				EXTENSION BEGINS	EXTENSION EDUCATION INTENSIFIED		

* TENTATIVE DECISION TO RELEASE—INFORMATION SUBMITTED TO CENTRAL SEED COMMITTEE FOR INCLUSION ON NATIONAL REGISTRY BASED ON DISTINCTNESS

** RECOMMENDED FOR RELEASE BY BREEDER OR COORDINATED PROGRAM—OFFICIAL RELEASE BY STATE OR CENTRAL VARIETY RELEASE COMMITTEE AND ADVANCE PUBLICITY INDICATING WHEN SEED WILL BE AVAILABLE

DISCUSSION

Da Silva

Several countries have seed laws recognizing the rights of the breeder. Breeder's rights are recognized in many countries of Europe, in the U.S.A., and in Argentina they are studying such a law. In many other countries these laws do not exist. There is naturally an advantage in interesting private breeders in breeding new varieties. They have accomplished much in many fields, including wheat. There are, however, it seems to me, many disadvantages. When you have a private breeder doing breeding, you have to have an organization for testing the material and making decisions on whether a line is to be released. They must ensure that this material can be differentiated from others. As a consequence, the material must be very pure, and be very uniform for characters that are unimportant agronomically. Thus, this may cause a delay in the release of varieties for 3 to 4 years. This slows down the utilization of the varieties by the farmers. There are real advantages and disadvantages.

Smith

As you mentioned, in the U.S.A. they did recently pass the Plant Variety Protection Act into law. As I understood it, one thing it will do, hopefully, is stimulate private companies to get into plant breeding with sexually produced crops. In the case of wheat, a farmer can buy one bushel and not have to, theoretically, replace that seed repeatedly as his source of seed. If a company is developing varieties, they can ask for protection under this law. To get protection, which I understand is essentially a patent, they have to prove it is a unique variety and also show that it is very stable, which is a second problem. However, once the farmer buys the seed, he can in turn sell the seed to his neighbor without paying a royalty even though it is covered under the law. He can sell it to anyone as long as it does not cross state boundaries. If it is sold at an elevator and resold from there to another farmer, a royalty must be paid if it is covered under the law. I think perhaps the law will be extremely difficult to enforce. Thus far there has been no litigation. Several varieties are already covered under the act. I think it, in most cases, would have to be a civil action of the developing country against the violator. It is not likely to be enforced easily, at least in the initial stages.

Douglas

I did not mention breeder's rights because I did not think it appropriate at this stage. When we do not even have seed organizations in many countries, it seems premature to think of breeder's rights. We may just as well delay the process of worrying about these. Certainly, at some point in time some countries need to decide on some type of program, but at this stage where much of the work is done with public funds or through institutes, it seems to me we should concentrate on more meaningful areas. This also applies to concern regarding seed legislation. This may not be the best thing to do first in trying to build a seed program. It is only when one thinks of getting a number of organizations underway and you think legislation will encourage them, not restrict them, then it may be necessary to have the necessary legislation.

Anderson

In general, there will be a restriction on the exchange of genetic materials if a breeder's rights law is passed. From this standpoint, I as an individual and I believe we as an organization would be against this in principle since we are working toward an even freer exchange of materials in the interest of the public in all countries. We should not like to see this movement proliferate rapidly.

As a second point, there is a danger, when we go into such a system, we may end up with a paucity of institutions who are engaged in plant breeding for teaching new plant breeders. I think the day will come, if all breeding is assigned to the private sector, that we would not have plant breeders graduating from an institution with a background that is sufficiently developed to give them the best education.

Eslick

Regarding foundation seed, the thing that worries me is that usually varieties are a heterogenous mixture of homozygous types. Relatively inexperienced people, of whom we have many in the United States, really don't know what went into the variety or what should be retained in it and in the process of going into a field and picking out plants one can shift that variety from what it is. In the same way, it could affect multilines, particularly when one wishes to maintain a certain proportion of each type. To avoid this, I sometimes feel the breeder has the responsibility to increase the 100 or 500 lines and then bulk these to serve as the foundation seed. I do not know the philosophy of CIMMYT or the other groups, but one can shift a variety very easily.

TECHNOLOGICAL ASPECTS OF CEREAL PRODUCTION CHANGE

Ignacio Narvaez M.

With the development of new plant varieties with different architecture and different water and fertilizer requirements as compared with conventional types of plants, many technological problems have originated that in turn have provoked a series of changes in the whole system of cultural practices in all the phases of development of the crop from seedbed preparation to harvesting operations.

The new plant types that I am referring to are the semidwarf varieties of wheat, barley, oats, rice, corn, etc. Probably the most dramatic change in cereal production in the entire history of agriculture has happened during the last decades, first with the cultivation of the first semidwarf wheat varieties and secondly with the dwarf types of IRRI rice varieties also characterized by shorter and stiffer straw as for wheat. These changes can be very well illustrated by production trends of wheat in México and rice in Pakistan very well known by all of you.

The agronomists, both those engaged in research as well as those in extension, must be aware that the most difficult part of the technological aspects in cereal production change is not in the techniques themselves that involve the manipulation of all the production factors such as the adjustment of inputs, calibration of agricultural implements, consideration of different economical calculations, etc., but rather the difficulty is in the minds of the people involved in agricultural activities.

It has been observed that whenever there is a need to introduce for the first time new technology in a country, an immediate rejection or negative reaction is generally developed among scientists and government officials and, less frequently, among the producers more directly involved with the use of the said technology that causes the change in agricultural production. This fact appears to be a universal phenomenon probably associated with the personal prestige or nationalistic feelings of the breeders and/or; the state of development of research and extension, that instead of activating the reaction or development or positive change in production, prevents it from happening.

The development of any kind of technology, when applied in the same place where the research was conducted, implies very little or no problem at all.

In many instances the lack of information regarding the performance of new varieties and availability of new technology prevents changes in cereal production. This lack of information or exchange in communication among scientists of different nationalities is already a serious problem due most probably to language barriers or geographic distances. In this regard there is some justification, but it is certainly unjustifiable when within a given country the advances of science rest inactive in the files of the research station or the scientists themselves.

The analysis of the technological factors that I am presenting to you are mostly based on personal observations and without presenting the specific bibliographic references. They are only ideas or questions

that demand more concrete answers or probably more intensive research under the different environments where cereals are cultivated.

An urgent call is therefore here proposed for research people to join efforts with the extension agents to find the solution to the problems in a more extensive manner.

The system of microplot variety trials and the semicommercial trials established in Pakistan during the last eight years has paid excellent dividends. Similar efforts are being initiated here in Mexico with the joint effort of research and extension.

Technological Aspects

I am not going to attempt to present the analysis of all the technological aspects involved in cereal production, only a few are given for illustration purposes and discussion with the aim of finding adequate solutions to them.

Plant Variety

The variety of a crop could be considered as the most important of the technological factors that generate change in production. Any other modifications of technology, such as cultural practices, water uses, and modifications in the use of other inputs, are just as important as the variety but they could very well be considered of secondary importance. The manipulation and adjustment of all the interrelated technological factors are strictly associated with the yield potential of the plant variety. Therefore, the variety should be considered as the catalyst, or the most important ingredient of the reaction that generates change in production.

Even when the dwarf varieties have shown wide adaptability to almost any environment, there still exists resistance of some farmers to using them, as in the case in rainfed areas. Do we have to go back and recommend the tall wheats for dryland regions?

With few exceptions, most of the wheat breeders of today are concentrating their efforts on producing only varieties with high yield potential and no attention has been given to develop varieties capable of feeding some cattle and also produce a decent grain harvest. There is an urgent need for wheat varieties that can be used for grazing purposes and capable of producing a good crop of grain. There is an increasing number of farmers in northern Mexico who are doubling their economic returns by grazing and harvesting grain, even with dwarf varieties such as Nadadores 63 and Siete Cerros 67.

Use of Fertilizers

With the development and commercial cultivation of the dwarf types, drastic changes have occurred in formulating traditional doses of fertilizers normally used with the conventional tall varieties. Formulations of N-P-K such as 20-20-00 or 40-40-00 have become obsolete as the new dwarf varieties become more and more popular.

Using higher rates in commercial wheat production in México, for example up to 200-100-00, are becoming the rule rather than the exception. There are cases reported of farmers applying more than 250 kg of nitrogen with satisfactory economic returns; this, of course, is happening in very nutrient-depleted soils and with an adequate supply of water.

Have we found the optimum levels of fertilizers for the new varieties?

Until now emphasis has been limited on increasing the levels of the major elements and little or no attention has been put on studying the performance of the high-yielding varieties with the addition of minor elements. This is an important aspect that should be studied more closely, particularly in those cases where the commercial yields appear to have reached the upper limit.

The possibility of fractioning the application of high doses of nitrogen and foliar applications of this element during the early stages of plant development is another area of research that needs more attention. The dramatic response that has been observed in rice with the application of very small quantities of zinc (one pound per acre of zinc sulphate) clearly suggests the need of expanding this area of research to other crops or areas that are already producing high yields.

Water Use and Management

In the case of irrigated crops the quantity of water as well as frequency of irrigations should be considered as one of the most important limiting factors of production that ought to be modified accordingly as the other production factors are adjusted to meet the requirements of high-yielding varieties. The demand of water or adjustments of the intervals between each irrigation may vary according to the amount of fertilizer applied and with the mechanical or physical structure of the soil, weather, etc., and most importantly, the relative water requirements of the variety as the grain yield potential increases.

For wheat, the amount of water and number and frequency of irrigations have been determined for most of the areas where wheat is irrigated. However, more information is needed when high doses of fertilizers are used.

For dwarf varieties of maize that are just being released to farmers more research under diverse environments is needed to find the optimum irrigation practices.

Cultural Practices

Although these factors are not as important as the others, it has been observed that depth of sowing and rate of seeding may influence the yield potential of a variety. At least for the new dwarf varieties the depth of sowing has been established not to be more than six centimeters. Beyond this limit, the stand of the crop, in most instances, becomes seriously affected.

It appears that the seed rate normally used with conventional varieties gives satisfactory results also with the dwarf plant types. As a general rule, with high seed rates, let's say above 150 kg/ha., the spike tends to reduce its size. However, there are wheat lines that even at 250 kg/ha. sustain the normal size of the head. This has been observed at the Agricultural Research Institute in Lyallpur, Pakistan.

This observations calls for more efforts in research in this direction.

The introduction of any or all of the technological factors mentioned above will never occur if they are not backed with adequate support of governmental officials directly concerned with agricultural development.

The application of research or experimental information by the farmers ought to be followed by proper credit policies, sufficient promotion, and ample and consistent demonstration of the new technological factors that are introduced for the first time. These demonstrations, if possible, should be conducted directly in farmers' fields and the benefits at the beginning should be dramatic, even when subsequent gains are less significant.

Planning and programing for production must be organized with coordinated efforts with most of the official and private institutions related to agricultural activities. If this coordination is not properly established, the effort exerted in promoting change in production will be miserably wasted.

THE ROLE OF CEREALS IN MULTIPLE CROPPING

D. M. Leeuwrik

Introduction

There are many references to multiple cropping from ancient times onwards. From the older references it would appear that the practice of multiple cropping with agricultural crops was always scattered and not very widespread. Even where the environment was favorable it seems to have been characterized as an exploitive practice, apt to deplete soil fertility and increase plant diseases, and it was not considered to be good crop husbandry. In many cases it was apparently only resorted to because of economic pressure on small tenant farmers under heavy burdens of rent and taxes. The basic farming system then was a grain-fallow rotation, which is still followed in many countries today and, without fertilization, is generally a cereal production system of low productivity. Low yields are obtained because nitrogen and other nutrients removed by the crops are not being replaced quickly enough nor in sufficient quantities.

Advances in agricultural technology have made it possible to crop more intensively and continuously without depleting soil resources or causing build-up of pests and diseases. Modern methods of irrigation and water management, fertilizer application, weed, pest and disease control and the availability of short-maturing, light-insensitive, productive varieties of crop plants have reduced the time required for the crop cycle and have lessened the dependence on any particular season. In addition, increased farm power and specialized equipment allow farm operations to be carried out more timely and with more precision, resulting in increased yields and a lower number of unproductive days in terms of crop growth. The present-day concepts of multiple cropping have their roots, at least partly, in the principles of rotational farming. The time frame required for a complete rotation has been, however, very much shortened. On the other hand, modern cultural and weed, disease and pest control methods have also resulted in highly successful, intensive systems of monoculture on a sustained basis.

In addition to increasing production and the income of farmers, multiple cropping has other advantages. One of the more important ones is the better and more constant utilization of labor throughout the year, leading to greater employment opportunities. Another benefit is that the risk factor in farming is spread over a wider and more diversified farming base, which is important to the small farmer with little capital, whose slim resources do not enable him to stand very great risks. Farmers the world over are always subject to risks due to (1) the weather, (2) pests and diseases and (3) price fluctuation. Multiple cropping will enable small farmers with few resources to participate in the fruits of technological advance in agricultural production.

Importance of Cereals in Multiple Cropping.

Because of the prime importance of reaching complete or virtual food grain self-sufficiency in many of the regions where multiple cropping could be employed as a strategy for increasing agricultural

production, cereals will continue to be the basic crops around which intensive practices will be built. Cereals will provide especially the small holder with his staple food requirements and give him economic stability. The introduction of other crops will further broaden his economic base and provide additional cash income. This will be particularly true for countries with high population densities and good potentials for irrigation. In countries where the population pressure is not so acute and where water is more at a premium, cereal production will probably be more confined to the rainfed areas.

To try to give an estimate of the increased production potential through multiple cropping would just be adding to the very broad and highly speculative statistics one finds in the literature today. Available estimates on existing and potential areas in the world amenable to multiple cropping are highly variable. And this is understandable if one considers the host of interacting factors that determine the type and extent of multiple cropping in any one area. However, considerable scope still exists for raising cereal production by increasing the number of crops per year from a given land area. Although the greater part of increased production of cereals will come from raising yields per unit area, it is not difficult to see how, where the level of technology is already fairly high, changes from single to double or multiple cropping could drastically increase the production output. After yields have been brought up to levels possible with the new varieties and improved farming methods, multiple cropping can add considerably more to the overall production increase, in areas where adequate, perennial irrigation sources are available.

Multiple cropping systems which include cereals are already being extensively practiced, although the total multiple cropped area appears to be small in relation to the total irrigable area. The practice is more common in the rice growing regions but wheat is steadily gaining ground. In most countries extensive cultivation is restricted to double cropping, although in some situations three or more crops can be, and are, grown. With the new, widely adapted and early maturing varieties the opportunities for cereal based multiple cropping have increased tremendously.

Throughout Asia rice is being double or triple cropped. In the irrigated areas of countries like China, Egypt, India and Korea both rice and wheat-based double and multiple cropping are practiced. Wheat followed by rice is also a common sequence in these countries as in Japan and its importance is increasing. This particular rotation, as well as the wheat-soybean rotation, so successfully grown in southern Brazil, would appear to have considerable potential in many areas, including the Caspian region in Iran.

Production Potentials of Cereals in Multiple Cropping Systems

The location- or situation-specific nature of multiple cropping makes it difficult to make generalized statements about the production potential of multiple cropping. For a realistic estimate of some of the production possibilities a closer look at multiple cropping in India is helpful. India, despite its diverse agroclimatic conditions, has temperatures that permit crop growth throughout the year in all but very few parts of the country. The existing irrigated area is about 20% of the total

cultivated area whereas the ultimate irrigation potential has been placed at somewhere near 45%. The population density is high, holdings are small and labor is generally plentiful and inexpensive. Against this setting India has recognized multiple cropping as one of its major strategies to increase agricultural production as well as employment opportunities and income of the rural sector.

A concentrated research effort to determine the production potential under different agroclimatic conditions found in the country has been conducted for a number of years under the aegis of the All-India Coordinated Agronomic Experiments Scheme. Although a great deal of specific information is available, the following general statement, extracted from its annual report, is of interest. "Generally, the results obtained over the last three years indicate that it is possible to produce 10 tonnes of grain/ha with 2 crops and 15 tonnes of grain/ha with 3 crops under good management conditions in different agro-climatic regions of the country." What is noteworthy here is that in India, with its diverse conditions, the production levels in different regions are very similar, almost irrespective of soil and climate, provided crops and varieties are carefully selected and latest farming techniques are followed. The Indian National Demonstration Scheme, which verifies and demonstrates the production potential of multiple cropping practices under actual farm conditions, also reports average production figures of 10 to 15 tonnes of grain per ha with 2 or 3 crops respectively. For instance, in 1969-70 the average grain production of rice followed by rice was 10.47 tonnes/ha; that of rice followed by wheat was 9.35 tonnes/ha. These are only average figures; the maximum production recorded with these two crop sequences during the year was 17.80 and 14.27 tonnes/ha respectively. The rice-rice-rice sequence yielded an average of 13.07 tonnes/ha (against 15.49 tonnes/ha in 1968-69) with a maximum recorded total production of 17.99 tonnes/ha. A record total yield of 24.28 tonnes/ha from three crops of rice in 316 actual crop days was reported from the Philippines a few years ago. This may have since been surpassed. On the whole, rice-based multiple crop sequences have given a higher total yield than those built around wheat.

Figures such as those above are respective of actual or potential production of large portions of the irrigated and high rainfall areas of Asia. In addition, there are large tracts of land in South America, Africa and the Middle East capable of growing more than one crop a year. When potential total yearly production figures are multiplied with the aggregate acreage potentially amenable to multiple cropping the result is indeed impressive.

Prerequisites For Development of Multiple Cropping

There is no doubt that multiple cropping as a strategy for increasing and diversifying production as well as providing greater rural employment opportunities and a more equitable distribution of income will receive increasing impetus in the years to come. For its efficient and widespread application, however, it will require a tremendous research and development effort, as well as the organization and provision of other necessary inputs and services for many small, individually managed holdings. A large number of staff will be involved in research and development because of the location-specific nature of multiple cropping.

Progress is likely to be slow unless concentrated action is taken

at the policy and executive levels to provide the necessary infrastructure and to undertake the large-scale developmental works that may be required and are beyond even the collective scope of the farmers. To give one example for successful multiple cropping individual farmers should be able to exercise fairly close control over the application of irrigation water. There are large regions where the increase of multiple cropping is impeded because the supply of irrigation water to individual farms is either inadequate, unreliable or both. Existing surface irrigation systems need to be modified and modernised to make them amenable to intensified and diversified cropping, keeping in mind a realistic compromise between the distribution and management problems of irrigation engineers and the requirements of farmers. This should also form an important consideration in the design of new irrigation projects. The exploitation and integration of ground water sources with surface irrigation should be expanded and farmers should receive encouragement and guidance to this end.

The pre-requisites for multiple cropping have been variously listed as:

- (1) Assured, year-round irrigation under a high degree of control by individual farmers.
- (2) Short duration, light-insensitive, high-yielding varieties of crop plants.
- (3) Availability of inputs like seeds, fertilizers, pesticides, etc.
- (4) Facilities for short-term credit.
- (5) Technical know-how and managerial ability for conducting the farm operation on a highly productive and profitable basis.
- (6) Adequate labor, both in quantity and quality.
- (7) Facilities for drying and processing farm produce.
- (8) Market facilities.
- (9) Guaranteed floor prices.
- (10) A continuing research effort to solve the problems of continuous, intensive cropping; to develop new varieties, practices and operational systems in order to maintain or increase productivity.
- (11) A competent and vigorous extension service to assist farmers to keep abreast of new developments.

Many of the biological implications of high intensity cropping have not been worked out. Much more information is needed regarding the long-term effects of continuous, irrigated cropping with heavy applications of fertilizers, herbicides and pesticides. Patterns of rapid removal and replacement of nutrients and methods of residue management have to be studied. Management systems for entire cropping systems rather than individual crops need to be perfected.

On the operational level, technology should be adapted to holdings of different sizes operating under different sets of resource constraints. The economics of various farming systems have to be brought to scale for most efficient use of available resources. At the same time it should be determined how in different situations limiting resources or production factors could be augmented or modified to further increase production and income. Moreover, it is important to demonstrate the advantages

of the new technology in a convincing way, particularly to small holders. The "small" farmer, unlike the "big" farmer, has neither the education nor the resources for much innovation on his own part. The dilemma here is that on the one hand, the practice of multiple cropping requires sophisticated technology and a high level of management. On the other, it is the type of agriculture that is expected to spread most rapidly on, and be most beneficial to, small labor-intensive holdings with few other resources, including managerial ability. It is clear, therefore, that under those circumstances a considerable amount of governmental or outside assistance and leadership will be required to promote the rapid adoption and spread of intensive multiple cropping practices. In addition to assuring the necessary inputs and price supports, farm planning and management services of a very high order, which are freely and easily available to the cultivator, are almost imperative. Only this will ensure that the intensification of crop production is achieved without accompanying deterioration of soil and other resources through exploitive practices resulting from lack of technical knowledge and managerial capacity.

The question of farm power and mechanization in labor-intensive production systems also should be more realistically appraised. Mechanization does not necessarily replace labor nor are the two always interchangeable in modern farming. In most multiple crop situations a certain amount of well planned mechanization is necessary to provide precision in the conduct and timing of operations as well as adequate power. Even in regions that are intensively farmed today a considerable amount of land remains under-utilized because of lack of sufficient power for certain operations during peak periods.

The issues raised above, as well as a number of other, could be explained at length in order to analyse the requirements to be met for realizing the increased production potential possible through multiple cropping. Suffice it to say that multiple cropping can be a means to considerably increased cereal production, just as the new varieties and technology can aid substantially in the further adoption and spread of multiple cropping. But the problems to be solved and the amount of work to be done in order to obtain a fairly extensive coverage of the areas suitable for intensive, continuous cultivation should not be underestimated. In the October, 1970 issue of Indian Farming the editor stated, "The provisional Indicative World Plan of the FAO--one of the most significant documents of this era--.....envisages an unprecedented disaster for the less developed countries by 1969 if we do not maintain a minimum of 3.5 per cent annual growth rate in cereals. We are no longer in terror of disasters. Because even the most well-intentioned statisticians do not take into account the possibilities of a giant heave of a determined human community. The speed with which our farmers took to the high-yielding varieties programme would not have gone into the calculations of statisticians. Instead of a disaster we are thinking in terms of abundance. It is in contexts like these we think of our multiple cropping programme." That was in 1970 when unprecedented production breakthroughs were made. Events since have pointed up the dangers of complacency and have brought widespread realization that the production battle has by no means been won. However, if the same spirit of optimism which was evidenced on the editor's page could be recaptured and put to work by various "determined human communities" to solve problems in the way of increased production, the battle will not have been lost either.

CIMMYT's Role

Productive capacity of land depends on a large number of interacting factors which are very specific to local conditions. Even individual fields on the same farm differ and therefore need different management for maximum productivity. Marketing opportunities also differ vastly in different localities. Furthermore, since technology, prices and market opportunities continually change, the generation of local information on which to base a profitable intensive agriculture in any region becomes a continuous process. It seems obvious therefore that most of the effort in furthering multiple cropping as a means to increase agricultural and cereal production lies with local research development organizations.

International research institutes can, however, assist a great deal in strengthening biological and economic research on multiple cropping and farming systems by placing more emphasis on the conduct and coordination of research in these areas, both at the institute headquarters and, more particularly, in their outreach programs. Of course, this has been recognized previously and many of the institutes, particularly the more newly developed ones, have this type of work within their terms of reference. CIMMYT also now has outreach staff involved in research on farming systems in our country programs. This work appears to be more concentrated towards problems of dryland areas, however, and could perhaps be expanded into the irrigated areas.

As far as multiple cropping is concerned, CIMMYT's main role during the coming years would probably lie in strengthening national programs by:

- (1) The continued development of disease-resistant germplasm useful for the breeding of "tailor made" varieties to fit specific requirements in tight cropping schedules.
- (2) The continued training of breeders, plant pathologists and, particularly, production specialists, since a tremendous number of competent staff will be required to mount local multiple cropping programs.
- (3) Aiding national workers in identifying situations where wheat or maize could profitably be introduced into existing or potential intensive crop systems and
- (4) Expand and broaden involvement in adaptive research on farming systems in outreach programs in both dryland and irrigated areas.

ECONOMIC ASPECTS OF CEREAL PRODUCTION CHANGE

Don Winkelmann

I have been asked to discuss the economic aspects of cereal production change. But rather than risk abject failure by trying to paint such a large elephant, I wish to concentrate on a single theme--the adoption of new technology in developing countries--and on a single aspect of that theme--the elements which induce a farmer to adopt new technology.

In the early 1950s those promoting development saw great opportunities for advancement in the marked differences in yields in the underdeveloped and developed countries. The obvious solution was to acquaint farmers in the undeveloped countries with the practices followed by their counterparts in the developed countries. To achieve this, it was thought necessary to emphasize extension programs in order to build channels through which information could flow to the farmers.

In time it became obvious that farmers in the undeveloped countries had little access to the inputs used by their counterparts in the developed countries so emphasis was then placed on credit programs. These were aimed at getting modern inputs, especially fertilizers and seeds, into the hands of the farmers. All the while there was in the minds of some, doubts that traditional farmers could be induced to change from their customary practices. Some saw those practices as having an intrinsic value to the farmer. Others considered the traditional farmer was not motivated by profit. For still others, the traditional farmers' behavior was not even purposeful. In any case, for those of these persuasions the farmers could not be expected to change their practices, even if the knowledge of new ones and the credit for their implementation were made available.

A member of this conference, Professor Schultz, was among the first to marshal evidence to support the view that traditional farmers are indeed purposive in their behavior. More than purposive, he argued, they managed their limited stocks of resources well. "Poor, but efficient," was his description of their behavior. Even so, however, the extension and credit programs had few notable successes--so few that planners were pessimistic about the possibility of inducing change among small farmers in general among less developed countries.

The seed-fertilizer revolution in India, Pakistan and the Philippines demonstrated that in developing countries farmers will, indeed, adopt new technology. The hallmark of this rapid change was a package approach. The system featured appropriate new technology mixed with a system for delivering information and inputs along with satisfactory markets. When all these ingredients were properly blended, traditional farmers manifested a ready acceptance of new production strategy, testifying to the willingness to change when change really suited their purposes.

What can we say about the experiences of more than two decades? First, the traditional farmer is progressive. He is purposive in his behavior. He is goal oriented. Secondly, he is sensitive to the nuances of the environment in which he is farming and that those traditional practices which he follows have evolved, for the most part, from generations

of trial and error in an essentially static environment. Finally, he will change his practices when he finds that such practices are suitable to his needs.

So much for setting the scene. It is that final phase that I would like to discuss--when he finds that the new practices are suitable.

Let's consider two consequences of the importance of shaping packages to suit farmers' needs. The first relates not only to the biologist, the agronomy specialist, but, and I think more importantly, to the policy maker interested in a rapid diffusion of new technology. This is the need for solid information on the farmers' decision environment. That information can tighten the link between the farmer, biologist and policy maker. The only results will be better policy.

In most developing countries, decisions on the use of existing agricultural resources are made by the farmer. This being the case, a new package of practices must be consistent with the farmer's end or he will not adopt it. It was the realization of the implication of this innocent point that first led some agronomists to shift from yield-maximizing recommendations to profit-maximizing recommendations. After all, what purpose does it serve to grow an additional 100 kilograms of wheat if that last quintal costs more than its value to produce? While it is fair to say that some agronomists have held out until quite recently before adopting the profit principle in shaping recommendations, it is now common to find that profit plays a dominant role in formulating new packages. Indeed, the modern agronomist is every bit as practiced in identifying the profit-maximizing combination of inputs as is his colleague in economics.

Maybe we have learned the lesson too well. If the package is framed only in terms of profit maximization, the assumption is that this is the only thing with which the farmer is concerned. Better yet, the assumption is that this goal so dominates all others that the others can be disregarded when making recommendations. Then, if a profit-maximizing recommendation has been formulated, and if the farmer has been informed through demonstrating the package, and further, if credit for the inputs are available, the farmer should adopt the recommendation.

But it doesn't always happen that way. We have some anomalies. On inspection, of course, some of these anomalies are readily explained, --the package was not really profitable, credit wasn't readily available and so on. Even so, anomalies remain. Some of the remaining cases arise because a second factor is playing a critical role in the decision making for farmers, especially those in rainfed areas of developing countries. This factor is the farmer's disposition to avoid risk and that itself is an outgrowth of his desire to survive. One manifestation of risk-averting behavior is diversification. A manifestation of its universality is the whole insurance industry. An example of its influence on crop breeding is the research for yield stability. Finally, when farmers persist with traditional practices, even though a new package of practices represents more profits on the average, this unwillingness to accept the new package might be a desire to avoid risk. Weather is variable, hence, risk occurs and the examples that I have offered are consistent with behavior in its aversion.

What might this mean for the formulation of recommendations? In some cases, happily, it will mean nothing, when agroclimatic conditions are such that risk is virtually eliminated. There is no problem. When the new package is better than the old one, no matter what the state of nature or the markets, there is no problem. Or when the circumstances of the farmer allow him to take the longer view, again there is no problem. There are other cases, however, where it can have an impact, especially when weather is more variable, when the practice which is best one year is appreciably worse than an alternate practice in another and when this year's crop is essential for survival.

Here we might well be expecting too much of the farmer if we argue that he should use dense seeding rates, sow it one date as distinct from another, use substantially larger applications of fertilizer. Those may well be appropriate for profit maximizing, but if he is influenced by risk, there may be too much in terms of his own needs. His goals are better served by packages which give him greater risk stability. Hence, he is more favorably disposed to adopt those packages which feature stability as opposed to those aimed only at profit.

Parenthetically, programs which aim at wide adaptability tend to get stability and this by-product could be an extremely important consequence of trying to achieve wide adaptability.

In the past, when new technology has made slow progress with farmers, we have heard "more extension, more credit, more inputs and better prices." Today, I wish to fly a new trial balloon. I would like to add two elements to the list. Moreover, as our attention turns more and more to rainfed environments, I would be disposed to rank these well up in the list. These points would be more information about the farmer and greater stability in the package.

MANAGING THE PRODUCTION PROGRAM

Robert D. Havener

The subject set was "Managing the Production Program." This is something that cannot be covered in 10 minutes. Fortunately, the three preceding speakers have all helped greatly with the job. They have, in fact, left me little useful to say about the general aspects of managing the production program. I commend to you two or three or four books if you are seriously interested in this subject. First, Dr. Schultz' book "On Transforming Traditional Agriculture" because, as Einstein developed the Theory of Relativity, at least among the social sciences that book set the framework which said agriculture could indeed change and that small peasant farmers were indeed profit maximizers when conditions were satisfactory. Secondly, there is that set of books by Arthur Mosher of the Agricultural Development Council called "Getting Agriculture Moving," "Building a Progressive Rural Structure" and more recently, a book on "Planning in Relation to Agriculture Development." These are very good fundamental readers which biological scientists can understand. They set forth the necessary components and ingredients for getting the agricultural sector of the nation moving.

A number of things are important considerations in planning a production program in a country. They are obvious, but often overlooked.

First, you start with the resource endowment of that country. Not all countries will become important in agricultural production. Not all countries have the human, soil and climate endowment to mount the massive production program and to do so where those endowments are not present is a worthless and frustrating task. We should not assume that all countries are going to share equally in the Green Revolution.

Secondly, as Dr. Narvaez indicated, the package of production technology must be adapted to the conditions in which it is to be applied, and I would only say it must be adapted to farmers' fields if we are to know that it is really adapted to the conditions where we are trying to apply it.

Government dedication to the agricultural sector. It was mentioned by Dr. Schultz and others that this was a relatively recent phenomenon, i.e., that governments believe that something can be done about agriculture. Dr. Paarlberg outlined the current situation in world food supply. I have just visited eight countries in the past two weeks, all importing food, all of them paying 50% more for the food grains they are buying today than last year and all of them suddenly terribly interested in agricultural development and how one goes about it.

Narvaez is one of the best people I know in getting government policy makers, planners and others interested in agricultural development. He has the personality that allows him to grab them by the arm and say, "Come to the field with me and see what I have just seen." This is a terribly important talent because unless and until policy makers and administrators have said (1) agriculture is important in our country and (2) have been exposed to the potential that you as crop scientists

can give for really shifting yield levels, they will not believe nor will they reallocate their resources to the agricultural sector.

Don Winkelmann mentioned an assured source of agricultural supplies, including credit. I would argue that these must be elastic. There must be a bountiful supply because policy makers always underestimate the needs they will have for fertilizer, seed, credit and so forth when the Green Revolution takes off. I would also argue with Dr. Borlaug that that is not possible in an abstract form. In April 17, 1965, Borlaug wrote a report in West Pakistan that said you better get ready, a Green Revolution is coming. You are going to need storage, you are going to need fertilizer, you are going to need marketing facilities. Hanson spread this to every policy maker in the country.

Do you know what happened?

Nothing! No one believed him and it was not until Lahora Stadium was filled with grain and the boys could no longer play soccer did anyone really get enthusiastic about building storage for grain. There will always be this sort of see-saw lead and lag in the developmental process. I think development is actually pushing through a series of barriers, then solving that problem and then pushing again through the next barrier. Glenn Anderson described this as creating a vacuum. Herschman at Harvard describes it as unbalanced growth. I describe it as management by crisis. All major bureaucracies only turn enough time and attention to a particular problem for a sufficiently long period of time when they are faced with a crisis. Piling the streets full of wheat is probably the only way you get a systematic look at the second generation problems of the Green Revolution, or a production program.

You must have, obviously, a minimum critical mass of trained motivated personnel. I think it is both easy to overestimate or underestimate how large or how small that critical mass must be. In many cases a dedicated team of 4 to 6 scientists have been enough to start the ball rolling. Obviously, eventually depending on the country's size, it will take hundreds or thousands of extension workers and farmers but 4 to 5 are enough to start if they are the right people in the right place at the right time.

Finally, economic policies, must be sustainable over a long period of time that will make increased crop production profitable, both for the individual farmer and for the nation. If this is not true, the production program will founder.

I would like to briefly refer to the psychology of a production program. It must be massive in nature if you are to have a real impact on a stagnant agriculture. Borlaug talks of the psychology of change and said, "Do you put 120 pounds of N on one acre or spread 40 pounds on three acres?" The lesson appears abundantly clear at this point. If you are trying to change a stagnant agriculture, it must be dramatic; it must be consistent and you must get the farmers, the policy maker and the researcher together in the same location so they can interreact with one another. Farmer field days on experiment stations at demonstration days with researchers present and with extension people present are an absolute must--interreacting with each other on a face-to-face basis if the synergism is really going to work.

One of my favorite themes these days is the extent to which mass media communications has been overlooked in mounting production programs. I had a graduate student who worked for me in West Pakistan and we sent him into the mountains of the Northwest to see to what extent the new technology was being adopted by the small rainfed farmer. Much to our surprise, the adoption pattern had been almost exactly what it was in the irrigated plains of Punjab. There was a lag time of about three years due to an explicit government policy to maximize production on the best acres, but the hill farmer got the technology and he found out how to use it. When we asked how and why, radio was mentioned in 27% to 28% of cases as the first most important source of information related to the new technology. In Bangladesh, when I was there in July, I went out to see a farmer whom I had met three years ago when we were introducing IR20 rice. I said, "In those days we sent you a publication of how to use this variety. Did you use it?" He said, "Yes!" I said, "Can you read?" He said "NO." I asked, "How did you read it?" He said, "I took it to my cousin who read it to me." I said, "What did you do with that publication?" He replied, "It is still here in the house; would you like to see it?" I said, "Why did you keep it?" He said, "Before I plant the crop next year, I take it to some one who is literate to read it to me."

When we were in Comilla, we ran a survey once of a targeted group of farmers in our cooperatives. If 75% of the population is illiterate, you should not use the printed word, but if your group is landowners 15 to 55 years old engaged in farming and in the labour force, at least in our case in rural Bangladesh, 50% of those farmers were, in fact, functionally literate. I think the printed word has been much underplayed.

So, management by crisis must work. There is probably no other way of preeducating policy makers about the secondary effects of the production programs until you have achieved the primary target, i.e., increased production. To do that you must have that package that Nacho talked about.

DISCUSSION

Da Silva

So many persons have talked about wheat, but the session was to talk about cereal production campaigns. Everyone talks in favour of wheat. I would like to call your attention to something against wheat. I am from a country that has nine-tenths of its territory in a tropical area. All of you know how hard it is to produce wheat in this type of climate. Thus, we should not consider wheat as the base food everywhere, especially in subtropical countries. If you see the statistics, you will see that wheat consumption is being enlarged because countries with large surpluses are stimulating consumption in tropical areas. If we are concerned with food, even from the standpoint of nutrition, we should not make wheat the basic food in tropical areas. For instance, in Brazil, rice and beans is a better balanced diet than a diet based on only wheat. I have been all my life working toward developing wheat production in Brazil. At the same time, I have been advising the government to slow down and to take measures against increasing consumption of wheat in Brazil. Wheat should be made more expensive than rice and beans in Brazil in order to discourage wheat consumption and favor consumption of the others. At the same time,

when you increase the price of wheat, you encourage the production enough to balance the needs of the country.

Havener

I don't think we have any difference of opinion. I don't think we focused completely on wheat. In fact, if I were to focus on West Pakistan today, the story would be on rice. It would be a far more interesting story. We talked about resource endowment and cropping pattern around major cereals. We talked about economics related to risk but I think more were directed particularly to the wheat plant. We certainly agree with you.

Paarlberg

I have a question for Dr. Winkelmann. We are obviously dealing here with an enormously important subject, that is, human motivation which in the past we have all too often oversimplified. He broadens out and introduces the idea of risk avoidance and has an explanation for behaviour and adoption or nonadoption of these new techniques. I can see in certain cases that this is a meaningful explanation, but again I feel this in itself is an oversimplification of human behaviour. As I observe people it seems to me that they are not always trying to avoid risk. If risk avoidance were the dominant attitude, how does one explain that people will buy lottery tickets, play bingo or enter into marriage?

Winkelmann

I think it is quite time. People buy lottery tickets. They do in Mexico. People play bingo. But just as God doesn't play dice with the universe, people do not tend to take those kind of risks when the survival of their family is involved. I feel there is a real distinction. It is like this. You and I could engage in flipping a coin for a dollar. This is a friendly game. You probably would not even check as to whether the coin was in good shape. If the bet rose to \$0.25 you would probably like to look at the coin. If it got to much over \$1.50, I would have to look at the coin and give it real consideration, and if it got over \$5.00, I would have to say even at 50-50 odds I still can't gamble. It is like the man who has one dime and he is trying to catch a bus and its raining. A fellow came up and offers to flip for it quadruple or nothing. He says, "I'm sorry, I would like to but I can't take the chance, because I have to get this bus". To me this is the situation in which the small farmer finds himself in many circumstances.

Schultz

On your point, I associate myself strongly with you. I would like to draw an illustration in terms of behaviour right in our own societies. Extraordinary work has gone on in the last 10 to 15 years in separating permanent and transitory income, even in the best endowed society. You find families with a small transitory and mainly permanent income. This is, e.g., characteristic of the small dairy farmer of Wisconsin versus the large wheat farmer of Nebraska. I refer to Margaret Reid's early work. People respond to this in the proportion of income they save, e.g., much less in Wisconsin than in Nebraska in terms of average income.

This is related to what you are speaking of and as you approach the survival level, the concept becomes extremely important. There is a discounting of the transitory part of that income stream and it becomes appreciable as you move into the rainfed areas.

The main comment was one I wished to make on the remarks of our Brazilian colleague. I think, in the long run, the view that we should impose our preference or that you should impose yours on the people of Brazil and say they should not have wheat except at twice its cost of production and that rice should be cheap in order to get rice grown is absolutely contrary to political economy that I was attempting to present the first day. It just cannot be defended and I will take that position.

Stakman

I am sure of this because I lived through it. I do not wish to say anything about economics but I think I can say something of the behaviour of farmers in the area in which I lived. I lived in grain country where it was a gamble to grow corn at that time although it is now in the heart of the Corn Belt. The diversification was forced on the farmers and they adopted it because of this very fact of trying to cushion the losses of one crop with another one at different times. I am sure this was responsible for the diversification of farming in much of the Middle West. Andrew Boss, one of the pioneer farm managers and not exactly an agricultural economist, agreed with this. What you heard among farmers in general was, "We musn't put all our eggs in one basket".

Paarlberg

I agree with all that has been said and I see the importance of it, but these explanations are all given in the economic area. I am an economist and think it a very important discipline, but I do not think it is a total discipline. We heard discussions of double cropping. I did some work in Malaysia. We were attempting to help increase rice production. There was resistance to it. It was demonstrated to be economically feasible and all the economic arguments were in favour of it. Yet, the people resisted. They were very slow to do it. I was convinced that, in part at least, the reasons were sociological rather than economic. They had developed a life style, an annual cycle of living which was geared to that particular crop--planting, harvest and even religious ceremonies. The whole fabric was built around this base. When we attempted to get them to double crop, this meant upsetting the whole fabric of their society. They were reluctant to do so in spite of the fact that they would have been wise to do so for economic reasons. Single or unitary explanations of human behavior, while making problems easier to see and offer hope for single solutions, they are unlikely to give as satisfactory an answer as the more difficult and complicated approach which recognizes the multiplicity of human motivations.

Stakman

I agree there are multiple factors involved.

Anderson

I would like to comment on Dr. Paarlberg's last remarks. I think this highlights one of the things emerging from this meeting--the gulf that exists between the planning level and the biological level. I would like to compare your experience in Malaysia where you state the conditions were economically favorable with the conditions existing in the Indo-Pakistan situation. Here too there were religious festivals built around cropping. When I arrived in India I was told that all wheat should be emerged in time to see the Diwali lights at the end of October, which meant sowing was done in October and this was traditional. The varieties fitted this pattern of sowing and the farmers had learned that they got greatest efficiency by doing just this. With the change in varieties and the demonstration made to them that these should not be sown earlier than the second week or middle of November, with later maturing varieties, and even later with the early maturing varieties, they changed. But they had been shown and I submit that this is essential. It is the effectiveness of demonstrating to him that to change is to his advantage. Once done, traditionalism is unlikely to stand.

Wright

I would like to comment on Dr. Da Silva's earlier comment. It seems to me that there is at least one area where wheat has been grown traditionally for a long time on which I wonder about the desirability of placing much research effort. I am thinking of the dryland area of south-central India. In India, dryland is that land which receives less than 25 inches of rainfall. That is still a considerable rainfall level. A large part of the states of Madhya Pradesh and Maharashtra grow wheat as a principal crop and grow it in a period when rain is unlikely to fall. It is all grown on conserved moisture when, in fact, during the warm season rain may fall to the extent of 25 inches or more. We have been advocating research effort for such dryland wheat. I maintain that this is displaced research. Why do we not advocate a warm-season crop during the rainy season. There are distinct reasons why this is not done, but there are good possibilities to reverse this procedure and grow a crop during the warm season rather than a miserable crop of wheat in the season when no rain falls. I would not advocate a political solution to the problem, but a development of technology that would make it more profitable to the farmer to grow something during the warm season.

Stakman

The trouble with you is you provoke though. I think everyone should know that in the late 1880's a bulletin was issued by the Kansas-U.S. Experiment Station saying that Kansas was not and never could become a wheat producing state and Kansas has produced 350 million bushels of wheat in a year. Why? The reasons are interesting. I say that the power of science is tremendous and the plant breeder's power may also be tremendous, so we must never assume that what has happened will for all time. We talk about irrigation, but look at what happened in the rainfed area of the U.S. Corn Belt. For 50 years average yields varied from 23 to 26 bushels per acre. Now the average is 3.5 to 4.0 times as high. They were not really taking advantage, for those 50 years, of the powers of science.

Bolton

D. Winkelmann stressed risk as one of the major factors affecting decisions. He qualified this. I was misquoted earlier as saying that everyone could grow wheat in a tropical area. This points out that risk varies with the character of the region to which you are referring. If it is in the tropics and moisture is good, risk does not have the same magnitude as that occurring where the farmers have been starved at various times because of poor moisture. We should, therefore, consider this criterion with reference to risk.

Smith

In Minnesota and North Dakota, farmers are beginning to grow dwarf wheat. In my travels there for the past three years, farmers have a tendency to try to find out all they can about new varieties and new practices. Then, in many cases, they plant five acres of the dwarf and test them out. After one or two years of testing the risk under their situation, they then will go over to the new type. In your situation, Dr. Winkelmann, do you find that farmers try to compensate in this way for risk or is it advisable to ask them to take this approach?

Winkelmann

It seems to me that this is sensible. You don't put all your eggs in one basket. Such an approach is a risk-of-earning strategy. You gather information in which you can change the probabilities associated with the activity by virtue of the information being accumulated and make the decision as to whether or not you wish to proceed with it.

Wright

The Turkish Government is interested in introducing some Italian varieties into the coastal plain areas. They have such desirable characteristics as long duration which allows them to escape the frost period. They have the very undesirable character wherein most are highly susceptible to stem rust. By virtue of the long duration they are exposed for a long period to stem rust. Thus, recommendations from Dr. Devicioglu to the farmers have been to try a little of the variety, not exceeding five hectares. One school with 40 hectares decided they had seen enough of Italian varieties to sow it on the whole area. Unfortunately, they were caught by stem rust and instead of a harvest of 3 to 4 tons, they got 700 kg/ha with this variety. The farmers do try these.

Upadhyaya

I do not agree with Dr. Wright when he says that wheat should not be grown in south-central India because its yield is low. Dr. Stakman has indicated that positions change as varieties change and, similarly, I would suggest that in changing cropping patterns we should change the nature of the varieties grown. We should grow varieties that are more thermoinsensitive. Thus, we could grow the wheat starting early in the season and still grow a good crop. Moisture conservation is important also. The monsoon or summer crops in the area never grow well or are subject to high risk because of erratic behavior of the monsoon. People from

remote time have learned to grow wheat in that area. It will be, in my opinion, difficult to change the cropping pattern.

Qureshi

I would like to point out one example of the fact that even a very small farmer would like to change his condition. We had experiments in different rainfed areas classified as high, medium and low. I wish to report on results from the low-rainfall areas where winter rainfall in the wheat season was below five inches. We had conserved the moisture and applied 60 N, 40 P₂O₅ fertilizer per hectare. There were two objectives. The demonstration was designed to show the advantage of using fertilizer and using new varieties. Close to maturity we held a field day. Administrators, research and extension people, and many farmers were invited. The difference in the sets was very distinct — between unfertilized and fertilized, and short and tall varieties. At least four times normal production was realized. The farmers themselves said that this difference existed.

The farmers were asked, "Why don't you take up these practices?" The answer, invariably, was, "We did not realize that they also wanted to change for their own betterment but this man whose crop you are showing us is a rich man. He can apply fertilizer and has the resources. They said if we have the fertilizer and can be supplied an implement with which to do deep plowing before the monsoon, we also can get a better crop." This shows that even small farmers will change from traditional ways.

Bolton

I would like to propose that we have a situation in Turkey which would be a testing ground for a cereal production campaign in two distinct areas. We have gone through one in which the Turkish Government imported 22,000 tons of grain in a short period of time. A massive radio extension effort was mounted in the coastal region with Mexican wheats. This was very successful. Now, we are involved in the dryland area, which is the major production area. We are not quite ready yet to start a campaign, but at the time we do we are still agonizing as to how to accomplish this because the inputs in the Mexican wheat program were varieties and fertilizer and techniques. On the other hand, the inputs in dryland involves equipment, a different sowing date, different methods of seeding and inputs may be much greater. Risk is also greater. So, speaking for my colleagues, we are searching for a system of implementing a campaign on dryland and in the next few years if any new methods appear we want to know about them.

DISTRIBUTION OF GENETIC MATERIALS: SEGREGATING POPULATIONS AND UNIFORM INTERNATIONAL YIELD AND SCREENING NURSERIES AND THE REPORTING OF DATA

Armando Campos

The first international nursery was established as a result of a joint proposal at the Fourth Latin American Plant Sciences Association meeting held at Santiago, Chile, in December 1958. A nursery became functional in 1960. In turn, the Cooperative Near East-American Spring Wheat Nursery originated as an outgrowth of its predecessor as a result of a recommendation by Dr. Borlaug and Vallega while temporary consultants to FAO in 1960 when they looked over the Middle and Near East barley and wheat improvement programs.

The responsibilities for increasing seed and making up nurseries was provided in the beginning by INIA and this was later shifted to CIMMYT, although we have very close associations with INIA through our work at CIANO, their main station of the Northwest. The objectives of the nurseries, from the beginning, were: (1) to serve as a link between fellow workers on wheat improvement; (2) to obtain basic information on the performance of varieties and advanced lines regarding performance of varieties and advanced lines regarding yield, resistance to diseases and general adaptation; (3) to use these nurseries as a vehicle for introduction of germ plasm from one country to another among the cooperating programs; (4) to develop basic information on the adaptation and disease resistance of the advanced lines being screened.

This information has been gathered, assembled, printed and returned to the cooperators as a guide for choosing parents for further crossing or choosing materials suitable for specific needs.

I will confine my remarks mainly to bread wheats, but I would like to point out that for each of the bread wheat nurseries there is an equivalent in durum wheats and triticales. The first and most important nursery is the International Spring Wheat Yield Nursery (ISWYN). This nursery comprises 50 varieties or advanced lines which represent the principal varieties or types grown in the world. Some varieties are repeated in successive years but new ones replace old ones dropped out. We always try to keep the nursery balanced, current, and meaningful to the workers throughout the cooperating programs. The seed is increased at CIANO. CIMMYT distributes the nursery and information received from cooperators is assembled in a comprehensive form with one table for each trial site. The grand mean is calculated and presented with all pertinent data. The amount of data generated in one year is enormous. We have a lag time in getting out results. About 20 months lag occurs from the time of distributing material and getting back 80% of the results. From this point, data is assembled, checked, passed through the computer and published for the use of the breeders.

The next nursery I will deal with is the International Bread Wheat Screening Nursery. This complements the first. In this case the nursery comprises most of CIMMYT's advanced lines. Sometimes this will reach 500. Because of the number of sites concerned we do not send a replicated trial. It permits us to study the selected advanced lines and pass back the results.

The third nursery is the Elite Yield Trial. This might be considered as the "cream of the crop" insofar as CIMMYT-developed lines are concerned. There are the outstanding varieties which may have come up through the screening nursery or other characters make them outstanding. These are placed in the Elite Yield Trial. In this way CIMMYT is able to promptly assess the performance of outstanding lines in many locations. The limited amount of seed has forced us to be fairly selective on trial sites, but we try to ensure that widely different environments are included. In some years we do not send out this trial as there are not sufficient truly outstanding lines.

We also have the International Septoria Observation Nursery. This nursery is oriented toward screening materials, particularly advanced lines, for resistance to disease.

The Latin American Disease and Insect Screening Nursery is our latest proliferation. This is a parallel to the Regional Disease and Insect Screening Nursery organized in the Eastern Hemisphere. This is the first year of distribution. It consists of advanced lines from any breeding program of the Latin American countries which are promising. Because of the large number, about 700 this year, we cannot make replicate trials. However, the information from this nursery will help CIMMYT and all the collaborators in Latin America as a vehicle for seed distribution, establishing for adaptation and assessing disease resistance.

In bringing together materials for the ISWYN, we ask countries to submit 200 grams of their best advanced lines and varieties. These are increased at CIANO. There they are compared with CIMMYT lines and after observation for disease resistance, yield and adaptability, selection is made for those to enter the trial.

When promising lines of the screening nursery are identified as having real potential, they are grown in preliminary multiplication plots in order to have these available in a small quantity to serve requests. Previous to release in Mexico, INIA will increase the prospective variety in farm fields. Seed is certified by the proper authorities. Similar procedures are also followed in other countries.

As you can see, CIMMYT has evolved with these nurseries. Some have a history of 8 to 10 years, whereas one is now in its first year. A similar situation occurs with durums and triticales, and soon with barley.

We have three types of material.

1. The screening nurseries are yield trials in the actual sense since we are looking at performance prior to placing in yield trials.
2. The screening nurseries used to identify resistance, adaptability and so on.
3. The genetic soup material, F2 populations for both irrigated and rainfed conditions, are sent out to many countries where they are screened and selected on site for specific needs.

The whole system has grown rapidly. In 1960-61 about 20 sets were distributed to 12 countries and only 14 sets of data were received. Last year, we sent 577 separate trials to some 63 countries. The materials move from 60° N latitude in Alaska to 40° S latitude at Plamerston, New Zealand. They move from sea level locations to 3058 meters at Santa Catalina, Ecuador.

Briefly, I would like to emphasize the importance of these screening nurseries.

1. They have identified wide adaptability.
2. They have served as a means of moving massive amounts of germ plasm to different countries. We might cite North Africa where we had trouble with Septoria in 1969. Although the problem is still unresolved completely, we have been able to move widely, diverse materials rapidly in order to screen them under their conditions. These are now lines released with moderate resistance.
3. Any plant breeding program will have a long way to go if it starts crossing its own varieties for upgrading. These materials can be moved in directly to assist in giving the necessary diversity.
4. The nurseries have been responsible for identifying varieties and developing new technology in many countries, including developed countries.

Wide adaptability continues to be one of the strong points of our program. Why are the materials widely adapted? Partially, at least, this is due to daylight insensitivity, straw strength to allow use of high soil fertility and their high yield potential.

REGIONAL EVALUATION OF GERMPLASM

Gerbrand Kingma

Introduction

Cooperation of North and East African countries and countries in the Near East and Middle East exists in developing and testing outstanding wheat and barley varieties. Wheats tested thus far are mostly of the spring habit, but in several countries winter wheats are grown widely and also tested in cooperative programs, such as the International Winter Wheat Performance Nursery (IWWPN). Durum wheat forms 30-40% of total wheat production of the Region. Many country programs have small durum improvement programs and cooperation has centered around work carried out by Italian breeders and by CIMMYT. Barley improvement is needed for approximately 10 million hectares that are planted each year in the Region.

Beginning in the mid-1950s, the United Nations Food and Agriculture Organization (FAO) in close cooperation with the USDA and European Cereal Rust Association distributed rust nurseries for disease testing and screening in many countries of the Region. Cooperation with the wheat program in Mexico, later to become CIMMYT, was greatly intensified when uniform yield tests were prepared for the Region. Some widely adapted high-yielding varieties were identified and it was estimated by Hafiz in 1972¹ that these occupied 12 million hectares in the Region from Morocco to India.

Yield Nurseries

The role of the International Spring Wheat Yield Nurseries (ISWYN) as distributed by CIMMYT and FAO has been very important to familiarize wheat workers with high-yielding plant types with aggressive response to fertilizer and good water management. The wide adaptation of some of the best entries was dramatically demonstrated in many areas of the Region where temperatures are rather mild and moisture supply is good (ISWYN reports, 1961-69).

In addition to these international yield nurseries, the Near East Region is now testing more lines in the Regional Wheat Yield Trials (RWYT). Jointly organized and distributed by FAO and Ford Foundation's ALAD, several outstanding wheats developed and/or selected by national programs in India, Pakistan, Iran, Turkey, Lebanon, Egypt, Kenya, Tunisia, etc., are tested. In Table I, top yielding varieties in these Regional trials are shown as observed during three different years in some 30 to 40 locations. The predominance of lines of the 8156 cross

¹ Abdul Hafiz, 1972 "Winter Wheat Conference Proceedings", Ankara, Turkey.

Table I. Results of Regional Wheat Yield Trials in Near East, 1969-1972.

Rank	1st MPWYT	Average ^{1/} yield	2nd MPWYT	Average yield	3rd RWYT	Average ^{2/} yield
	1969-70	(28 loc)	1970-71	(43 loc)	1971-72	(30 loc)
1	Indus 66	3468	Super X	4175	Arz	4529
2	Mxp 69	3378	Mxp 69	3964	HD832-On x Kalyan	4371
3	Mxp 65	3367	Inia 66	3801	Barouk	4340
4	C271-Son 64	3084	Chenab 70	3796	Chenab 70	4305
5	Chenab 70	3051	Penjamo 62	3772	Zorawar	4259
					Mexipak 65	4254

1/ Yield expressed in kg/ha.

In 1969 and 1970, 10 varieties were included and in 1971-72, 50 varieties.

2/ Super X and Mexipak 69 not included in 1971-72.

Arz is new name for: Mayo 54E x LR/H490 (LR64-TzPP x Y54) II21419-288

Barouk is new name for: (Mida-NTh K117A x Indus 38) 8156 Pk1115-2k-2f

is clear (Indus 66, Super X, Mexipak 65 and 69). Chenab 70 (C271 x WtE-Son 64) was among the top five each year, and resulted from a large crossing program in Pakistan. Several lines from Pakistan have shown wide adaptability in these RWYT tests.

The top-yielding variety in 1971-72, recently named Arz, may be used to exemplify how international and regional wheat work fits together. Our earliest records indicated that this line was grown in Tunisia during 1968-69 from seed received from India. The cross number shows that the cross was made in Mexico, probably in the early sixties. It showed good rust and Septoria resistance in Tunisia and was therefore sent to Lebanon where its yellow rust resistance was confirmed in 1969-70. It entered the Lebanese National Yield Trials in 1970-71 and yielded above Mexipak, the standard for selection. In 1971-72 it showed up among the top 10 varieties at 20 of 30 locations.

In a presowing "flash" to all cooperators sent by FAO and ALAD, attention was drawn to top-yielding varieties in 1971-72, encouraging rapid increase and further evaluation of these wheats. By this system small quantities of seeds are already available in all cooperating countries when a specific line proves superior in many places. This can greatly accelerate the increase of seed supplies when a change of varieties becomes desirable and/or necessary.

Screening Nurseries, Crossing Blocks and other Nurseries

Other nurseries are also distributed in the Region and to selected places in other parts of the world. Table II gives a summary of last season's and the current season's distribution. The materials are brought together from nurseries and collections contributed by nearly all national programs of the Regions as well as by CIMMYT and several European Cereal Improvement Programs.

Over 2,000 wheats, barleys and triticales are first screened for diseases in the Regional Disease and Insect Screening Nursery (RDISN), in 35 to 40 "hot spots" of attack. Lines with sufficient levels of disease resistance are grouped in a regional Crossing Block (RCB). Those showing high yield potential are included in the Preliminary Observation Nurseries (PON) for selection of varieties for the yield trials. Repeated over years, these nurseries form the basis for selection of varieties for the yield trials. The PON contains bread wheats and durums which are grouped for their early maturity, bread-making quality, and/or their yield promise under rainfed or irrigated conditions.

The 3rd RCB includes bread wheats of spring and winter habit, durums and barley. Groups of lines and varieties are characterized by their ability to yield and to resist disease attack (based on RDISN notes from most countries in the Region). The Crossing Block is the stepping stone to create varieties and is made available to 16 countries with substantial crossing programs.

As mentioned before, seeds from many countries are used, but a majority of the promising material is contributed by large programs such as in CIMMYT, India and Pakistan. These programs also collect data from the nurseries received from the Near East Region. Outstanding lines are immediately included in the appropriate nursery and thus progress made in one improvement program becomes rapidly available to the others. Field books distributed with the new nurseries contain summarized notes based on the previous season's work. Some of the recent results are presented in Table III to serve as reference for those who do not have access to the nursery books.

Cooperation of Programs

Almost all distributed nursery material is observed at least once in a centrally located program such as in Lebanon. This has been effective in avoiding unnecessary duplication and usually aids in securing adequate amounts of seed.

For the 1971-72 season, additional nurseries have been prepared by various programs in the Region. Separate winter wheat screening nurseries were distributed by the Mid-East Wheat Project, based in Turkey, for screening material in the cooler areas. About one-third of the data of the IWWPN are collected by country programs of the Near East and Middle East.

The Arab League Arid Zone Research Center in Syria distributed a Rainfed Observation Nursery and two yield trials to six Arab countries in the Region.

Besides the extensive regional disease screening nurseries, an Egyptian Trap Nursery is grown by several countries as well. Also, International Screening Nurseries for the various rusts and the USDA nurseries are regularly evaluated in selected countries in the Region.

CIMMYT is a major contributor with guidance and breeding material to many of the Near East Cereal Improvement Programs by sending yield trials, screening nurseries and disease nurseries. Almost all countries request more material than CIMMYT can supply directly and the regional nurseries are utilized to meet needs in many countries. Frequent visits by staff located in the Region appear to have been effective in the standardization and rapid distribution of results and technology. Timely assembling and nurseries dispatch has also served well to strengthen regional and national cereal improvement programs.

Further Developments

As mentioned in the introduction, large acreages of winter wheats, durumms and barley are grown every year to traditional varieties. Only limited efforts have been made to produce varieties with higher, more reliable yields than these original types. Crossing work for the colder areas of the Region has started now, but will greatly benefit from further close cooperation of country programs in Turkey, Iran, Algeria, etc. The Regional Crossing Block that is distributed now includes spring and winter wheats with high yield potential and disease resistance. Each country has additional desirable types that need to be intercrossed and added to this large germ plasm pool. More wheat scientists will need to work in the colder areas, where the majority of the wheat and barley is grown. Selection and disease screening under a similar system as for the spring wheats will accelerate crop improvement and production. Also, quality demands for local bread types need to be closely related to our crossing work. This area of wheat improvement has suffered so far in our efforts to improve yield and disease resistance.

Summary

Many country programs in the Region have a large improvement program for spring wheats. Cooperation among countries has given many rewards. It accentuates, therefore, the need for much more cooperation in the improvement of winter wheats, durumms and in barley. The Near East Region has most of its cereals acreage in cold rainfed areas and crop improvement programs should be directed more to them.

A c k n o w l e d g e m e n t s

The work described here is closely tied to the Regional program of Food and Agriculture Organization for Near East, based in Cairo, Egypt. Nursery preparation and data summaries are carried out in close cooperation. The field work involved in yield testing and seed production and packaging for regional nurseries is supported by the Agricultural Research Institute, Tel Amara, Lebanon.

Table II. Summary of Regional Cereal Nurseries and Extent of Distribution.

Name of nursery	1971-72			1971-73		
	No. of entries	No. of sets prepared	No. of countries cooperators	No. of entries	No. of sets prepared	No. of countries cooperators
RWYT	50	39	26	25	20	18
RBYT	25	16	12	25	25	19
RfWYT	-	-	-	10	20	19
RCB	335	16	12	367	20	16
PON	355	25	23	163	25	24
SP	136	20	17	66	12	11
RDISN	2400	40	22	2100	35	22
RTN	40	79	29	54	95	36

RWYT	=	Regional Wheat Yield Trial
RBYT	=	Regional Barley Yield Trial
RfWYT	=	Rainfed Wheat Yield Trial
RCB	=	Regional Crossing Block
PON	=	Preliminary Observation Nursery
SP	=	Segregating Populations
RDISN	=	Regional Disease & Insect Screening Nursery
RTN	=	Regional Trap Nursery

Table III. Selected Bread Wheats, Durums and Barley with High Performance and/or Disease Resistance in Near East Region in 1971-72.

Entry number	Variety name	Pedigree	Yield 1/ level tons/ha.
<u>PON</u>			
6	Inia 66 x Bb	26478-7y-8m-2y-2m-0y	4.1
99	Nor 67-7C	30367-1m-2y	4.1
159	HD832-0n x Kalyan	Pk3001-4Mu-0a	4.1
175	Super X - Check		4.1
84	Kalyansona x FAO 215	1-2-3L	4.0
182	Tanori 71	25717-11y-3m-1y-0m	3.9
161	Barouk	Pk1115-2k-3f	3.9
163	Roque "S"/G54-36896 x Gb54/Gb56		3.9
121	Son 64-TzPP x Napo 63/Napo 63 - Tob x 7C	35563-500y	3.8
55	Kalyansona x Sh. Sonora	Jit 16-3L	3.8
<u>2nd RCB</u>			<u>YR</u> <u>LR</u> <u>SR</u>
551	Arz "B"	II-21419-288	R R R
532	Barani 70 "S"	Pk50-7a-2a-4a-2a-1a-0a	R S MS
538	UP301		S R R
559	8156 x Son 64	21005-6-8	MS R R
633	Aust. line	II-61-127-18-85-3-2-4	MR MR R
676	LR64 ² -Son 64	II-19865-58M-100M-101Y- 100M	MR R R
707	Meng x 8156 (R)	H-223-64-14-66-14-16- 4y-301y-2b-300y	MS R R
<u>DURUMS</u>			
37	Cocorit 71 (Ave.of 30 locations in 3rd RWYT) 4.063 kgs/ha.		
<u>PON</u>			
204	21563 x Cr. de Chile	31536-5L	3.8
234	Ganzo	25550-10m-5y-1m-2y- 1m-0y	3.8
211	Jori "S" x (BYTE-Tc) (Z-BxW)	31543-7L	3.7
214	Jori "S" x (BYE ² -Tc) (TglE-Tc ³)	31545-4L	3.6
235	Ganzo	25550-10m-5y-1m-2y-2m- 0y	3.5
236	Crane "S"		3.3
<u>RCB</u>			<u>YR</u> <u>LR</u> <u>SR</u>
01	Durum Variety 24	California	R R R
02	Wells	U.S.A.	MS MR MS
011	Cocorit 71		MR MS S
027	Flamingo	27582-8m-12y-5m-500y	MR MR MS
034	Cocorit "S"	27617-9m-5y-5m-0y	MR- MR MS
			MS

Table III (Cont'd)

Entry number	Variety name	Pedigree	Yield <u>1/</u> level tons/ha.		
037	Grulla x BYE-Tc ⁴	25612-5m-2y-1m- 1y-2m-0y	MR	MS	MS
052	Pelicano		MS	R	MS
<u>BARLEY</u>					
<u>2nd RBYT</u> (11 locations)					
19	WI 2197		3.1		
11	Clipper		3.0		
13	Giza 120		2.9		
17	Beecher		2.9		
8	Sv. Hellas		2.9		
<u>PON</u>			<u>Yield level</u> <u>tons/ha 1/</u>		
254	Wing 11046		4.2		
348	Giza 119		3.3		
339	A16		3.2		
261	Apizaco		3.1		
285	Atlas Kindred		3.1		
272	WW Cilla		3.0		
280	Bussell		3.0		
260	Porvenir		2.8		

1/ Yield level as indicated by averages of 10-12 locations and nonreplicated plots.

REGIONAL DISEASE AND INSECT SURVEILLANCE

E. E. Saari

A striking breakthrough in wheat production has occurred in several countries throughout the world. In some, the wheat revolution has not been so dramatic, and in other instances, it has failed to reach all of the farmers that could benefit from such production technology. As we look into the 1970s and beyond, we need to extend the breakthrough technology to those not yet included. Where this technology is not applicable, we must strive to derive new technology.

Many of the reasons for the success of the green revolution such as adaptability, high-yield potential, fertilizer responsiveness, management and policy factors have been discussed in detail. Another important and vital reason for success was the superior disease resistance of the dwarf wheats. Initially, most of the dwarf wheats were resistant to the three rusts which on a worldwide basis constitute the most serious disease problem of wheat.

Another little-appreciated fact is that the varieties selected from cross 8156 which contributed so much to the wheat revolution still retain their superior resistance to such diseases as bunts, loose smut and powdery mildew.

However, the age-old problems--the cereal rust--are, as Professor Stakman labelled them a few years ago, "Shifty Enemies". They have over the centuries been a major deterrent to stabilized wheat production and, in some cases, a limiting factor. I believe that stabilizing production through the control of the three rust diseases will be one of CIMMYT's major activities in the 1970s and beyond.

Other disease and insect problems will also demand CIMMYT's attention in the 1970s. Some of these diseases may have been underestimated or increased in importance with the introduction of dwarf wheats and the technology that accompanies their management. Such an example occurred in the Mediterranean region with Septoria tritici. To claim that S. tritici was not a problem previously is incorrect if one reviews the history of wheat culture in that part of the world.

Increased awareness and concern about such a disease as Septoria resulted from several factors. The original dwarf wheats as a group did not possess a high-level of resistance because they were not subjected to selection pressure against this disease. Equally important was the change in the microenvironment which results from additional inputs of fertilizer and water. The succulent plant growth and minor environmental changes favor development of those diseases which are endemic and potentially epidemic when adequate resistance is lacking. The control of the wheat rusts through resistant varieties also allows diseases such as Septoria to be more expressive, and thus seemingly more important.

Other reports of new diseases are not always valid. Our growing interest about and knowledge of the diseases and insects present in the region are largely responsible for such claims.

What are some of the areas in which I think CIMMYT should or could participate regarding disease and insect surveillance?

First and foremost, CIMMYT must continue to be a creator and a source of genetic materials which can be used by all countries, particularly for those countries which do not possess the facilities and manpower to generate their own germ plasm.

Because wheat is so extensively cultivated, the most practical and realistic manner of controlling the wheat rusts will be by using resistant varieties. Other diseases and possibly insect problems may also be controlled by resistant varieties. CIMMYT will have to make judgements as to their importance and assign priorities accordingly.

CIMMYT also needs to be a source of information and material to those national wheat programs which can exploit such knowledge. The development of resistant varieties by national programs can be accomplished with greater confidence through such exchanges. Strong national programs will help CIMMYT to be more functional and assist other countries by contributing to the effort of broadening the germ plasm base through the exchange of materials.

There is a need and a responsibility to maintain constant vigilance for the new and unusual disease or race that may present a threat to wheat production. We cannot allow a situation to arise in the developing countries such as occurred recently in the United States with maize blight.

New races of the rust fungi still constitute the greatest disease hazard to wheat production. It will be necessary to maintain surveillance for the new and potentially dangerous races. We know from experience that at some locations in Asia and Africa severe rust development occurs almost every year. We are also aware that at these sites we frequently detect new races that later become important to commercial wheat production.

By using such sites for testing it should be possible to identify sources of resistance and potential varieties at an early date. This procedure could eliminate the dilemma of wheat improvement programs having to wait until a new race makes its appearance in the commercial acreage before an active program of breeding for resistance can be undertaken.

Usually there is a time lag of several years between the identification of a new race and when it becomes a threat to wheat production. Although exceptions occur, this time lag can be extremely valuable for developing new resistant varieties. We need to extend this grace period as much as possible.

We also know that races originating in one area can migrate long distances. The spread of a new race to other areas or within an area is an important factor in understanding and controlling cereal rusts. The general epidemiological patterns of the rusts and other diseases needs to be documented. For example, in India the pattern of stem rust (P. graminis f. sp. tritici) movement was determined to be continental from north to south. The small acreage of wheat grown in South India serves as a focus or target area for the primary inoculum. This inoculum multiplies and moves northward to infect the main wheat growing areas.

Consequently, the varieties grown in South India influence the rust race flora and are of major significance in the overall epidemiology. By recommending resistant varieties or varieties representing different sources of resistance a manner of "gene deployment" can be practiced.

I feel that CIMMYT should undertake defining such epidemiological zones. The zones become important in the identification, diversification and development of resistance. For smaller countries that lie within such a zone, this information becomes indispensable to the varietal improvement programs.

Monitoring for the origin of new races and the surveillance of their spread are valuable services that could be accomplished through a system of trap nurseries, survey personnel and race identification. In this case, CIMMYT can either carry out several of these functions or assist other agencies to undertake such activities.

The subject of horizontal or nonspecific resistance has received much attention lately. Additional understanding on this subject is required. The CIMMYT wheats originally introduced into India are, for example, now susceptible to leaf rust (Puccinia recondita). When disease increase curves are compared with older local susceptible wheats, there appears to be some buffering to rust development with the CIMMYT wheats. This may represent the action of several genes for resistance or the accumulation of gene blocks which may be one of the components of nonspecific resistance. More studies are needed to understand this type of response. Other factors and components of nonspecific resistance may exist and should also be studied. Wherever CIMMYT can, it should explore and exploit this type of resistance and encourage other institutes to assist in this area.

The exchange and testing of germ plasm collections with different disease populations is a valuable service. CIMMYT is in a unique position to conduct or help other agencies to carry out such tests. Varieties that are considered susceptible in one region of the world frequently are resistant in another. These resistant genes could be lost if they were tested only in their zone of origin. There is a need not only for locating such genes, but to determine their potential value and add them to the germ plasm pool.

In conclusion, we should not lose sight of CIMMYT's original objectives, but there is a need to stabilise and minimize the potential hazards of epiphytotics and insect infestations. No man or organization is in a position to make guarantees against the vagaries of nature, such as drought, pests or epidemics. We, as wheat scientists, are learning more about the frequency and probabilities of the occurrence of epidemics, but we are not in a position to predict when they will occur. We also know that through plant breeding efforts epidemics have been reduced in occurrence and severity. We are now obligated, however, to concentrate our efforts to further reduce the probabilities of epidemics and to reduce their magnitude if they should occur.

REGIONAL SEMINARS

Abdul Hafiz

Background Information

In this paper the Regional Seminar is dealt with in its broader sense, covering workshops, meetings, conferences and symposia, aiming at the same objectives of collecting a particular group of persons at a place for discussions, and sharing knowledge with each other for improving both cooperative and national programmes of work. In the field of wheat and barley improvement, it was in 1952 when FAO held its first meeting on a regional basis, attended by 5 countries. Since then 9 such meetings have been held by rotation in different countries, to begin with every year and later on every alternate or every third year.

During the period under report, the following regional seminars, meetings, workshops, conferences have been held in the Near East Region:

1) Nine FAO meetings on wheat and barley: 1952 in Ankara, 1953 in Cairo, 1954 in Damascus, 1955 in Karachi, 1957 in Tehran, 1959 in Ankara, 1961 in Beirut, 1965 in Tehran and 1969 in Beirut.

2) Three FAO/Rockefeller Foundation wheat seminars arranged for the Mexico-trained persons in 1965 in Italy, 1968 in Pakistan, and 1970 in Turkey. The 4th seminar is scheduled to be held from 21 May to 2 June 1973 in Tehran.

3) Two Ford Foundation workshops held in 1970 and 1972 in Beirut.

4) One international winter wheat conference held in June 1972 at Ankara by USDA/USAID and the University of Nebraska in collaboration with FAO.

5) One FAO/SIDA regional seminar to be held in September 1973 at Cairo for the plant scientists trained in Sweden during 1960 to 1971.

Apart from the above regional seminars, 15 regional training centres (8 in Mexico under the FAO/Rockefeller Foundation Training Programme: 1961, 1962, 1963, 1964, 1966, 1968, 1970 and 1972; 5 in Sweden: 1960, 1963, 1966, 1970 and 1971; and 2 in the Near East Region under FAO/SIDA Training Programme: 1963 and 1965) were held. The participants for the various regional seminars were mostly drawn from the persons trained in these various training centres apart from top scientists invited to present papers on new advancements.

The usefulness of such seminars for devoting attention to the solution of local as well as common regional problems has been very much acclaimed. Moreover, these seminars provided an opportunity for the plant scientists from the regional countries to meet and discuss with top scientists from the developed countries, thereby creating a better climate of cooperation and coordination. These seminars also provided an occasion for the plant scientists to acquaint themselves with the latest research developments,

as well as with the programmes being followed in the host countries. On the whole the seminars helped in the development of team spirit and healthy competition leading to the improvement of research and production programmes. This also created a confidence with the Governments in supporting the various programmes resulting into outstanding increased production of wheat in the Near East Region which was termed the green revolution.

Philosophy Behind the Seminars

There is no denying the fact that seminars are very important tools for improving both the research and production programmes in a country. However, there are certain prerequisites which control the philosophy of the seminars. These must be met with in order to make the seminars more effective and remunerative. These prerequisites are:

a) There should be a special group of plant scientists for whom the seminars should be arranged. The success of the previous seminars hold testimony to this requirement. This group of plant scientists was especially created in the Near East Region through holding various training centres over a number of years before the first seminar was arranged. Similarly, in case of FAO Wheat and Barley Meetings, efforts were always made to bring in the selected persons every time who were directly involved in the improvement of wheat and barley crops in their respective countries. Through this procedure it has been possible not only to keep a good follow-up of the trained personnel but also to educate them with up-to-date advanced technology, help them in the solution of their problems as well as maintaining the continuity of work and stimulating the cooperation. Changing the audience of seminars every time will not be fruitful because of the diversified interest and possibility of discontinuity of the programmes. The experience gained in the past has also shown that apart from the trained group of personnel, it is also desirable to invite from each country a senior scientist or an administrator in order to solicit strong support from the governments to the programmes recommended to be carried out by the seminars.

b) After having developed a special group of plant scientists, the next important aspect is to decide the frequency, place and timing of seminars. It is desirable to hold the seminars after every two to three years so that it is possible to evaluate the work carried out by the trainees as recommended in the previous seminar. As regards place, it is advantageous to hold the seminar in various countries of the region by rotation in order to encourage them keeping in view that the host country has sufficiently good programme under implementation because it will be useful for the participants to learn the various country programmes as well as problems and steps being taken by the governments towards their solution. The timing of the seminar should preferably be in a pre-harvesting period and adjusted according to the growing season of the crop in a host country when it is possible to evaluate the results of the various experiments, nurseries, crossing blocks, demonstration plots, etc., and also visit large-scale areas grown by the farmers. The possible objection to this suggested timing is that the participants are also busy with their experiments during this period in some of the countries. This can only be avoided by fixing the time in the early growth period, but the experience of the past three

FAO/Rockefeller Foundation seminars has clearly indicated that the seminar held in Italy in the off-season was not as successful as those of Pakistan and Turkey held during the preharvest period. In fact, field trips are as important as papers and discussions. Without field trips the real value of the seminars is adversely affected.

c) The programme of the seminars should be equally divided into two parts--one dealing with country reports, lecturers and discussions and the other with field trips to the experimental areas and farmers' fields. The country report which should be prepared jointly by the delegates of a country should be presented by one of the delegates from that country. It should cover the salient features of the research work and the production programmes carried out during the intervening period and also highlighting the major problems in both fields. The subjects for special lectures should be selected according to the specific current problems of the countries so as to present up-to-date information and suggestions for effecting improvement in the programmes. These subjects should deal with the various disciplines of improvement and production and the right type of lecturers with practical experience should be selected from inside and outside the region. Ample time should be provided for discussions, both after the lectures and in group discussions which will need preparation of a suitable time table. Similarly, a detailed programme should be prepared for the field trips and social activities. It will be advantageous if cyclostyled copies of lectures and write ups of field trips are provided to the participants at the beginning of the seminar.

d) In the Near East Region we are lucky to have developed very good cooperation and support of various agencies such as Rockefeller Foundation, SIDA, CIMMYT and Ford Foundation in holding of regional seminars. From the beginning we in FAO have been trying to synchronize the various meetings, conferences, seminars, etc., in such a way that these activities were well spaced out to avoid overlapping because of the same audience for all these functions. It is, therefore, suggested to follow the same procedure in order to maximize the benefits of regional seminars/meetings. This can be done through the proper collaboration of all the agencies concerned who should jointly plan and implement the future seminars pooling their financial, administrative and technical resources in order to assure greater success and benefits to the participating countries. Decisions regarding the holding of seminars/meetings/workshops, etc., should be taken at least one year ahead of time and all the parties concerned should be involved from the very beginning.

Each seminar apart from providing up-to-date information and knowledge on various disciplines relating to research and production should end up with some practical recommendations. These recommendations should be in line with the national development objectives so that it is easier for the governments to carry out the programmes. Necessary provisions as regards training, equipment, land, water, laboratory, plant material, inputs, etc., should be made in order to cope with the suggested programmes. Without these additional provisions it will not be possible to carry out the increased load of work effectively. There should be good follow-up both at country and regional levels. The plant scientists should be encouraged for their good work and made responsible so that they should not feel that work is being forced on them.

It is very much hoped that the useful activities pertaining to regional seminars/meetings/workshops, etc., will not only be continued but will also be further strengthened and coordinated to maximize the benefits for the regional countries. The more we cooperate, the better it would be in the long run for bringing peace and prosperity in the world. Only through immediate and resolute endeavour can the Twentieth Century transmit its heritage intact to the future generations. Only through boldness and vision can we create a better world that may be worthy of man's ever-questing spirit.

COLLECTION OF GERMPLASM

K. W. Finlay

We have heard, I think, a fascinating story of what is truly an international breeding program--the movement of germplasm throughout the world, the selection of germ plasm throughout the world by nationals of many different countries. I did a count not long ago and about 80 countries are involved in this movement, use and development of germplasm.

The point we must realize, I think, is that progress in the development of germ plasm is only possible when there is genetic variability. If there is no variability, there is no flexibility and there is no place to go. You cannot improve, even though you cannot get any worse. We are using germ plasm at a tremendous rate. We are using it, hopefully, in a constructive way and I hope the results are an indication of it. It does, however, bring up the question of our basic store of germ plasm.

For what now must be millions of years, Nature has been developing plants and animals. As the Earth's crust moved, barriers were erected. Ice ages came about to shift plants. The interaction of all these things has created a tremendous milieu of variability in nature. Man, as he developed, has been able to harness this and as Vavilov said, "This is evolution at the will of man". This is what we are seeing on a grand scale at the present time.

I think we have four basic types of germ plasm which we should consider:

1. The current breeding material and current commercial varieties, genetic stocks and so on. In these I place those things we are presently using. Breeders have these in collections around the world and they are in a form that we can use and interchange through nursery programs.
2. The obsolete cultivars. These are the ones we used to use but no longer do. Most of these are still available in collections in national programs. The USDA collection in Washington is an excellent example. With wheat there are something of the order of 22,000 or 23,000 lines from different parts of the world. A high percentage of these are obsolete varieties, but their characteristics are still in store.
3. The group of primitive cultivars and land races. These should occupy our concern. These varieties are the ones that man has used in many of the lesser developed countries for centuries. They are often mixtures. They are in balance with nature and diseases and so on. Some of these varieties, mixtures or populations are being replaced by the change in agricultural practice.
4. The wild species, related to our commercial group, make up the fourth group. By genetic manipulation we can transfer some of the characteristics again which they have developed over eons to the commercial crops.

There are three questions we should consider.

- a) Where do we go to get this germ plasm?
- b) What is the present situation regarding germ plasm as a whole for our future work?
- c) What does CIMMYT intend to do about it in the future if anything?

In answer to the first question, we are greatly aided by the work of that most remarkable man Nicolai Vavilov. Dr. Vavilov, a Russian, set out to collect cultivated plants. From 1923-31, he and his colleagues assembled a fantastic amount of germ plasm from around the world. It included about 26,000 lines of wheat alone. At the same time he also established and directed more than 400 research institutes and experiment stations to look at this germ plasm, to study it physiologically and pathologically, to experiment with it in every way and also to hybridize this material to improve their plant material. It was unfortunate that this tremendous forward thrust into this area was nipped in the bud at this time because of the injection of political genetics at that stage. Being a traditional geneticist, he fell into disfavor and disappeared about 1942 along with many other scientists. This was a great pity for, as Dr. Borlaug mentioned the other day, I think some of the current large purchases of wheat by the USSR would not have occurred and we could have had a Green Revolution in the late 1930s as a result of a continuation of this thrust.

Some of Vavilov's material is still available, but has been unavailable up to now. The main result of his investigations was the delineation of areas of the world which he termed centres of origin for different species. We think more of them now as centres of genetic diversity. He found that certain regions showed a very wide range of genetic variability. In the case of wheat, this was in the Central Asiatic Region, the Near and Middle East, the Mediterranean Centre and the Ethiopian Highlands. This is the main area in which this natural germ plasm has developed and diversified.

Let us look at this in relation to what we have been hearing about this week. Surely this is the same region in which the Green Revolution is making its greatest impact at the present time, if we look at the figures for this general area, and I am widening it out a little to include parts of India which may not have been in the original centre of diversity, in 1965 and 1966 there were about 9,000 hectares of these new wheats. By 1967-68, it was over four million hectares and by 1970-71 it was over 10 million. You can see here the impact of new germ plasm replacing much of the important group, in particular the land races and primitive cultivars of the region.

This then is one of the important problems to the biologists--the need to do something to conserve these. CIMMYT has made a commitment on two grounds. One is a moral commitment since it is the organization along with its collaborators that is making the largest impact in a very short time. We feel we must preserve this material in the region. Secondly, there is a very pragmatic reason for doing so. The very material we are helping to displace has the collections of genes for wide adaptability, for disease resistance and many of the characters for which we are looking. Therefore, the very things we are replacing are the very things we will need in the future to continue what we are doing.

Through a grant from the Rockefeller Foundation, we will in the next few years put in a concentrated effort to try and stimulate our own group and other groups to collect materials in this region and tie it in with a larger movement that is underway now. This material must be preserved in the collecting centres. As far as CIMMYT is concerned, we are placing it fairly high on our priority list for the 1970s.

DISCUSSION

Anderson

These remarks are in line with the general theme of this session. I think it is quite evident from the presentations thus far that the strength of the international programs lies in the genetic diversity and the testing of that genetic diversity. This can best be done under the collaborative system that has been established. In order that we do not reduce this plus effect, it is necessary for each of us to send back to CIMMYT any material which we plant breeders consider to be useful, not only in our program but potentially useful to others in the various areas. CIMMYT acts in this way as a type of clearing house for such materials --receiving and dispatching to the various programs. I would urge each of you individually and as leaders to urge your colleagues in national programs to increase this flow of material. For example, someone in one area finds there is a level of Septoria tolerance in X lines. These lines we will undertake to receive and circulate out to those countries where this disease is a problem.

One other point--in these international and regional trials, I would ask each leader and breeder to submit their few outstanding lines as early as possible for regional or global testing. This is not just to help the other countries. As Dr. Saari has repeatedly shown, the width of the disease resistance is shown by the lines' performance on a wide geographic area. This will provide confidence in making a decision on which variety or varieties are most likely to remain in production. We urge everyone to make the greatest use of this facility.

We would like to receive from you new varieties which can be placed in the international yield trials. These trials, as you are aware, can only be so large. You may submit the variety and you may be disappointed to find it missing in the succeeding trial. We must reserve the right to make a final decision based on its relative performance against other varieties and lines submitted from other countries. In choosing varieties for the ISYWN, for example, there are often only a few new entries. The larger the group we get at any given time, the greater the chance will be that the varieties are superior.

In certain countries, the policy will not allow sending unreleased varieties out for testing. This is a short-sighted policy since it is against the interest of the country concerned.

Borlaug

When materials have gone into these tests, it is fully understood that any materials submitted for inclusion in this nursery is available to any country for use either commercially or otherwise. The only rule is that the country employing the material recognize the country of origin. Up to now there has been no problem. Yet, I think we need to emphasize this point because as the number of nurseries expands, whether in durums, triticale, or barley, we do not want misunderstandings to arise. As Dr. Anderson pointed out, there are countries from which material cannot be sent until released. This of course, is a national consideration.

There is a second kind of thing, however, that falls into this category in a different way. In any case, where you see an unusually outstanding line that looks like it would have value as a parent, we would like 10 to 15 grams for rebrewing of more genetic soup so that it is crossed back into the pool and be again fed out around the world. If you don't want that line multiplied for international yield, state that and it will only be used here for crossing.

McGinnis

I had an opportunity to visit the People's Republic of China this past summer. I am happy to report that they have very sophisticated programs underway in almost all of the crops we have been discussing in the past few days. It seems to me that the time is ripe to work out an exchange or collection program with China. CIMMYT and FAO are the kinds of organizations who could conduct such operations. China has a vast untapped reservoir of germ plasm. I was fortunate in being able to become acquainted with some of China's plant breeders. They gave me three triticales, two winter wheats and two spring wheats which they considered to be among their best varieties. They are presently growing in Winnipeg. Should anyone like to observe this material, we would be happy to pass some on directly or through CIMMYT redistribution. I think that at this time that collection should be done in China. We have seen virtually no varieties in 23 years.

Schultz

As a concerned person viewing science it seems to me to be one thing to try to retain the natural stock of genetic diversity. Somehow, Nature over millions of years has provided it and you do not want to lose it; you want to husband it and you want to cuddle it. Eventually, it seems to me you must come to a point of diminishing returns if you are committed only to that stock. You may see this as a very long way away, but the implicit logic seems to me to eventually lead to diminishing returns. I come back to the thoughts of yesterday. Isn't it possible to create wholly new genetic species, subspecies, etc., with the openings now coming into the biological sciences. Should this be outside of your long run interest? I assume this involves another kind of research, another gamble in research, but in the long run this may be very important.

Finlay

I don't believe we are completely reliant just on the material that is available. Most of the genetic variability existing in primitive cultivars really has not yet been tapped to any degree. We have been around and around in the commercial variety type development for a long time. We have pulled out bits and pieces but there is a big reservoir which I consider will last a long time. On the other hand, I agree with you wholeheartedly. I thought somewhere this should come up as a part of our program because a greater effort is being put in by CIMMYT to get funds for doing exploratory work based on the success of triticales as the first one. We also tried an Agropyron-Triticum cross and this can be done fairly simply. I think the potential is there. We are still in need of drawing on the same pool for the pieces we need but it will create new variability. For example, in triticales there are certain characters not normally present in other germ plasm.

Shebeski

I would like to refer to one approach in which we have interest but have put on the shelf because of lack of facilities and finances. This is the Agropyron elongatum seven-paired chromosome group. We have at least three synthesized ABE species on shelf. These have a very interesting kernel. It is hard and vitreous with high protein content but we can, I am sure, take this type and develop a species which would have its uses on a wide range. This is just one of many that could be made in this whole species synthesis concept. We now have the tools to break many of the evolutionary hurdles and we are just getting started on this type of work.

Borlaug

Would you please comment on somatic hybridization for the benefit of many of the younger people here?

Shebeski

At the Prairie Regional Laboratory of the National Research Council of Canada, they are looking at hybridization at the cellular level. They are working on a fairly large scale and have a good group. They have successfully removed the cell walls of cells, brought protoplasts together, washed out the enzyme and reestablished the cell wall and have grown plants from these initial cells to full growth. But the concept is interesting. They would like to inject just a little DNA from a legume into wheat by this mechanism with the hope of transferring wheat into a legume crop. This is the kind of thinking presently envisaged and shows something of the challenges for young people in the future.

Borlaug

We think about these things but in our kind of institute we have to feed bellies as a first priority. One which we have bet on for the moment, although not very conventional, is triticales. We are trying

to push it across in cooperation with Dean Shebeski's group in Canada into a commercial crop. I think this will happen fairly soon. But we too are interested in the farther out. Perhaps not as much at the cellular level of fusion but in moving via the sexual route using new techniques. Some of these have been available for a long time and were used in making the original triticales crosses. Here I refer to embryo culture, colchicine, etc. With modifications we can conceivably cross a lot of plants that have never been crossed going the sexual route. For the past 2 to 3 years we have been talking about this.

Dr. Lynn Bates, who as a graduate student for his M.Sc. discovered the lysine level of opaque-2 maize, is this kind of a thinker. Several of us here and Dr. Roberts of the Rockefeller Foundation have discussed the whole question of sterility barriers with him. Dr. Bates is a biochemist and has looked into all the literature bearing on these problems. There appears to be real hope that this can be done. In the past year, the Rockefeller Foundation has provided some support and we have a joint operation here between CIMMYT and Dr. Bates at Kansas State University. This was the road that the triticales also took in allowing CIMMYT to become involved. Hopefully, if we can get means of removing sexual barriers between species or stimulating pollen growth through nonreceptive stigmas, we may get any number of new combinations becoming a reality. I would like Dr. Bates to say a few words.

Bates

The literature I have looked at have led me far afield in many cases. Basically, I would like to begin by trying to find chemicals based on a couple of hypotheses that we may have an immuno-competent system in plants similar to that in animals which has been suggested for a number of years. There are several ways of approaching this. I am simply taking another approach, viz: to try to find chemicals which will modify the cellular environment. We may be able to get things together in the cell as in normal sexual cycle, particularly for wheat x barley in order to move characters from one cereal to another.

Wortman

It has been possible over the past several years to be of assistance in dealing with some of the problems mentioned today. We have supported for many years the collection of germ plasm and I suspect between 1-2 million dollars have been spent on this in the last 20 years. In the case of wheat, the Rockefeller Foundation has given a grant to CIMMYT to get in the materials that they feel are still needed for safekeeping. Our big problem, frankly has been to get the geneticists and plant breeders to stop saying we need it and tell us specifically what was needed, and where it was so that we could put funding toward such a collection. That has now been done.

In the area of wide crosses we have also been very interested. Again we have a subprogram on wide crosses which we submitted to our trustees. Let me say our big problem is to find people who move out of the general rhetoric of talking about the importance of wide crosses and present to us a plan with sufficient vision that we can fund it. Money is not a limiting factor in the area of wide crossing today. It is the lack of

proposals with good scientific groundwork. I will challenge any group in the room to come forward with a proposal that would merit funds and I think the funding can be found.

Stakman

One difficulty always is to get someone to undertake a problem unless he can be sure he is getting results. Thus, we are developing people who are doing an excellent job of description but are afraid to take the time to try to make discoveries. Insofar as the collection of wheat is concerned, there is no question but what this is close to the heart of the Rockefeller Foundation. A number of years ago, the Office of Special Studies had already become the World Centre for collection and recombination of the genes scattered around the world.

Paarlberg

How do you get rid of the losers? The propagation of particular progeny from a given parent is so potentially great that a large percentage will be carried along and the work can expand at an enormous rate. I know that sometimes work can be carried along because resources are available in a Parkinsonian fashion, "The work done multiplies up to the amount of resources and time available for its doing". You now have more resources. How are you going to keep this work relevant to sort out the losers and stay with those that show real promise? I am not a wheat breeder, but I am a bureaucrat and I see the potential problems. I wonder whether you have focused on this one.

Wortman

One of the major problems in this general area of germ plasm collection is that of how much money should be devoted to this and how much material should be maintained. There is presently a proposal before the TAC and there has been foot dragging by some donors who feel that if they were to give large amounts of money to collect large amounts of material of doubtful value, that this would not be a service to the scientific community. What we have attempted to do is ask the scientific community--the people with the greatest knowledge--to identify specifically those materials and those regions of the world that have not been adequately collected and then send out experienced people and bring in collections which really represent gaps. There is, therefore, a mechanism for governing the extent of collections.

Rodenheiser

As one travels around the various stations of the world and reads reports, some of us are struck by the number of nurseries grown at individual stations. As you read those reports and look over the material there is obviously considerable duplication of effort. Many

of the station people feel the need for some coordination somewhere along the line to remove this. It is not unusual for an agency or a few agencies to send out a letter, e.g., "Please test these things for a specific reason," and yet many of the entries are duplicated in others being grown. I feel these should be cut down and it may be advantageous to have some organization with the responsibility of doing this.

Stakman

I take it you mean unnecessary duplication. Would someone else like to sharpen up this point. There are a number of different agencies and obviously this leads to duplication and certainly as Dr. Paarlberg says you just don't have time to quit your projects and examine them carefully enough so that they become routine.

Kingma

One of the reasons we have this large screening program in the Near East Region is to try to reduce the number of items going to many of the countries. CIMMYT sends most of their nurseries to Lebanon. There we cull the best out and send it from there. Probably not more than 25% is removed. Your point is well taken. There are many nurseries which continue by inertia but our cooperators are sometimes partially culpable. If by October or November they have not received a certain nursery, we get letters saying that they have received it for three years and why didn't it come again. Seemingly, they are counting on a lot of these nurseries. They have space assigned and they want it. Also, they feel they have a good chance of turning up new and useful things in these nurseries and perhaps sometimes they feel if they are going to continue to have cooperation they must grow the whole nursery in order to retain the data requested which can be of value for the whole region. I feel that we should try to grow the various nurseries in one or two key places in a region and cull from those the ones which are most useful, sending them out on a broader scale. We are trying to avoid unnecessary duplication even now.

Stakman

Am I right in assuming that there are different types of duplication between agencies, for example, CIMMYT, FAO, F.F., ALAD, etc. My opinion is that these agencies should get together and come to an agreement on how the most effective results could be obtained.

Hafiz

FAO started this program in the region in 1952 under Dr. Harrington. These nurseries were only for screening varieties against disease. Later, FAO began cooperation with CIMMYT and yield trials were cooperatively carried out from 1961 onwards. In 1969 when Ford Foundation entered the picture in Beirut, they started two nurseries. Later, we felt there was duplication between FAO and Ford because they were working the same region. We came to an agreement and tried to prepare nurseries jointly to cut down duplication.

Secondly, we wrote to the various countries stating which nurseries we were preparing and asking what ones they would like and that we would distribute material according to country need. We may have duplication but we are trying to keep it to a minimum.

Klatt

While on the subject of nurseries, I would like to mention one more that we have just undertaken in Turkey. We have called this the International Winter Wheat Screening Nursery. We also have an International Winter Durum Wheat Screening Nursery. These have the same principles as those of Mexico except that winter wheats are involved and only winter wheat. We will try to send it only to regions where winter wheats are grown or where cold-tolerant types are needed. We are looking for more locations; we are soliciting materials from other programs and will be glad to incorporate these into our screening nursery. We are trying to distribute this by September 15, but this may not be possible with our delayed harvest in Turkey. For the most part the nursery will comprise the advanced lines of our Turkey breeding program at Eskesehri, Ankara, and other centres. If any of you would like this, we will receive your request and try to fill it.

Talaat

Dr. Hafiz, what is the future of the FAO-Rockefeller Foundation Training Program? To me this has been the most valuable and efficient training program developed thus far. We would hope this useful program could continue for at least five more years. I believe this program to have been one of the cornerstones of the Green Revolution. I was one of the trainees of the first course under this program.

Hafiz

There is no question of the need. We very much support the idea of training in the Near and Middle East. It is a question of funds. Dr. Tahir last year prepared a global program which included 5,600 people to be trained in Spanish, English or French over about 25 years. I have tried to impress upon all the need for such a program. I do feel, however, that perhaps the global figure, while it is needed, is not as important as the lesser figure needed to continue the program as in the past and I hope arrangements can be made.

Stakman

I wish to thank all speakers. Secondly, today we had some economists and people from different disciplines. There was no evidence of guilt consciousness and I could see a synthesis and a long step toward the development of a guiding philosophy based on mutual understanding and cooperation. Insofar as the international phase of this is concerned, I am very sorry that our various countries are not closer apart so we could all be farther together and discuss these things more often.

PHYSIOLOGIC RESEARCH AS A TOOL IN IMPROVING YIELD POTENTIAL

R. A. Fischer

I think most plant breeders recognise a growing need for physiological information which can be used by them in selecting parents and progeny. I need only recall the remarks of Dr. Klatt, Dr. Anderson, Dr. Borlaug, and Dr. Rao during this conference.

Such information is needed particularly in order to further advance yield potential, by which I mean yield in absence of fertility, water and disease limitations. There is also some hope, expressed by Dr. Klatt, that physiological knowledge will help in selection for yield and yield stability under water-limiting conditions--dryland yield potential.

To set the present scene with regard to yield potential under irrigated conditions, I would like to show you some data from my trials at CIANO (Table I).

TABLE I. Grain yield as % of Nainari 60 under irrigated high fertility conditions and without disease (1970-71 and 1971-72, CIANO).

Year of release Variety	1950 Yaqui	1960 Nainari	1962 Pitic Penjamo	1966 Siete Cerros Inia	1970 Yecora Cajeme
Grain Yield as % Nainari 60	93.5	100	123.5	132.0	148.0
Progress by steps	+7%	+24%	+6%	+12%	
Progress by decades	+7%		+48%		

The varieties shown represent milestones in the Office of Special Studies CIMMYT/INIA breeding effort for yield potential. Progress over the last decade has been relatively substantial by any standards, and associated particularly with reduction in stature and the concomitant increase in lodging resistance.

Looking at the variety Yecora, apart from its shortcomings in disease resistance and perhaps quality, which are really not relevant to my argument here, it is difficult to say what is wrong with the variety. In other words, without evoking plant ideotype concepts which are largely, I believe, unsubstantiated as yet, or without resorting to a discussion of its deficiencies in certain numerical components of yield, a discussion, I believe, would not very helpful. The breeder is finding it increasingly difficult to select for yield potential above that of Yecora 70. More than ever he needs new selection criteria, feasible techniques based on knowledge of the aspects of morphology (plant type) and physiology which presently limit yield to the 7 to 8 ton/ha maximum achieved with Yecora 70 and its 3-gene dwarf relatives.

How should a physiology program go about this task? Very briefly I will mention the two rather distinct approaches I have taken in my two years here.

The first approach involves the detailed comparison in the field under optimal conditions of a large set of diverse genotypes, amounting to approximately 50--what I call a streamlined crop growth and yield analysis, along the lines of the crop physiological work of Blackman, Gregory and later Watson and Thoren in England. As a first step, my idea is to try to relate grain yield differences to the various measured aspects of crop morphology and physiology. Such an approach, if the genotype set is sufficiently diverse, is largely unbiased by preconceived notions about what might be the best morphology, etc. A wealth of data has been collected but it has only been partly interpreted. An example of the simplest type of information coming out of this approach is seen in Table II.

TABLE II. Important growth and yield parameters illustrating the physiological nature of genetic progress in the last decade; optimal disease-free conditions (Trial BI, CIANO, 1971-72).

Variety (ies)	Height class, cm	Mean date of 50% anthesis	Mean grain yield g/m ²	Mean total dry matter g/m ²	Harvest Index
*Gabo, Nainari 60					
Napo 63	tall, 140	Feb. 23	381	1330	0.28
Gabo, Nainari					
Napo 63	tall, 140	Feb. 23	484	1440	0.34
Pitic 62, Penjamo 62	E ₁ , 115	Feb. 24	560	1480	0.38
Siete Cerros 66					
Inia 66	E ₂ , 105	Feb. 23	550	1410	0.39
Yecora 70, BbxInia	E ₃ , 85	Feb. 21	618	1410	0.44
Olesen	E ₄ , 55	Feb. 19	560	1280	0.44
SE of mean			18	40	0.01

*With natural lodging; all other results in absence of any lodging.

We are again examining the genetic progress, this time over the last decades according to the steps by which height was reduced. Elimination of lodging increased yield. Reduced stature, even in the absence of lodging, also increased yield. This increase was associated not with an increase in total crop growth, but rather with an increase in the harvest index or ratio of grain yield to total crop growth--a more efficient distribution of dry matter arising the shorter the variety. The very extreme dwarf (E₄) studied in this trial showed an interesting drop in total crop growth. One of the important questions facing physiologists and breeders is whether to try to make something of these E₄ types. Even so it is clear we are coming to the end of the "reduced-

stature" road as a reliable way to further increases in yield potential.

The second approach I have followed has taken the best current varieties, concentrating especially on Yecora 70, and studied their reaction to manipulation of their environment in the field under optimal growing conditions. This manipulation includes shading, thinning, crowding and CO₂ fertilization treatments in an effort to identify yield-limiting processes and critical stages of growth in the life of the crop.

It is suggested that such trials help us narrow down the possibilities in the attempt to understand yield control. For example (Fig. I) it is clear from these and other results that early crop growth (tillering if you like) is not so critical for yield in the experimental situation studied.

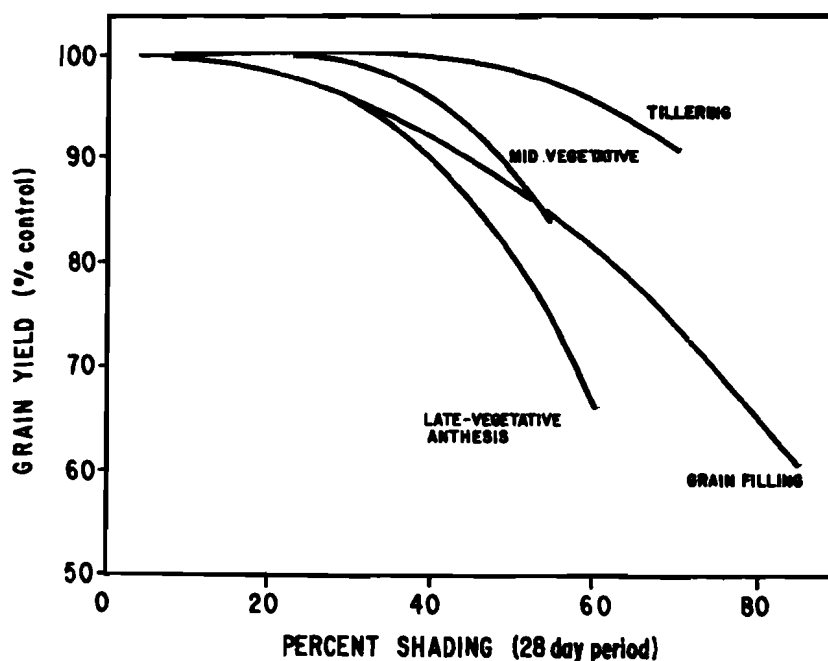


FIG. I. Effect of shading on grain yield.

What of the future? I think the above type of work needs to be curtailed, at least in the field at CIANO, until it has been fully analyzed and interpreted. At the same time I think we need to open up other avenues of attack:

1) Let us make some considered guesses about useful improvements in plant type or physiology and try to prove their validity. For example, circumstantial evidence is strong enough to justify a look at erect leaf type in contrast to the floppy types we presently have. Such work has begun in a small way. Other considered guesses one could glean from the literature include low tillering, high-tiller survival types (Bingham); reduced thermosensitivity, not only in the immediately postseeding period but also in the postanthesis period; increased photosynthetic efficiency; ramified ear types; etc. Several approaches can be taken in each case; the best is probably to set up populations showing variability in the character of interest once sources of such variability have been located. Isogenic lines may also be considered here.

2) Initiation of detailed crop growth and yield studies on certain key genotypes at sites other than CIANO both within and outside Mexico but designed to sample the various key climatic regions under which wheat is grown. Only with such trials can we start to understand the physiological basis of adaptability. Perhaps this approach could be considered an international physiology trial, designed and coordinated by CIMMYT. It would take substantial resources. This year we plan to initiate work at two more sites within Mexico.

3) Studies on selection strategies. I am worried about the problems of identifying high-yield potential in spaced plantings of F_2 and F_3 generations as we are presently trying to do here. I think the circumstantial evidence is strong enough to warrant the testing of alternative strategies for certain promising crosses. I am sure Dean Shebeski can give us some helpful suggestions in this area.

4) Yield potential under dryland conditions. We have begun some studies comparing diverse genotypes under simulated drought conditions at CIANO. The aim is to identify unequivocally drought resistant varieties and if this is possible, to characterise them in a manner useful to the breeders. If the methodology proves successful, such studies could in the future be expanded to include barleys and triticales in particular. I would also envisage close cooperation with ALAD.

5) Finally, I think the CIMMYT wheat physiology program has an important role to play as a coordinator and stimulator of relevant physiological studies on wheat at other institutions; for example, those with controlled environment facilities or with a special interest in crop growth modelling or with graduate students who wish, through their theses problems, to have contact with an experience in international centres.

In summary, I have mentioned many possibilities. It is necessary to assign the priorities in view of the limited resources; this is difficult and we could use advice. If pressed to reply, however, I would opt for the first and the third of the new avenues of attack just proposed,

that is, studies of likely useful plant characteristics (for example, leaves) and a study of selection strategies. Hopefully, with the assistance of a young Dutch scientist who is joining the program next month, work will soon be initiated in these two areas.

DISCUSSION

Upadhyaya

We find that, under rainfed conditions, when Gabon among the aestivums and Gaza in the durums are used in crosses to breed new varieties there has been a good increase in yield and the plant seems to be quite efficient in using low soil moisture levels. Perhaps this finding should be used in physiologic studies in future.

Fischer

Since I was Australian, we put this in the drought trials which would support what you said about that genotype and its ability to perform well under dry conditions.

Shebeski

Dr. Fischer mentioned that he had strong circumstantial evidence for the advantage of the erect type plant and yet in the picture he showed of the triple dwarf Yecora, it did not look like an erect type. You implied that it will be difficult for this to be beaten in yield. How do you rationalize your statement about this and still suggest another is better?

Fischer

The circumstantial evidence comes from other crops. In rice it has probably been established as well as in any crop that the erect leaf is useful, under tropic and subtropic conditions at least. In corn there is a lot of work and I suppose one might say half are in favour and half against. I would also say that other circumstantial evidence comes from theoretical models of crop photosynthesis where you can show in the lower latitudes, at least at certain sowing times and with large leaf area indices, a substantial advantage to erect leaves. There is some evidence also from the Canadian breeders in Ontario --Statzkof and his colleagues. This evidence being what it is, I ask myself why the best varieties coming from the program are quite floppy leaved. One here is not selecting completely objectively for yield. Each breeder tends to have certain characters in mind. It could also be that up to now breeders have not been interested in the erect type. Another suggestion is that probably under spaced populations erect types would not look as good as the floppy-leaved plant types. I suspect they may be less able to exploit their immediate environment as well. Certainly, if there were interplant competition in the segregating population, I would expect the erect types to exert less competition against the others in the mixed stand. Peter Jennings, for example, at IRRI, states that the erect-leaf types in a bulk population would not have survived.

Wright

Are there any erect types to speak of in the varietal picture? There are tremendous numbers of floppy-leaved types but there are few erect as I have seen them!

Fischer

I agree there are not many, especially if the materials are under high N. If N is low virtually all are erect. So, if you are interested in the type you must have high N and these are the conditions where it may be an advantage. We have found some in both bread and durum wheats. I would stick my neck out and say that from a distance one or two look like IR8.

Taha

How do you measure your dry weight? At what stage of growth do you take it? The yield index has been known to vary with variation in sink capacity. We know we can raise sink capacity.

Fischer

We take the total dry matter at physiologic maturity. We are, in certain trials, making other harvests earlier. We haven't observed a drop in total dry matter so I think there is a fairly wide period of 2 to 3 weeks in which you can measure total dry matter. Perhaps there is no drop because there is no rain in the postflowering period at Obregon and rain is what can reduce dry matter. If a breeder is interested in harvest index, the only time he can get at this is at maturity. I think breeders will be interested because of a recent paper of Dr. Jim Syme in Australia showing a very good correlation between harvest index measured on potted plants with that obtained in the field. He grew the 50 varieties of the 5th ISWYN and grew them in the greenhouse. He measured their harvest index and ran a correlation with the mean yield of these over the 70 or so sites reported for the 5th ISWYN. His r^2 value was about 0.85. This amazed me and I feel there is something very meaningful about harvest index.

On the question of sinks, I would have to agree. Two years work at Obregon indicates that sink size is one of the limiting factors and also pinpointing the late preanthesis period as that in which sink size is being determined and the time in which we should be doing more detailed studies on the crop. This is one reason for my interest in erect leaves for I think the real advantage will come when the crop has a high leaf area index, which is just before ear emergence. The advantage may come both from added crop photosynthesis, but there is also a better distribution of light among the tillers. In Yecora in this period, the number of living tillers drops from 1,000/square meter to 500/square meter. This represents a very large loss in potential sink. So we are interested very much in sink control.

Johnson

In your future work, you did not mention the roots as a valuable or significant part of the total plant, particularly under dryland conditions.

Would you care to comment on this?

Fischer

We have discussions on this. Under irrigated and fertile conditions, I do not think we need to worry about roots. Under dryland conditions, I agree that we need to worry about roots but since it is so difficult to measure roots, I think the only way to do it is get at it indirectly in a simulated drought study or trials in drought regions. Once we get real evidence that there is drought tolerance, i.e., varieties which do better than others starting off even, one can attribute this to what you suspect is a better rooting system. This is the time to start digging for roots. I feel that although much is written of drought resistance and lots of people believe in it and believe in certain mechanisms, much of the evidence does not stand up to close examination. The exception is the work of Hurd in Swift Current which I believe showed Thatcher had something in the way of a vigorous and deep rooting system. In our spring wheats we are trying to identify drought resistance. Once we have identified it, we will look at the different parameters in the plant that would explain this resistance. Then if we dig roots and find they are important we have to translate this into some type of selection criteria which will, I think, be difficult.

Bradfield

I was very much interested in the data shown on the slide that percent dry matter formed which goes into the more valuable part of the crop--the grain--varies widely in otherwise closely related material. I think this is a phenomenon of general and very significant economic importance. I have made a few observations with corn. If you take the varieties that yield high in the Corn Belt of the U.S., they are not tall varieties but medium in height. When you take the tropical corns, most of them are tall. The ear is very high. They produce a great deal of dry matter, have much leaf surface and have much photosynthetic activity but the photosynthate produced is low-value stalks instead of high-value grain. What can the physiologist tell us in the case of wheat about the physiological mechanism that diverts the photosynthate more into one or the other form?

Fischer

There is nothing very clear, but certainly some ideas. If you look at these varieties before anthesis, before they have even started to produce the grain, you can see the potential harvest index if you like, i.e., simply the weight of reproductive tissue over the total dry weight. You already see the advantage of the short ones compared to the tall. I would say, therefore, that the advantage in harvest index comes from the preanthesis period and is probably directly connected to their short stature. Carbohydrates are not going into stems but going to form larger ears. The fact that there is a larger ear means there is a larger sink, as Dr. Taha said, when you enter the grain-filling period. In many of our varieties it seems it is not photosynthetic capacity that is limiting so much as the sink, i.e., number of grains present and their capacity to take photosynthate and form it into starch. Just the other day Dr. Laing from the University

of Sidney reported very interesting results on this. He compared Gamenya, an Australian Gabo type wheat, with Penjamo 62. He measured crop photosynthesis every few days through the grain-filling period. Both gave the same amount of photosynthesis, but the grain yield of Penjamo 62 was about 100% of the photosynthesis of that period and 30% higher in yield than Gamenya. I feel that the larger ears, larger sink and shorter stature were responsible for this. Gameya, on the other hand filled its sink and extra photosynthate went to the roots or stem, or was respired away.

Rodriguez

Perhaps I misunderstood your statement. You said our present methods used to select F2s on space planting might mean we are missing good plants. Would you comment on alternative selection methods?

Shebeski

I agree with Dr. Fischer that when we space plant F2s we have preconceived ideas and we are looking for vigorous plants. We may have had a tendency over the years to select for quality types. I know that the type of work in which he is interested is important because if we can get some selection indices at the F2, we can begin to concentrate on what I believe is the real method of selection for yield at the F3 level and that is by actually measuring yield. I believe we can begin selecting for wide-range adaptability at the F3 level with some of the new concepts now being put under test. But if we could get selection criteria at the F2 level when we do space plant, then it would help the plant breeder considerably.

Goldsworthy

As Dr. Bradfield rightly says, it is the contrast in two types that is often interesting. When I arrived here about the same time as Dr. Fischer, we encountered very tall maize plants, the sort of thing Dr. Fischer has described in wheat. The advantages of short plants lies in the fact that one can begin to manipulate them agronomically. They don't lodge and you can use high levels of N. In the maize program now a large part of the effort is being put into producing shorter plants. In the past few years it has been very clear that we can manage these shorter types in an entirely different way from the original tall tropical materials. We are increasing yields with higher populations of plants and a high level of N in the sort of ideal field management conditions Dr. Fischer has been speaking about. Popultions are about three times those being used by breeders or in traditional commercial field practice. We are still up against a problem as Dr. Bradfield suggested, in contrast with wheat, that a large amount of the crop photosynthate is going into the production of more stalk. Dr. Bradfield asked how to get the plant to put its resources into the grain. Once grain formation begins, how do you ensure all the photosynthate goes into the grain? Even with the short plants we now have, one of the problems is that we are still getting stem elongation at the internodes and development of the meristem in the stem. There is a significant increase in dry weight of this part of the plant at the time that sink components are increasing. We start off in maize here with

6 or 7 fully differentiated lateral inflorescences (ears), yet at harvest we have one.

At the sort of management for which we are aiming, we are going up to 10 to 15 plants/square meter compared with five the breeder presently uses. These are the levels at which we are getting highest yield, and our problem then is that we have a high proportion of plants which are not producing ears. Yet these also start off with the 6 or 7 differentiated. These are interesting comparisons and are exactly the same lessons in general that you are speaking of in wheat. The application in maize is quite different in other ways.

Someone mentioned erect leaves. We can maintain in even tropical materials high crop growth rates as measured by high dry weight production. Our problem is not yet a question of looking at erect leaves and distribution of light to increase rates of dry weight production. Our problem, currently, is to get the dry weight into the right place.

Fischer

I would like to return to Dr. Rodriguez question, which I consider important. I am not proposing a change in the breeding system at the moment. I am suggesting that there is evidence that we should be testing alternative strategies in the physiology program. This is probably our responsibility or the responsibility of someone working between physiology and breeding. Of course, these are alternative strategies for advancing yield potential. It has nothing to do with simply inherited characters such as disease resistance and quality, many of which can be evaluated on spaced plants.

I would like to expand a little on alternative strategies based on what Dean Shebeski has just said. He mentions it is possible to yield test in F3, thinking in terms of microplots, yield plots, repeating checks or other methods. But of course, you will all say this is a high use of resources because it involves cutting, threshing, taking yield figures, etc. I admit this. You immediately reduce the number of crosses of F3 lines you can handle with given resources. I submit that you, however, would make a substantial gain in precision in the assessment of the different yielding abilities of your progeny. It is possible that this gain will compensate for numbers being handled. I think it worthwhile to test some strategies.

Anderson

Dean Shebeski has shown his method to be very successful under the conditions he uses for testing and selection. Since his nurseries are predominately rainfed, I would submit that his approach has different advantages. Under these conditions, it is more difficult to have as great an expression of genetic potential as opposed to environmental effect. This is not nearly so true on irrigation. There is no question that the number of progenies will be restricted by Dean Shebeski's method. It is my contention that taking these things into consideration and remembering that we are predominately producing genetic material to be tested on a very wide set of conditions, it is large amounts of material

with a large degree of genetic diversity that seems important. We must retain a method which allows us to pump in a very large number of crosses for exploitation, not just in Mexico but in the many programs with which we are cooperating.

PRACTICAL TRAINING FOR JUNIOR SCIENTISTS AND THE IDENTIFICATION OF SCIENTISTS FOR GRADUATE TRAINING

John H. Lindt, Jr.

CIMMYT offers wheat training for breeders, wheat pathologists, quality chemists, production agronomists, and special opportunities for senior visitors.

Our objective is not to create a breeder-geneticist who's sole interest is "chromosome knobs" but rather an agronomist who can build a high-yielding variety to meet the needs of the environment-physical, economic, social and political--and to develop a package of practices to maximize the benefits to the farm family and the country.

George Harrar described our needs "not for people to disappear into laboratories, but for humanists who will help people to help themselves".

Soon after Ernie Sprague arrived at CIMMYT, he asked me to describe the end product of our training program. My answer was: to create a team of agronomists like the Three Horsemen--Bradfield, Mangelsdorf and Stakman.

What is an Agronomist?

At the "Production Agronomists" conference at IRRI in 1971, a number of you who are present today described an agronomist as: an agriculturist working to increase crop production at the farm level; he is an authority on cultural practices, needed inputs, markets, storage, utilization, credit and transportation of his crop speciality.

The characteristics needed for the production agronomist most nearly indicate the general characteristics we want to develop in CIMMYT wheat graduates. Our training has three main objectives:

1. To develop a research and production attitude

Team work, enthusiasm, an inquiring mind, adventitious attitude, the ability to make decisions, and an appreciation of the dignity of work are some of these attitudes.

2. An understanding of agricultural development and recognition of the factors involved and their interdependence.

3. Technical knowledge and skills with the emphasis on "how to do". The common core, common to all our programs includes:

*Learning about the wheat plant: environmental reactions, growth, and genetics.

*Diagnostic skills: the identification and correction of diseases and deficiencies.

*Experimental skills: to develop information and the evaluation of the research of others.

*Identification of a package of practices.

There are specialized skills for each training program: Breeders learn how to develop and introduce a high-yielding variety. Pathologists learn the skills supportive to plant breeding. Chemists learn to evaluate, for market use, breeding materials. Production specialists learn more cultural-experimental and communications skills, and how to manage training programs.

If you look at the training programs at CIAT, IRRI and the Interasian Maize Program you see considerable resemblance in both contents and methods.

These programs have stressed "learn by doing" with as much flexibility as possible to meet the needs of the participant country and the trainee's preferences and deficiencies.

The general opinion has been that this approach to practical training tailored to meet the specific objective of increasing food production in individual countries has been successful.

Our Training Strategy.

First, we start with testing and counseling to identify the trainee's knowledge, skills and interests. Testing is also used to permit him to assess his own progress and to identify deficiencies in our instruction.

Motivation is reinforced by bringing the trainee into the team assignment of responsibility, peer pressure, recognition by honors, and encouraging personal relationships with other trainees and staff members. Pep talks by Norman Borlaug and the trainees identification as a representative of his country are also important.

Development and Knowledge and Skills

The wheat staff has identified what the trainee must know and be able to do in order to contribute to the improvement of wheat production. These are described in terms of "behavior objectives" or how the trainee will act when he has acquired the knowledge or skill. Let me give you an example:

We don't care if he can write a 50-page paper on how to apply 100 kg/ha of nitrogen fertilizer, but he must be able to "show me". For the 100 kg of nitrogen, he calculates he will need 490 kg ammonium sulphate per ha; then he calibrates the drill and operates his tractor so that he applies it evenly and at the desired depth.

Byrnes and Golden have described the "resistance to change" by farmers as more often a resistance to the "change agent" or agronomist, because the farmer is not convinced that the agronomist knows what he is talking about.

How Does He Learn?

We think he learns best by doing, with sweat, or in the mud at Toluca, repeating the task until he has developed skill and appreciates the day-to-day repetition.

Let's look for a minute at the development of a wheat agronomist.

THE DEVELOPMENT OF AN AGRONOMIST FOR ACCELERATED WHEAT PRODUCTION

Age	Activity	Training
0	Born a farmer's son, perhaps, but most likely the son of a city dweller.	
6	Enters primary school	
14	Enters secondary school	
17-18	Completes secondary school enters vocational school, college, or university	
22	Enters first job as technician	On job instruction
24	Selected for in-service training	In-service training at CIMMYT or in the region
25	Returns to job	
27-30	Selected for M.S. study	Study and thesis in country, if possible
30-32	Returns to job	
32-35	Selected for Ph.D. study	Study and thesis in country or foreign
35 +	Returns, utilizes training, and develops on job, perhaps becomes a project leader.	

Selection for Training

Breeders, wheat pathologists and quality chemists are trained here at CIMMYT. Production agronomists; A few of the very best production agronomists are trained here, but most in country or in regional programs, which I think need to be developed soon.

SELECTION CRITERIA FOR IN-SERVICE TRAINING

1. Socially motivated, wants to help people in his country.
2. Enthusiastic, will work with hands, will sweat.
3. Has a position in an accelerated country program.
4. Has a BS or Engineer degree.
5. Good physical and mental condition.
6. Capable of adjusting to a new environment and separation from family.
7. Age: 24 to 35 years, mature.
8. Capable in the language of instruction.

While the trainee is at CIMMYT, we will make several evaluations of his performance and discuss them with him. The summary of these evaluations is available to the sponsor and employer upon request. We also try to

identify individuals of outstanding promise for later follow-up.

The on-job evaluation is, of course, of much greater value. This we see for ourselves when the senior staff can visit or when you make your own judgments. I have asked some of you to evaluate returned trainees this week.

SELECTION CRITERIA FOR GRADUATE TRAINING

1. Demonstrated use of technical knowledge and skills.
2. A thirst for more knowledge, imaginative, adventurous.
3. Demonstrated leadership ability, can inspire and motivate others.
4. Has played on the team.
5. Demonstrated interest in farmers and the development of his country.
6. Mature, good physical and mental health, able to adjust to prolonged separation from his own culture and family if going to another country.
7. Fluent in the language of instruction.

Interest in farmers and the agricultural development of his country should have been demonstrated. Before he goes to graduate training, there should be a definite job to which he will return. The reasons for this are to:

- (a) Identify the specific skills he should learn
- (b) Encourage a feeling of belonging while away
- (c) Reduce his doubts and to encourage a more rapid readjustment upon his return.

Where Should He Be Trained?

The home country is preferred when possible, but the complaint is often made that training programs lack quality and motivation. Therefore, many people feel that training should be in another country. I think a better alternative is to up grade the home-country institutions.

Some examples of improved home-country schools are:

Chapingo, México; Mostaganem, Algeria; and Katsetsart University, Thailand.

Training for graduate students should be of the highest quality and application possible, if not all countries initially, then selected regional centers with similar environmental and social conditions to allow appropriate and relevant research and training.

Some Guidelines to Outside Training

1. Similar to home country.
2. With an opportunity to permit contrast to the home country and see in other ways of doing things.
3. To provide a broad experience for the potential top leaders.
4. Many have complained that home country as well as European and American training is too theoretical.

Again, I suggest we select the home-country or outside training

and education carefully to be sure it is relevant.

We can also supplement academic training with a finishing visit to CIMMYT or another program to put the returning graduate back on a realistic basis.

OPPORTUNITIES FOR SENIOR SCIENTISTS OF NATIONAL PROGRAMS TO PARTICIPATE
IN THE CIMMYT CORE RESEARCH PROGRAM, BRIEF ORIENTATION VISITS OF EDUCATORS
AND RESEARCH AND GOVERNMENT ADMINISTRATORS TO CIMMYT AND OPPORTUNITIES FOR
POSTDOCTORAL TRAINING FELLOWSHIPS

Ernest W. Sprague

During the course of this conference we have discussed a number of issues revolving around the generation and utilization of technology to accelerate wheat production. Indeed, without a continued effort in this area it is unlikely we can meet world food needs. However, remember that it is equally important to continue to find ways of developing people simultaneously with the development of technology. In the long run this may be our most important contribution.

We have just heard about CIMMYT's role in in-service training. In-service training is extremely important and the starting point but certainly not the end point. The in-service training activities with the international institutes and in national programs provides an excellent mechanism for screening out those individuals who have the capability of developing into leaders in the field of agricultural research and production.

Often the lack of an adequate number of qualified personnel is the first limiting factor to increased production. Although there is no blueprint for a system that will fit the needs of every country, some general guidelines can be proposed that have proved to be successful in certain countries or regions and might prove useful in other individual countries.

One thing is certain, if the people of the world are to realize the potential from international agricultural programs there will have to be a continuous flow of genetic materials into, and among, national programs. There will also have to be more sharply defined national efforts and more opportunities for national staff to participate at an international level in order to keep abreast of, and have access to, the best ideas and breeding materials.

In my opinion it requires about 50 scientists in most countries to staff a national program for one crop at a level that the country will be self-sufficient in its research and production effort on a sustained basis. Of these at least 6 should have a Ph.D., 15 a Master of Science degree, and the remaining a Bachelors degree or equivalent.

If one assumes that the Bachelor of Science or equivalent degree may be obtained within the particular country or region a staff development program phased any time, will normally require about 15 years to complete. At present costs it will require approximately US\$1 million to finance such a staff development program.

In addition, a local training program should be developed to train extension personnel. The number will depend upon the size of the country, the size of the holdings and the speed with which a country wishes to accelerate its production.

Meeting the staffing requirements is just the start. Continued

opportunities for younger staff improvement must be taken into consideration. Also, opportunities for senior staff study leave is essential to assure that the national program does not stagnate.

We all know that a great deal can be accomplished with less people of lower qualifications than has just suggested. Every country that puts high priority on food production should get a program underway with what talents they have.

In the long run, however, if a nation wishes to maintain a competitive position in the international supply of food grains, they benefit from planning a staff development plan phased over time with the objective of becoming self-sufficient in their research and production personnel requirement. In preparing such a plan it should be remembered that over 10 to 15 years there will be a substantial attrition rate. Therefore, the plan should provide for more people than are required to staff the program.

Ideally, every person would have the opportunity to participate in a dynamic research and production program before starting his advanced degree program. Although this would be ideal, few in fact have that opportunity. Also, the vast majority of advanced degree candidates do not have a strong rural background and therefore, no experience with production problems at the farm level.

It is then extremely important that the student have the right kind of advanced degree opportunity that will overcome the deficiencies in background in his educational program.

There are few, if any, educational institutions in the world that can correct these deficiencies. Further, it will require a completely different understanding and philosophy on the part of educational institutions before these deficiencies can be overcome.

The idea of a group of scientists across disciplines working together on problem-oriented research projects for the most part does not exist in formal educational systems. To be sure, university professors say they work together across disciplines but this is rarely in fact the case (as we define the team approach).

The student is more commonly trained within a very narrow aspect of one discipline and the examples he is exposed to illustrates little or no cooperation with other fields and a great deal of duplication of effort.

Further, he is immersed in the philosophy of designing research that will produce data for publishing first and a contribution to agriculture production second.

I am critical of the educational system and philosophy that graduate students are exposed to. This philosophy prevails in the maturing as well as the more mature nations. In fact it is near universal.

Many students going through the degree systems complete their education equipped to do very well a very narrow range of investigations, but are not equipped to look at the total problem of agricultural production,

analyze the situation, set appropriate orders of priority of investigations, etc. In fact, they often are not knowledgeable of nor equipped to recognize the real problems that retard production.

A large number of advanced degree holders return to countries that do not have a dynamic research and production program or a critical mass of scientists from which to continue his professional growth. Such situations, and there are many, cause some people to question the value of the advanced degree for young people.

Learning is a continuous process and as a general statement completing a Ph.D. program equips an individual to start really learning his profession in depth.

After the degree a person needs the opportunity of working with more mature scientists who have learned more about their profession, who have learned that the plants, the environment and the rural community are great teachers.

Should we not question the type of advanced degree training that young people receive and do all that we can to improve graduate programs rather than to shy away from the issue? The picture is not all dark as there are a number of people in the educational institutions who are beginning to question the relevance of the type of degree program that is now offered.

When one looks at the world, one soon realizes that the need for training and education is great. The least well off countries in terms of trained manpower cannot today mobilize a complete team if they assigned all of the Bachelor of Science degree holders to one crop. Other, more mature countries have more advanced degree holders than effective demand.

I think it is particularly important that we all do what we can to influence and assist educational institutions to alter their programs to meet the needs of the student. I believe that this applies equally to the new graduate schools that are developing in various countries as well as the older well-established schools of the more advanced nations.

As stated earlier, ideally every candidate for an advanced degree should have about two years of experience in a dynamic program. This experience helps instill the philosophy of broad thinking, enthusiasm and dedication to the objectives of accelerating production. It further provides him the practical knowledge of the problems in production. The real question at hand is where and how can adequate numbers of people be afforded this opportunity. The international institutes can provide part. National programs can provide part, but still there will be many over the next decade who will begin their graduate education without adequate practical training and education.

Postdoctorate or postdegree opportunities can provide the practical experience for relatively few after they have obtained the degree. Opportunities of this type are also inadequate to meet a rapid staff development program on a global basis.

There are ways, I believe, where improvements are being made in the degree program that help considerably in training as well as educating the graduate student.

A number of universities in several countries are now allowing a student to do his academic program on their campus and return to his home country or a similar environment to do a more applied piece of research to meet the thesis requirement.

I believe that this is substantially better training for the student than researching a narrow problem unrelated to problems in his country and in a totally different environment. Further, it provides added research where it is badly needed.

These opportunities are restricted to those situations where the degree-granting institution has an individual national or foreigner that they will accept as a thesis advisor.

Many more such opportunities could be possible if there were a mechanism whereby universities would accept qualified people who were not members of the university staff to advise thesis research. This would no doubt require travel on the part of university staff and the thesis advisor. This would, in the long run, probably be beneficial as it would help inform more agricultural educators of the importance of the appropriate training for graduate students.

Another approach to providing broader training at the research level for a group of 3 to 5 graduate students representing 3 to 5 disciplines doing a broad research problem that would involve all of the disciplines represented. If this were done, the student would learn the concept of working as a team. They would also face the reality of the interaction of the various forces in solving the problem. An additional advantage would be the interaction that would more automatically come about among the professors guiding the students.

Still another approach would be for a student who had his Masters degree in one discipline to take his Ph.D. program in another and minor in a third. This approach at the academic level at least would prepare the student more broadly than following one discipline through both degrees. If the thesis research in this approach was of a practical nature the student should be much better prepared than is the usual case.

I believe any of the programs discussed is superior to the traditional system. Further, I believe that such deviations from tradition will greatly influence the educational institutions.

At this point I would suggest that nations sending students to foreign countries have a role to play in looking for the best opportunities. Those countries and funding agencies that have collaborative programs with various universities should be quite demanding that the cooperating universities find ways of meeting the students needs even if they deviate from the traditional degree programs.

Thus far I have discussed graduate training which really prepares the individual to begin practicing and, therefore, learning his profession in the broadest context.

There is a real need for a scientist to have an opportunity of continually interacting with other scientists in his country and internationally. In this respect, conferences such as this partly serve the purpose. More importantly, however, is the need for scientists to have the opportunity of spending 6 to 12 months occasionally as visiting scientists in other programs such as the international institutes operate. This provides him an opportunity of working with different materials and using different techniques. Not only will he profit from this experience, but so will CIMMYT.

Assuming that the scientific team is properly trained and doing an outstanding job, do the national planners and policy makers understand the importance of the program?

In general, policy is controlled by lawyers or civil servants. Planning is controlled by economists, and the agricultural scientist, who is by nature conservative, fails to communicate with the planners and policy makers. Therefore, there is a genuine need for policy makers and planners to visit the field program and to visit CIMMYT.

VISUAL AIDS FOR TRAINING

Claire Tailier

Miss Talier was born in France, is a biology teacher, and is currently employed by the Ford Foundation in North Africa to develop a series of visual aids that will help audiences as different as farmers, technicians and research workers understand the cereal production and cereal problems in North Africa. She has been asked to prepare 50 different series of slides, all relating to various phases of cereal production, and she is showing examples of three series prepared in Algeria in 1972.

The first series relates to the preparation of a F_2 nursery with segregating materials. Soil preparation and properly laid out experimental areas are illustrated.

Further steps are the preparation of alleys and the actual sowing by experimental planter.

The second series relates to the preparation of a variety trial and the various stages of development. She first showed identification of a proper soil where the experiments will be conducted, soil moisture being an important factor. She then showed how the experimental area is measured and stakes are placed in their proper place, then fertilizer is distributed so that the proper amounts of granules are evenly spaced over the experimental area. Next, bags of seed of the various varieties to be sown are carefully lined up. Then, the amounts of seed to be planted in the available experimental area are weighed out and the number of seeds to be planted per stretching meter are shown. The planting equipment was illustrated and attention is drawn to the importance of carefully cleaning the seeder after the first variety has been planted and before the next variety is sown. The results of the seeding operation are shown when the variety has germinated (eighteenth day). The continuation of this series deals with the management of the crop during growth. She illustrated side dressing, spraying 2-4D and plant development when the yield trial is at flowering stage and close to maturity. Roguing the variety to insure proper seed purity was illustrated as well as combining with the plot combine.

The third series describes various diseases, predators and accidents that can affect the cereal crop. She first illustrated diseases like yellow rust and powdery mildew. She also showed the damage caused by Hessian fly as well as the damage caused by birds and by improper treatment with 2-4D. Besides these slides, Miss Talier brought a manuscript that describes these slides with diseases, the animal predators and the various management accidents that can happen to the cereal crop. Copies of these slide series can be obtained from the Ford Foundation Office in Tunisia, 5 Mohamed Avenue No. 60, Tunis, Tunisia, Attention Dr. Piero Bronzi.

DISCUSSION

Cummings

In the discussion, we might bear in mind not only the specific content that we have been discussing this morning, but also think in terms of where training might go in the future. Mr. Hanson has indicated that he would like to get ideas as to not only the kind of training but also

the quantity of training that might be required or desired of CIMMYT in projecting its program for the future.

Wright

How can we obtain copies of the slides Miss Talier has shown?

Bronzi

Address requests for copies to the Ford Foundation, Tunis.

Da Silva

I wish to comment on the organization of research and training for research. We have had in the world a lot of information on how good the system of land grant colleges is. Every country knows about it and many have been trained in these U.S. institutions. I agree that they have been outstanding. However, in some countries I find the idea prevalent that agricultural research should be conducted only at such universities. I believe that such international centres as CIMMYT have shown that there is another way. They have a different philosophy and a different type of organization. There is another alternative, therefore, and I think it should be studied on the basis of a research organization. In many countries we have so many institutions doing agricultural research that direction and organization of research should in itself be a discipline.

Finlay

John Lindt stated that we like to get the trainees with an Ingeniero or B.S. degree. I don't want the group to get the idea that this is the only type of person we accept. We do prefer this level or above, but we appreciate that some developing countries need support and have no or very few young scientists at this level. Obviously, in training our job is to take the best available and try to improve them so they can build a research organization.

There is need, I say to funding agencies, for third-country training programs. Often it is difficult to get this type of support. We often get support for people to go to the country of the donor agency, but that country may not provide the type of training that we feel is best for that particular program. We must look at this in terms of greater flexibility and in the use of training funding. Then, from all points of view, the type of training offered is the best for the particular situation for which we are aiming.

Bolton

I would like to comment briefly on Dr. Sprague's presentation and then ask a question. I think we have to admit that usually when there is a consulting person who is requested to come, there is not need to bring them always from far away. I would like to see, when we have a situation where there is an outstanding scientist of proven ability in the region and a problem arises that he can field, that we find some way of using his services in this work rather than those of us who have more leeway in doing this work. There are two problems. Firstly, who pays the bill?

I would like to know what the thinking is concerning this? I feel it would give the individual an opportunity to demonstrate that he has the training and ability and a lot more competence within a region than for those of us from the developed countries to develop our experience more and more.

I would only say that I would agree. I see no reason why expertise in the region should not be used. The question rather is where can you get the best expertise and, irrespective of where it is located, that is where we should go for it. I think that one of the advantages of the international institute system is that, in some cases, funding can be obtained without going back to the funding agency for assistance.

Hanson

For a centre like CIMMYT, I believe this practice has already been followed in several instances. I think the starting point for us is our host country. A substantial number of our consulting services from CIMMYT are being performed by Mexicans who were initially trained under this program and are now staff members and going out. Certainly most of our consulting work in Latin America is being done from CIMMYT by Latin Americans who are on our staff. As I recall when you, Dr. Cummings, were in India and I was in neighbouring countries, there were a number of borrowing of staff from other countries in the region. There is no question but what the principle is sound. I think what Floyd Bolton is suggesting is that we should pay more attention to this opportunity.

Douglas

One of the points I was trying to get across in my talk the other day, was the desirability of having tied to the breeder-production agronomist training a small section on seed production. I talked to John Lindt and found that within the CIMMYT program there is a small section of seed production tied to this program. Certainly it might be larger or there is also the possibility what when you have in-country or regional training opportunities for people in this area, CIMMYT should not forget the seed production section, which is the next step after the variety is ready to go.

Hafiz

I would like to give a few observations based on our experience of the program which we (FAO) developed with CIMMYT from 1960 onwards. Firstly, this was a very good program and I wish to congratulate Dr. Borlaug for suggesting it when he was a member of the team of three who went over the region of the Near and Middle East. There are certain fundamentals which must be observed to have the right type of people and there must be a person in the region who knows those people through his frequent visits to those countries so he can decide on the possible candidates for such programs. He must be associating with them periodically and discuss with them their activities and what are they doing? What are their intentions? Would they like to continue in the program or do they want to shift to another? As you know, there is a great deal of changing of jobs in developing countries from one place to another. So we must see if those people have stability. This regional person should suggest to the officials in the country, since it is the privilege of the

country to recommend the person, that such and such a person deserves training. This is simply making the suggestion based on knowledge to avoid the appointment of the wrong man because of outside influences. It is fundamental that the training organization receive the right person for training. I can quote examples. A person is now doing a wonderful job in one of the countries. When I was observing him for 2 or 3 years as a possible candidate, I visited his station. On one visit we went to the fields and we were going through the experiments when it became 9:00 a.m. He said, "Let us go back. It is now breakfast time." I told him, "You can spend another half hour and this will save us coming back again." He stayed on but it was obvious he was not too happy. On the second day, we were again in the fields and he again said it was time for breakfast. I said, "Have you a clock here? I haven't seen you looking at your watch." I then said, "Look here, I was thinking you would be the next candidate to go to CIMMYT and if you do this there I am afraid of what Dr. Borlaug will do to you." So he then said, "I am sorry and I will never do it again." I recommended his name and he went back after training. On my next visit to that country, we started at 6:00 in the morning and returned at 4:30 p.m., and he never talked about breakfast. So this is the way it goes and now he is a very suitable candidate for a Ph.D. I am watching him. Thus, there must be a person who can identify the right people or otherwise there can be many wrong selections. Putting money and energy into these wrong people is a waste of time.

Secondly, as Dr. Finlay says, in the very beginning when we started the program there were no graduates in many countries so there was a choice as to whether or not we should send a candidate. After thinking it over, we decided that if we didn't send someone we might have to wait five years to get a graduate so that the program would be delayed accordingly. We, therefore, selected some good people from Libya, Afghanistan and other countries so that in the very next year a program was underway. No doubt they did not have all the background but they sowed the experiments correctly, took the readings and did the other things they were taught. Thus, when we don't have people, we should not ignore those countries, but select the best.

Thirdly, backstopping those people to look at what they are doing after training. We have sent 63 people for training from this region and 58 people are working on the jobs for which they were trained. Why? Because, whenever I visited those countries and through personal correspondence, I always told them that if they had any difficulties either in the work or of a personal nature, to just write me a letter. I have tried to solve these. Whenever I learned that a trained man had been transferred to another section, I would go to the country and get the administrators to put him back where he belonged. One man was transferred as a horticulturist and after three years I asked him what he knew about horticulture and why he transferred to this job. He said, "Well, this was a promotion for me." I said, "Do you like this job?" When he said, "No", I said, "Why don't you tell the administrators?" "They won't listen and put me back," he replied. I began to pursue the matter and after three years he is now back and very happy. Backstopping is essential.

Otherwise, I can tell you that there are many training programs going on in the countries and there is no way of tracing where so and so has been placed after his training. He either has left the country or

changed to another subject completely so that he is not proving useful. A good follow-up is very essential.

Cummings

I think many could bear witness to the effectiveness with which Dr. Hafiz has followed up on these trainees when you see the network of scientists that have come through here and that are performing within the area in which he has been working. I think these are very pertinent points.

Lindt

Firstly, the language. I admit this is a difficulty and is one of the limitations we encounter when people are taken out of their region. I would guess that to do all instruction in three as opposed to two languages would run into a real barrier in regard to time. We are going to appoint a second training officer in wheat who speaks excellent French and is familiar with North African problems. We hope this will help to some degree. Insofar as publications being developed in French, someone else might speak to this. So far, CIMMYT has limited itself to two languages. While considering it would be desirable to do it in three we have not had the capability to do so.

Secondly, I wanted to say something about the degree of training prior to when the man comes to CIMMYT. I realize a number of countries had a very limited number of people with college training when the programs started. We accepted people without degrees. Some have gone on and they have worked out well. Others have served in somewhat subservient positions on their return. In other words, they were placed under an ingeniero or more educated person later on who was not willing to make changes in approach. These people were in a position of limited capacity to train other people. Thus, since our opportunities for training are very limited now (30-40 per year), we must put these to the best advantage. We are not about to say that he must have an M.Sc. or B.S. degree, because we will accept experience, in some cases, as a substitute for education and we need this type of flexibility. I think that as the countries improve, we will increasingly ask for candidates who are more and more influential in the position they will occupy on return home.

Saari

Firstly, Mr. Lindt's reference to the need for candidates to be socially motivated. In my experience, these candidates are often too young to have developed this feeling. In the boys I have hired, I looked for self-motivation. In many cases they have had a difficult struggle to arrive at that point. Then you must try to determine that intangible--can you turn this ability to a socially motivated drive. It is difficult for these young people to have this motivation until they reach a position where they are able to demonstrate it. The ideal, I feel, is fine, but the reality is less clear.

Secondly, you commented that the plant pathology training stresses work with breeders. I feel this should work the other way. My experience has been that as a plant pathologist, the breeders have been giving me support. My biggest criticism of plant pathologists, in general, is that

they do not have this attitude. If you turned this to the positive, you could get better results.

McCuistion

Since CIMMYT is getting deep in programs of North Africa I would like to say a word on our ideas for training. Most of you know that we are very short on trained people. In Tunisia, Algeria and Morocco, there are differences in the level of training. In Tunisia, there are many more B.S. level people in relation to percentage of people in technical work than in the other two countries. Several of these have gone out and received graduate degrees and returned. There are two who are well advanced toward the Ph.D. Therefore, this group is already at a much higher level. Soon there will be a good cadre of people to take over that program, but they tend to be limited to the genetics-plant breeding-pathology disciplines. To the present, we have not had people available to go into production and yet they are thinking of concentrating in this area.

From Morocco, there have been many trainees at CIMMYT, as in the three countries, and this has been our main source of training --here in Mexico. They come back and are given positions with tremendous responsibilities. They take over direction of a whole region or whole program. With nine months training at CIMMYT, it is a lot to ask of a young man who is 25 years old to run a whole regional program. But they are game and they are trying. We just do not have anyone else at the moment until these colleges get their first class graduates.

In Algeria, we have five B.S. level people in our cereal program of a total of about 150 people. The rest are technician, or as we might say, high school level people. They are all in very responsible positions. We have not one we can send out for an advanced degree. Although we are limited with people and we have only five B.S. people, we must sacrifice and begin to send them off for higher education. We cannot afford to wait too long to begin. In Tunisia, we began immediately to send young men out for training and in some cases we weakened our own program, but we felt the advanced degree attainment was also important. The main point I was coming to is that within the next 3 or 4 years, these countries will need many opportunities to get advanced training at universities in the U.S., Europe, Australia or other countries. These would be in various phases of genetics, plant breeding, plant pathology, quality, entomology, agronomy and rotations, etc.

The problem is that when we start looking for support and start looking for a university, we do not find many that we feel meet the requirements for what our staff need. We don't want to send a young man out for a very specialized degree in genetics. We are not at a level that we can become sophisticated in our research program. We need to send the young man to a university that does have a team approach--where the pathologists, entomologists, cytogeneticists, plant breeders and quality people work together. They have to be a team because when this man comes back to direct a program he has to direct the whole effort. He is director of

the cereal section, for example, and is responsible for the whole experimental program. He cannot be a specialist. If he is, he will be ineffective. As we look for universities with a team approach, we do not find many. I challenge you in the universities and we here in the supporting agencies to keep pushing at getting the team approach at the university level. Dr. Sprague mentioned the need for a team approach in the universities. The trainee gets it when he comes to CIMMYT. He comes back motivated with a team approach and in North Africa this has to be built from scratch because it was organized in the traditional sense of fragmentation. There is not the coordination of effort which is needed. If we are to develop this for the good of the country, they have to absorb this idea in the training programs outside. For us in North Africa, we will send many people out to train over the next three years. There will be a big demand and we want the team approach.

Cummings

I believe this is the first comment with respect to the quantity aspects of need.

Klatt

I would like to give strong support for what Dr. McCuistion has said. I would like to bring up one other problem we face in Turkey and it will probably develop in North Africa and that is the question of language. Very few of our young graduates in Turkey can master the Toeffel test sufficiently well to enter university. We have located two universities that provide training in English before the student begins. I would like to recommend this to other universities. This would help a great deal in providing a wider experience through using more than the few universities.

Borlaug

Mr. Bronzi has just handed me a manuscript in both French and English on diseases which is beautifully illustrated, "Diseases of Cereal Grain of North Africa". I guess it refers to Algiers and Miss Talier is no doubt responsible. I have heard several groups talking of getting together an illustrated extension type publication and it behooves all concerned to look at this. Maybe it is already done here and only needs revamping for other languages and other regions. I suggest that all you pathologists have a look at it.

Hafiz

I comment on what Dr. Saari has said because Dr. Stakman is here to assist us. There is a controversy in the region between breeders and plant pathologists. Although I used to be a plant pathologist, I find both tend to express extreme views. For example, Dr. Saari knows that last July in Czechoslovakia there was a meeting of Mediterranean cereal people on rusts. I presented a paper, "Can Cereal Rust Studies Be Made Productive and Relevant." My paper was placed last. The first man gave a paper on epidemiology. He said he was using a computer to establish new facts. After his paper, I asked him to tell me, even though epidemiological studies have been conducted for 40 years in many countries,

what practical use this has been to the breeders on the production of the country. They say we want to develop a prediction formula. What will you do when you predict an epidemic? Will you spray 40 million hectares of wheat with chemicals? Is it economical? And after spraying, there is rain and the chemical is washed away. Will it be sprayed a second time? Would it not be better to tell your plant pathologists that they should thoroughly assess the cultivars in a particular country and tell the breeders that this variety is resistant and this susceptible. Breeders will do their job. I feel plant pathologists are giving the results of their work to the breeders and letting breeders sow the nurseries, spraying the spore suspension and deciding what is good and what is not good. So we don't need plant pathologists. So the plant pathologists should work in collaboration with the breeders in such a way that they are interdependent. They will find plant pathology is important. Otherwise, they only report that they are doing this and that study, that one strain is more aggressive than another, etc. One man gave a paper outlining his results of counting spores per pustule. He said that this pustule gives so many billion and that one gives less billions so one is aggressive and the other is not. We need a happy symbiosis.

Finlay

One of the things which concerns us is future activities and we are speaking of training. Obviously, CIMMYT will not become a university. We are not going to that level although, as Dr. Sprague said, perhaps we will take some thesis projects. At the in-service level, we have to realize that international centres are still new organizations. We are receiving new requests and I think this is leading us into a new line of thought in this evolutionary process, asking in what way can CIMMYT help countries that already have programs well underway, to set up their own in-service training. I think this is one of the areas that CIMMYT will seriously consider in the future and I think this is one of the ways to overcome language. The problem, however, is not quite as simple as it sounds. To have a training program, we feel that there must be a strong, vigorous breeding program on which to base the training. There is no point in taking a trainee into a dull and listless environment and try to stimulate them. Thus, the evolutionary process is one of building a strong national program, getting it to a stage where there is enthusiasm, vitality and drive before the training program is undertaken. A number of the programs that have been operating for some time are reaching this level of enthusiasm so that in the next few years CIMMYT will be looking at this to see how it can be turned into a multiplier effect. Obviously, we cannot train all the people required nor should we try. But we still need training and the right kind of training. We have to stimulate these young people. I suggest we will be involved in the next decade in finding ways to assist in developing training in areas in the local language in a way which will help to provide this stimulation.

Cummings

It seems to me that there is a common thread in all of this which indicates some unique features which the institute can put into this training program of developing professional competence for making a real impact on food production in the areas concerned.

1. You have a highly motivated team at CIMMYT which can transmit

this infectious motivation and help in creating a germ for motivation of science.

2. I think that at whatever level of training you have emphasized here, that a person learns by doing. He must have the understanding and ability so that he is able to do it himself and know what the requirements are if he is to be an effective worker.

3. You have a multidisciplinary team which is truly working together. One can get from the training program here a recognition of the fact that the solution to the problems that are going to be faced do require a contribution of several disciplines. There is also a recognition of the necessity and real benefit coming from these. Teamwork and complementarity in this is certainly very important.

4. One of the things you have been emphasizing is the question of an analytical approach to the problems, whether in giving advice to farmers as to how to produce more wheat or how to solve a problem on the land, a person has to school himself to a point where he is able to look at the situation, recognize there is a problem, identify what it is, be able to define it, and be able to recognize what the components are that will be necessary to give a solution. Finally, he must address himself objectively as to how he will go about its solution.

5. This institute has demonstrated that it can make a definite contribution to training. I hope it can stimulate this type of approach in the institutions to which it sends its trainees.

6. We all recognize there has been a tendency toward narrow compartmentalization of knowledge. The problems with which we are dealing are not ones which can be solved by the narrow approach.

7. I am sure the Director has received the feeling that this institute has a continuing, and not diminishing, role to play in the future training.

Borlaug

We started out on the first day covering the general conditions and in the last four days have considered more specific areas of agricultural research in small grain improvement. I was pleased to hear Dr. Cummings summarize considerations we have to keep in mind in trying to push up small grain production. It will not be done by a single discipline. I grow very impatient with those who become concerned with a specific discipline. I do not want such people on my staff. There is room for all. Sometimes you see the best cooperation where you least expect it --in disciplines far removed from agronomy and breeding. For example, here in the core program, the protein and industrial quality laboratories are probably the best team players we have. Drs. Villegas and Amaya have a grasp of the whole program. They put in more than their fair share and these are the things we are trying to achieve if we are to improve our efficiency.

I am sure that it behooves us all to look at ourselves each morning irrespective of our discipline, and decide we are part of a team. Unless we work as a team, we are not doing the best we can to fill empty stomachs around the world. This is the job we have been assigned by the

Board of Directors of this institute and by the funding agencies.

Now in looking at some of the points, it looks like sometimes people have too much faith in us. CIMMYT cannot do all things and it was never intended that it should in the first place. In the second place, it is not capable of doing so. Our first priority is to try to strengthen national programs across the board, both in terms of genetic materials, and information on agronomic practices, fertilizer use, diseases, industrial and nutritive value of the product and so on. We have to have an order of priorities. Without this we would not have a directed program. For example, should we become over stimulated by the possibility of wide crosses before we make a crop out of triticales on a commercial basis we would be remiss. That does not mean, however, that we cannot look at this and stimulate activity in this field at some centre where competence has been developed. Then, when the time is ripe, we can examine our position in relation to food production or to newly developed situations.

Again, I am impatient when people look for the ultimate, whether it is in the variety or in any field. There never has been or never will be a perfect variety. The wise plant breeders and wise pathologist who is working in the field will make their decisions in favour of what is the best at any given time. I have seen many plant breeders waste a lifetime looking for this perfect variety resistant to all diseases, have perfect agronomic type and be the highest yielding. Obviously, he has never found it nor has he ever produced anything. In one way, he has been a social parasite since almost always he has been working in a public institution. He may not realize that this is so. I am making a plea here for the use of common sense in how we go about trying to solve these problems or trying to alleviate the desperate food situation.

Someone mentioned earlier about the danger that if we get more funds we may fill up the institute with worthless material. This becomes the case when he who knows not how to discard and doesn't have the courage to discard is not an effective plant breeder. You will almost always find that the most effective plant breeder is one who knows his material well, studies it well, discards ruthlessly and keeps dynamic material coming along to fill the vacancies.

CIMMYT has been a privileged organization. I mentioned in my opening remarks that we sort of evolved like an insect from which one of the instars grew into the Mexican National Program (INIA). CIMMYT, I guess, would be the moth since it flies off internationally. I think if we look ahead, this moth might evolve into a monarch butterfly, much more beautiful and more utilitarian, hopefully. On the other hand, it might change into a boll weevil and anyone from cotton country knows this is not a good fate. I say this seriously.

In the earlier days, we were part of a national program. We felt the urgency as Mexicans, if I may be permitted to say that, to get the job done. This was the spirit permeating the whole organization. I think most of the old staff members still feel this way but we are now in a privileged enclave. We don't have a national program. The closest we have to this are the outreach programs. For this reason, I feel these are very important if we are to remain viable in the future. We must

not isolate ourselves in these beautiful surroundings.

We have been blessed with simple administration in these institutes. Little effort has been spent on report writing. We try to put out a decent annual report to our funding agencies once a year but there are not too many. I suppose as our funding becomes diverse, the organizations will want different kinds of reports. If we are transformed into a report writing agency, Heaven help us! You know what will happen to our efficiency.

So, as we look ahead it depends on those of us in these institutes, and I am more concerned about the core staff than the outreach staff-- they are on the firing lines. We can go down a dead end or we have a worldwide horizon with great opportunities to improve the standard of living of the world.

REPORT OF DRAFTING COMMITTEE

Haldore Hanson

DRAFTING COMMITTEE

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We have come to the last session of this symposium. As is generally observable, the last two or three days are often the best. People know each other and seek each other out for rebuttals of things said in the meeting. I think we get less cautious and less diplomatic in how we differ with one another and this helps in the exchange of ideas.

The wheat staff collected all the manuscripts used by speakers here. They have recorded statements made by speakers without a manuscript and reporters are preparing a summary of important parts of the discussion period. All of this will constitute a kind of proceedings. It is my understanding that the wheat staff will not publish the proceedings in any formal sense, but we ourselves want copies of these documents for our own working papers. Dean Shebeski and others have said they would like copies for the staff at home. Those of you who want them can get them. These will not be published in the sense that they can be quoted or reproduced unless it is with permission of the authors. CIMMYT wishes to safeguard those who presented papers or entered into discussion.

The paper we will discuss this afternoon is a different one. I visualize it as a paper of 5,000 words, perhaps 20 pages, which will have some statistics in it on the role of wheat in world agriculture. We will have to do further analysing of those statistics beyond what we get from the FAO Production Yearbook because the FAO statistics do not separate

developing and developed countries. In the case of wheat, this is an important statistical distinction. In the case of rice, most is produced in the tropics, which is not the case with wheat.

We will have to, with the help of some of those in this room, analyse for various countries; how much of their wheat is winter and how much spring; how much bread and how much durum. In the case of barley, we are interested in knowing how much is produced in countries in which it is primarily used for human consumption as opposed to malt or animal feed. We are hoping to provide to you a set of statistics that is more analytical of the discussions we have had aimed at developing countries, not merely a world research picture.

CIMMYT has received a wealth of ideas from the contributions of the people in this symposium. I am not suggesting there have been new, startling scientific judgements expressed here. However, many of you have come from individual countries or from organizations working in a particular region, and have expressed judgements, for example, that a given disease is number one in your area or the indications you have given on need for staff development and training is helping CIMMYT staff to rethink what our program should be in the rest of the 1970s.

Instead of trying to circulate a document which necessarily would be incomplete and probably casually done if done since yesterday's meeting of the drafting committee, we have decided to give you two oral statements as the basis of discussion. Mine is limited to what different country participants have said about the services they have received from CIMMYT and those they would like to receive.

Glenn Anderson has the task of qualitative evaluation of issues that have arisen and trying to merge some of them into a single topic. Most of my comments will be based on yesterday's meeting of a drafting committee of 19 people. We were most grateful to have so many. Our discussions continued for five hours. Some of this comprised lively discussion among friends on what priorities should be.

I do not expect to give you a comprehensive view of what was said. I picked a few of the key judgements they gave us on the most important remaining problems and problems of staff development, germ plasm needs and so on.

In opening the meeting, we used a preliminary draft of the beginning of the report. It says, this report will attempt:

1. To identify major unresolved problems in the production of wheat, barley and triticale in the developing countries.
2. To assess the progress of governments in achieving their own capability for greater research, training and production in cereal grains.

Time and again it has been mentioned in this room that CIMMYT regards the development of national capability as more important than what goes on here at CIMMYT. Even in our training our objective is to train people who can go back and do their own training.

3. To explore complicating factors, such as population growth and

related rising demand for food in developing countries.

4. The slow rate of adoption of new technology in some areas and the need for better government policies and services to stimulate increased food production.

I am not going to discuss this particular item this afternoon. I think we had from Dr. Paarlberg excellent observations on what population growth is doing to food demand in the 1970s. Dr. Winkelmann commented on the slow rate of adoption in some areas and his speculation as to why this is so. Dr. Swaminathan's paper gave many good observations on better government policies and services to support increased food production. Finally, and this is the ultimate problem that faces Drs. Borlaug and Anderson, to restate CIMMYT's research goals, its training capacity, its strategy for assistance to national programs and, thus, to reformulate the role of CIMMYT in the remainder of the decade. Again, that's not a topic we are going to try to formulate this afternoon, but when you each get this publication, which we hope to have out before long, you will see how this problem was met. Incidentally, this statement will be submitted by the wheat staff to the CIMMYT trustees and with their approval will become the basic statement for the next few years of what our wheat program is expected to do.

Let me now turn to some of the geographical observations made yesterday. About 20 countries are represented in this room and we called on 6 or 7 individuals yesterday. One interesting observation came out when we started analyzing who we were talking to in that room. I will talk of Asia for a moment. There were representatives there from India, Pakistan and Turkey. When we look at the statistics on where high-yielding varieties of wheat are being grown this year, we had a list of 12 to 14 countries which were producing this year 10 million hectares of high-yielding varieties of wheat. Eighty-five percent of all that area is located in India, Pakistan and Turkey. The three men we were speaking to were the coordinators, each in his own country, of the research group on wheat. We can say we were speaking to three very knowledgeable people who were responsible for 85% of the high-yielding varieties of wheat being grown in the developing countries.

I am not quoting individual judgements here, but trying to give you a general impression of what the committee found and when we publish this it will be merged into a series of conclusions.

India commented that the number one problem in irrigated wheat was achieving stability of yield. As all of you know this means to a considerable degree greater resistance to diseases and this, as we discussed it, a recommendation to Drs. Borlaug and Anderson that what they are trying to do in providing horizontal resistance to rust is very important to India. In the case of dryland wheat, someone pointed out that although India has doubled its irrigated wheat in the last six years, still more than half the acreage is rainfed wheat. The need here is for a more efficient use of water, both by the plant and by the farmer. In other words, this comment was aimed at the CIMMYT staff. Unless they can do something about what has been called the dryland wheat problem (drought resistance problem), India cannot move very much further in their dryland wheat crop. Also, several speakers pointed out that this is, in large part, an agronomic problem involving how you use water and how

you conserve water. They were also commending to the CIMMYT agronomic staff and to our collaborators research on what can be done on the better use of water for dryland areas.

They spoke of need for protein quality in wheat for India. India, perhaps more than most countries, derives about two-thirds of all its protein from cereals. It derives about 20% from legumes and not much over 10% from animal sources. Obviously, if anyone is to help India or its protein problem in the next 10 years, it is likely to be through improving the protein content of their major cereals. Hence, all comments we heard from our collaborators here on the need for protein improvement in wheat were being listened to by India.

For barley, India confirmed the obvious statement made here that the principal problems of this crop were lodging and disease resistance. On all these points, the Indian Government is very actively engaged in research itself. However, they are saying, whatever you can do to help we will incorporate in our research program. On triticale, India is one of the most active developing countries in its research. They are prepared to use triticale for whatever competitive advantage it may prove to have. If better for bread making or chapati than wheat, they will use it for that. If it is available for forage, they will use it that way. Thus, they are endorsing all that Frank Zillinsky and his colleagues are able to send them.

On winter-spring crosses, India is looking for the benefits in both directions.

So much for the problems. I have given you a longer list for India than others because they were one of the first to speak and there is no need to repeat the list.

On training, India has the largest wheat research staff of any developing country in the world, but they cited two needs for training that they wanted from CIMMYT. Firstly, they wished to send a few people for the production training course, primarily to get that extra spirit that John Lindt spoke of this morning and to hope that such men could go back and transfer this element into their own training program. Secondly, they would like to see an exchange of doctoral fellows with CIMMYT so they could have people here for a year or more working with CIMMYT staff and still be able to fill their jobs in CIMMYT while they were gone.

On nurseries, the comment was that they are excellent, keep them coming.

In the case of Pakistan, more or less the same list of technical problems was covered. This is not surprising in view of the parallel ecological zones of the two countries. Pakistan has sent more training fellows than any other country. They have sent 30. Pakistan's representative said they had a particular need to send people for several reasons. Firstly, because their wheat staff have proved so successful in Pakistan that the Government is transferring some of them over to other crops and hoping they can introduce some of the same research methods by team work. Secondly, a number of the trained people have moved up to become station directors, university officials or ministry officials. As we discussed this, several countries spoke up and said one of their trainees

had become a minister. In one country the comment was that some of our trainees had left the government but are still engaged in wheat research for private seed companies. I generalize here. I do not speak of Pakistan alone in training needs, but for many of the countries. The continuity of need is not because of the fact that some fixed quota has not been met, but because after creating a reasonably strong cadre of staff, they began to lose some and feel they need a continuous flow of people of the same type.

Going to Turkey, their representative commented that 8% of that country's wheat is winter wheat. This explains why the focus between CIMMYT and Oregon State University has been on Turkey and confirms the discussion of the last few days that some of the benefits from Turkey will be moving out of there to other countries with problems in winter wheat. The Turkish representative also commented that since most of their wheat is rainfed, whatever is done about getting more efficient plants to use the available water will be relevant to them. On the question of diseases, they added Septoria to the discussion. This was discussed as a major problem of North Africa, Brazil and Argentina and we thus increased the list of those speaking up on the same problem.

On staffing, Turkey has made a very good start in putting together a team. They haven't been in position long enough as yet that these are being lost but I am sure that the Turkish Government will recognize the comments of some of the teams that have been in existence for a little longer that training becomes a continuous operation.

On nurseries, the Turkish and other programs endorsed the continuation of nurseries but with the very constructive suggestion, "Can't someone please pull the donor agencies together and reduce the duplications of circulating nurseries in the Near East?" I gathered from the discussions that there has been a problem which is partly between regional nurseries or partly between regional and international nurseries. At any rate there was a consensus that something should and could be done to remedy this.

We did not have in this discussion of Asia, representatives of a number of very important wheat countries, for example, Afghanistan, Iran and Iraq which are multimillion-hectare countries. I am assuming that when we covered the largest wheat producers in South Asia and Turkey, we have some indication of disease and other technical problems are in between.

Let me now go on to the Mediterranean. I really should ask Dr. Hafiz to comment on this since he has been living with this for some 20 years. The number one problem as reported to the committee was yield stability for the areas that have already made considerable progress. Certainly the plateau of top yields is readily available but average yields have not yet been brought up. Septoria was considered the number one disease problem. Durum wheats were emphasized as being a much larger crop proportionally in this area than in any other area. The durumms are generally grown by poor farmers and when you work on durumms you are also working on the problem of low-income farmers. The winter-spring wheat crosses mentioned in Turkey and India are felt to be very important around the Mediterranean. Barley as a human food is more important in this region than any other region in the world. The CIMMYT barley scientists are

well aware of this since they do much of their outreach testing in the North African and Arab countries.

On staffing, except for Egypt, there is no country of the Mediterranean that has made any more than a bare start on training. Tunisia now has its first two Ph.D. candidates abroad. Each of these countries has a skeleton staff on duty, but the future of training is a considerable problem. Dr. McCuistion can add to that if he wishes in the discussion period.

The comment was made that the Mediterranean needs and will get a regional training program, primarily to provide an Arabic-language training centre and to stress training production specialists. On the need for advisers or resident foreign personnel, a comment was made that this region needs and would ask for more help than CIMMYT and other agencies are able to recruit.

On tropical Africa, I would like to invite comments from the participants from Ethiopia, Kenya and Zambia. We did not have a representative from that area on our committee. They represent perhaps ten countries in an area with considerable wheat acreage and I would like to see this covered.

In Latin America, we discussed mainly the need felt by Argentina and Brazil. In Argentina, Septoria was described as the number one disease problem of wheat. They believe CIMMYT has helped them considerably and they would like to see more work done on that particular problem. Speaking on durum wheat, Argentina will be one of the first clients for anything CIMMYT produces, but they stress that industrial quality must be good enough to meet market requirements of Italy since that is where much of the Argentine durum wheats are exported. You will recall one of the few lively moments in the week was on the question of whether CIMMYT is moving sufficiently fast on quality of durums.

On staffing, Argentina was one of the earliest collaborators with CIMMYT. The participant from Argentina gave Dr. Borlaug considerable credit for having helped build a good staff. But like Pakistan, Argentina has lost some of their staff to private seed companies and he would like to see further training. They feel that they are getting their most important inflow of germ plasm from these international nurseries and they hope they will be continued.

One person said India had had a truly remarkable experience in terms of millions of hectares that had more than doubled their output in the last six years. Brazil should be added to that list in a different sense. They started from a much lower base but have increased some 4 to 5 fold their output of wheat in the same six years. This undoubtedly reflects a very active research program and a quality of staff that is perhaps small but very energetic. Here Septoria is again the number one disease problem and a representative from Brazil told me this morning that if CIMMYT is prepared to place a Septoria specialist in any country, and is to give full time attention to Septoria and make that knowledge available to the world, Brazil would like to be host.

Dr. Borlaug mentioned that Brazil has special soil problems which are more widespread than any other major wheat growing country and that this would require attention, whether from CIMMYT or not, but CIMMYT

should be concerned. Brazil has trained 14 scientists at CIMMYT and wishes to increase that number. The nurseries were particularly emphasized by Brazil. On technical assistance Brazil has an excellent five-man team from FAO working at Passo Fundo on wheat for the last 3 or 4 years. Anything CIMMYT can send will be incorporated into that program, among others.

I have not spoken of Chile. Chile is another large wheat producer and we would welcome a statement from their representative. Among the Andean countries, there is a special high-altitude problem for wheat in their type of stripe rust which is not identical to Mexico. It will probably be necessary to mount special research in that region to cope with this.

I have talked predominantly about individual countries and I would like now to talk of some regional programs. The Mediterranean and Near East Program for Wheat and Barley Improvement is generally cited as the oldest of the current programs. It runs its own workshop and circulates its own nurseries. We have discussed here this week that they want a surveillance system for diseases, particularly the spread of new races of rust. There was general agreement around the table that not only did the Mediterranean represent an outstanding achievement, but probably should be copied. I will mention other areas that could benefit from this type of regional cooperation. There was a comment in connection with the Near East that CIMMYT is receiving requests for assistance on wheat and barley from at least five countries of Eastern Europe. I am not sufficiently familiar with the flow of germ plasm between Western and Eastern Europe, but the implication seems to be that it would be easier for these countries to seek their assistance on germ plasm and nursery circulation from the Mediterranean region than to try to establish this contact with their neighbours in Western Europe.

We discussed at length the needs for a Mediterranean-type cooperative program in the Inter-American area. Those countries represented said they were trying to initiate exchanges with their neighbours. For example, Septoria is the common problem of Argentina and Brazil. It is logical that they exchange materials. Workshops which could be held in Spanish would have many advantages to having an annual meeting. The idea of disease surveillance, I gather, was favored by these countries and CIMMYT was asked if they were in a position to survey and organize such a system.

The last regional reference made was to Mainland China. One of our participants here spoke briefly of a visit to China in 1972. He was unable to give us much information at that time because he was commenting on a different subject. I sought him out afterward to find out about his trip. If he will forgive me, I will repeat some of our conversation. He went as a member of a Canadian Trade Mission which went in connection with the Canton Trade Fair. It was not a prearranged visit for wheat scientists to talk to wheat scientists. The Chinese asked him to Peking and assembled an auditorium full of people who turned out to be their top wheat scientists. He was asked to talk for four hours. At the end of this time he was asked to come back for a further four hours which he did and a third time he was asked back at which time he spoke to the top wheat, triticale and hybrid wheat breeders of China. He was

able to bring back some of their latest materials.

He learned that China has been working on triticales for 23 years and has materials comparable to those of Canada and CIMMYT. He also found they were experiencing the same problem with hybrid wheat that has been experienced in North America. It is a stimulating thought which raises the question of whether the international nurseries going to South Asia be looked at as an extension for Mainland China. If we can exchange visits of scientists and germ plasm with the Chinese, this will probably produce recent or old germ plasm from China that is not presently in the active breeding programs.

In summary, as we look over the comments of this group of countries, there is no question but what some of them have achieved outstanding results in developing their own scientific capability and a beginning of their own training program. India is undoubtedly ahead on training and in the forefront of scientific research. Pakistan and Turkey can be added to that group. In terms of trained manpower, Egypt would be added to the group. Then there is a group of countries who started more recently, such as Argentina, Brazil, Tunis, Algeria, etc. CIMMYT will continue to be asked by those countries for the traditional in-service training. We will likely receive an increasing number of exchange scientists that Dr. Sprague spoke of this morning. We may get the one-year-residence postdoctorals that India is speaking about.

Training is a continuing activity as Dr. Cummings mentioned. It is also a more diversified program for the future. On nurseries, except for the minor problem of occasional duplication, we heard nothing but urgent recommendations that these should be continued, especially in the case of the disease resistance nurseries which should be more widely distributed to countries with those particular problems. On consulting work their seemed little need to discuss this. As long as a few international scientists can move from country to country every year making comparisons and passing on ideas, there was unanimity on its importance. On resident staff, CIMMYT has staff in the Maghrebian countries of North Africa and Turkey. There were indications that three other countries were now negotiating for staff and that there might be a net increase in demand for resident staff in the 1970s.

I will not summarize the unresolved research problems. My summary is one in which I tried to summarize the sense of priority or urgency as CIMMYT interprets some of these problems. I would ask Glenn Anderson to take up that side of it.

SUMMATION OF SOME OF THE ISSUES RAISED IN THE SYMPOSIUM AND CIMMYT's PRESENT VIEW OF ITS CAPABILITIES

R. G. Anderson

As a lead off, I would like to elucidate CIMMYT's philosophy. This will have a bearing, possibly, on what CIMMYT can or cannot do in future years. This, of course, can change as need arises but we would be loath to change our basic philosophy.

Firstly, CIMMYT exists only for the benefit of the national program with which it collaborates. Its activities are, therefore, of a service type. It seeks to accomplish this through the supply of germ plasm, through training of young scientists to staff these programs and for the future I would see it playing an increasing role in assisting the formation of associations between national programs or facilitating the formation of those associations so that in regions each national program will assist the others and in this way there should be a magnified effect of the national efforts.

Secondly, CIMMYT operates globally and collaborates with any country working with wheat. The developing countries, of course, have priority. If there are materials left after this first cull we will supply developed countries. Similarly, there are countries which may not be classified as developing countries who also send a few trainees to CIMMYT.

Thirdly, CIMMYT believes that a straight-line policy of research should be followed. We feel that we have certain capabilities and we should stick with these and not add a great many side issues directly into the base program. We seek rather to locate expertise outside the organization to carry on that research which we feel is necessary but ancillary to overall development of research. We will then operate in close cooperation with scientists at other institutions. One of the problems ensuing if we were to digress from this policy would be the increase in staff members and increase in what Dr. Borlaug refers to as bureaucracy. We would then not have a sharply focussed force bearing on a particular line of endeavor.

We believe in the pragmatic approach. If one thing works when we try it, and we will try a line of approach after due consideration, we will use it. If it doesn't, we do not try to put more money on the losing horse and will step out of that program.

If we continue on the straight-line approach and stay in the area in which we have developed capability, we encourage all institutions to cooperate in whichever way they would care to with CIMMYT or if they have special expertise in a concerned field we would certainly welcome and appreciate this assistance.

I would like to especially thank all the speakers who came, in many cases, from faraway countries for presenting us with the groundwork thinking on wheat problems in the early days of this week.

We have looked at the question of demographic change expected. A figure of six billion people was mentioned as the expected level at the

end of the century. It was then stated that the up and down swings in production observed this year is actually a variation around the trend line. Probably the statistics bear this out but it does not detract from the fact that we are in a very vulnerable position in those years when the dip occurs below this trend line. It is absolutely necessary to have stocks available for distribution in such a year. I refer here to the suggestion made by Dr. Borlaug on many occasions to many groups that regional world granaries are needed desperately under the aegis of an international body like FAO or other suitable organization so that food could be moved into crisis areas. There are many in the room who are familiar with the story of Joseph and the Pharaoh. The principle is just as apropos as it was in those far-off-days.

The availability of new land for food production is very limited. In this connection, Latin America probably represents one of the last great frontiers for additional land development. Dr. Da Silva spoke of several million acres that might be brought into production in Brazil, for example. This would apply in a relative fashion to other countries of this region, particularly in countries where large irrigation projects could be developed in desert regions. We have here then one region with the possibility of expanding production on new lands. This may lie somewhat out of our purview, but it behooves all of us to encourage governments to set up these projects and do them properly. As we biologists know, some irrigation projects are put in without drains and we end up with widespread salinization and it gives a very bad name to irrigation projects.

We had a very full discussion on the genetic, agronomic and plant protection roles in producing foods of high yield and nutrition, prepared by Dr. Swaminathan and presented by Dr. Rao. In this paper are many of the points which most directly relate to CIMMYT's operation and suggestions made there were very well taken.

As Mr. Hanson mentioned, the question of yield stability emerged as a major problem for all countries in varying degrees. Under irrigation, the disease problem is the major one affecting stability. The availability of water and electricity or other power for pumping, as Dr. Rao mentioned, can be a real problem. Indian farmers are provided with electricity for only two hours each day for irrigation wells and this will have a definite effect on the country's production.

On the unirrigated land, however, there is no question that weather becomes a major factor affecting yield stability. In addition, agronomic practices and water use practices are of extreme importance. I do not wish to go into these in depth.

I would say there is a need for developing genetic resistance to the major diseases and we should attempt to control some of the minor diseases by chemical means rather than trying to bring into our varieties factors for resistance to all. However, Dr. Stakman has spoken to me several times this week on the need for wide, or horizontal, resistance in our varieties. He refers to this as a basic health measure for the plant. We do not know enough about the sources of horizontal resistance and it is likely that we will need to cooperate with some institution

that has expertise and can study this in depth so that we can put these "types of resistance" together. It also came out in the conference that thus far we do not know how to select for this type of resistance in the field in early generations. It is only after the variety is developed that we can ascertain whether or not it has adult-plant resistance.

We spoke of the multilineal approach. This is likely to be expanded. The initial attempt is being made in cross 8156 background. There are also other widely adapted types, such as the Pitic sib or derived varieties, that have universally shown good yield but are very weak on disease resistance. The Anza group of varieties, derived from the cross Lerma Rojo 64-Norin 10B x AndesE shows a similar wide adaptability but there is difficulty in introducing resistance into these types. We have been watching in our nurseries for varietal sources of resistance which will improve these types. There seems to be some genetic mechanism which stands in the way of transferring resistance from many varieties. We are going to try to build multilines on these backgrounds.

The question of acid soils of Brazil was mentioned. Here is a case where liming of soils, the usual process of amelioration, can be done for the top part of the soil only. The roots grow through this limed area and into the low pH soil. We have to breed for resistance to aluminum toxicity which exists in these low pH soils.

Saline soils were mentioned yesterday. We feel that we should not breed for resistance to salinity. I say this with all due deference, Dr. Rao. Salinity results from lack of drainage. Even with so-called genetically tolerant varieties, the yield is still very low. We should spend our money on drainage rather than try to convince the legislators that they should neglect drainage because you have a variety that will grow in a miserable way on salty land.

On the point of insects and rodents, we have had reports of greenbug and other aphids in Argentina and Brazil. Different insects, such as the Hessian fly, sawfly, Sunn pest and cereal leaf beetle, are pests of North Africa and other areas of the Mediterranean. We can and are working on resistance to Hessian fly and sawfly.

On the question of weather and its effect on stability, I think that it is possible to produce varieties which are much superior at low levels of moisture in the soil. I think the root system that Dr. Fischer was discussing this morning is a case in point. I would refer back to Dr. Qureshi's variety which indicates a deep root system. These, I feel, can be produced. My contention is that the winter-spring crosses will produce many of the characters needed. We have every hope that these and durum wheats will provide us with much better genetic material for incorporating drought tolerance in the spring bread wheats. It is essential that we produce varieties of varying maturity which will fit into rotations or into climatic conditions that vary from conditions where residual moisture is present from a previous wet period or sowing is to be done on soil reserves to get an early start. This was discussed at length. I would agree that this is important and large areas could benefit from having different maturity types which could be sown and remain vegetative over the ensuing dry periods that follow seeding. This

kind of variety can be produced. I have seen this type from winter-spring crosses grown in Turkey, in Lebanon and other countries where superiority was being expressed. I am confident that through judicious selection we can get varieties which will fit individual requirements.

CIMMYT's involvement in cultural practices lies largely with the outreach program through personnel working in other countries. We feel this is logical since it is there that the problems exist. They have the environment and it is under those conditions that methods of handling soil can best be worked out. We feel that a centralization of this type of work is not indicated at this time. We will try to instill in the production trainees coming to CIMMYT a basic understanding of principles and the kind of results being found by the agronomists in the outreach programs. However, the actual research should be conducted within the national programs.

Dr. Wright suggested the otherday that we no longer needed to test varieties for fertilizer response. I thought this was a slip on the part of an agronomist who makes his living by conducting fertilizer studies, but he qualified this by saying that as new varieties are developed, new techniques may be required. I think this is true. There will be a continuous need for this and in many countries the agronomic practices have not been worked out for those national programs. In addition, micronutrients loom large as a developing restriction on yield. As we go into multiple cropping, as Dr. Bradfield discussed at this symposium, we are putting much greater pressure on withdrawal of nutrients from the soil. We are also, in the interest of transport costs, moving to high concentrate fertilizers without carrier which in some cases seems to supply certain trace elements. In India, for example, farmers consider calcium ammonium nitrate to be superior to urea as a fertilizer. It may be that since this a zinc-short area, the carrier itself carries enough trace zinc to improve their yields. There will, in my opinion, be an increasing need, as this high withdrawal under multiple cropping and use of high levels of the major elements is practiced, to add minor elements in quantities. The ability of the soil to supply these from decomposition may not be adequate to crop needs. This is beginning to show already.

I was talking to Dr. Virgil Johnson about quality of wheat varieties. It appears that some of the materials investigated by the Nebraska group show considerable promise for high protein and high lysine combined. These may be possible to exploit. We have been actively interested in this program and will continue to be. In our own program, one of our scientists is working on developing stocks of these characteristics in good agronomic background as one of his activities. We will do all possible to step up nutritional values in the wheats. We have discussed quality in relation to durum. In the durum a deep yellow colour due to carotene, a low lipoxidase level which is responsible for its destruction, and ability to produce smooth macaroni with good cooking quality are the characteristics which are desirable. In barley we covered quality quite thoroughly. We will continue to incorporate identified sources of high lysine content in our crossing program. Apparently, according to a number of the people here, high lysine content is found quite widely in the barley varieties and there are more mutants than presently reported in the literature.

In the production of barley, Dr. Rodriguez gave you some of the

problems we face. Most barley diseases can heavily damage the crop. We cannot even select for diseases at a single location because one disease takes everything and one cannot see the symptoms of the others. We are immediately sending out our parent materials for screening in widely separated geographic locations with the collaborating programs to establish in which varieties genes for resistance are located. This can be determined in those locations where a single gene occurs. Last year Dr. Kaveh accompanied a group of us to Kermanshah. The barley nursery there had scald well developed but the other diseases were essentially absent.

In the future, we in the tropics will depend increasingly on multiple cropping. As Dr. Bradfield said yield per hectare per year is more important than yield per crop. If varieties can be developed which fit into such rotations so that total yield can rise per unit land area it will be of great benefit to these countries. I would say that where there are small farmers with small acreages and high family labor input, this is the only way such a family can gain a living. I know no other way. I have seen near Patna, Bihar, families living on an acre and a half of land growing five crops per year. They managed this as Dr. Bradfield said by increasing the length of year by interplanting before harvest. These people had water but they had little land on which to make a living. Thus, with high labor input, this very intensive farming can be done.

On seed production we did not have sufficient discussion. It is a very essential part of the total production package. It is surprising how many programs represented here have or are experiencing this lack of a link from the research field variety to its production on farms. The various disciplines represented in producing the variety get the material to the finished product and the seed organization is not set up to efficiently produce the seed which the farmer can buy. Dr. Demirlicakmak explained how Turkey's seed organization works. I would say that Turkey is somewhat unique in having the large state farms which can successfully look after seed production. I am sorry that you are unable to sell more seed, but you do have the ways and means to produce it. This means that all of us, including CIMMYT, should be very interested in developing efficient seed production programs as an integral part of the collaborative national program. A beginning is being made on this in North Africa. Negotiations are underway to develop seed production technology training on a restricted regional basis. There is no real reason why this needs to be done at CIMMYT and our decision was to place it in operation within the outreach program. We hope this can operate regionally.

How can agricultural change be brought about? This was discussed at length. One of the things that emerged in this conference and which came from different viewpoints is that political and economic planning are separated by a seldom-bridged gulf from the biological scientists. This was expressed yesterday by one of the participants in the drafting committee when he said, "I no longer can get through to the ministry with my ideas." This is a very weak point in almost all countries. Every effort should be made to overcome this gap if the results of research are to be translated into meaningful action. It was suggested this morning that economists should be trained in biology and vice versa. I think this would be very desirable so that each would have an appreciation of where each one fits. Planning done for agriculture

without benefit of biological interpretation can lead to all sorts of abnormalities. For example, when fertilizer should be available, how much, where and what kinds are things which a biologist can contribute to the planner. On the other hand, the planner can interpret to the biologist the political, social or economic reasons why actions which are recommended can or cannot be done. These require an intimate collaboration of biologist with economist. I hope that as we go forward, this existing division would be bridged and decisions result in greater efficiency for the country.

We discussed the strategy to be used in order to get adoption. In our present world, we feel we should have a full-scale plan outlining where we are headed in exact terms. One of the problems encountered lies in the fact that the model produced is often not applicable beyond the borders of one country or there is great variation from country to country as to what can be done or at what stage it can be done.

So I think we are faced again with the need to use the pragmatic approach. We should take one of the simpler things central to the whole problem and try to do this first. On the basis of the wealth created by this action, other things come into focus as representing the next requirements and the next step is taken. In this way national governments are not frightened away from embarking on a program which seems larger than they can possibly afford. We know it can arrive at the same endpoint by easier stages.

Let me give, for example, the story of tube wells in the Gangetic Plain. Many years ago the World Bank provided a loan to India for digging deep tube wells. At that time, the cost of such a 1.5 to 2.0 cusec well was about 130,000 rupees, equipped with a pump. In the flat Gangetic Plain over geologic time the rivers changed course many times so that they built up successive aquifers of sand in the old river beds that had been buried by silt. In most places in the upper Gangetic Plain, ordinary wells could be dug to 90 or 100 feet which can be pumped on a 24 hour basis at a rate of 0.5 cusec at a cost of about 3,500 rupees with the pump set and casing. Hydraulic studies had not been done to see whether these wells were interrelated. About 1966, the Bank again was approached for a loan to dig deep tube wells. Now we had the condition of a 1.5 to 2.0 cusec well at 130,000 rupees and the 0.5 cusec well at 3,500. It seemed very reasonable to all of us in biology that the farmers should go for the cheaper types first and exploit what they could. This is exactly what they did with the added benefit that the water supply was under their control. With this approach they created wealth which could then be used to finance the deeper wells should that become necessary. Thus far, for the most part, this has been unnecessary. I think then that we have to look at some of these things to assess the capability of the economy at a given time. Further, we should do the easier things first which can create wealth which can be used for further development.

We have discussed international collaboration. As Mr. Hanson pointed out, there is need for greater cooperation among international organizations. I believe this is so insofar as is possible. However, each organization has some different ideas as to how to go about things. This means that there are certain areas then where cooperation is difficult because of the differences in basic premises of the organizations concerned.

Therefore, organizations have to take their own direction in certain respects but in other ways cooperation is possible. As an example, I would like to show how cooperation can proceed. Dr. Hafiz has sent to CIMMYT 63 trainees and 58 are still in place. I would defy any other organization to present any better record. I would like to publicly give you credit for a job very well done.

As far as our core activities are concerned, the value of germ plasm distribution has been well indicated. I think that the screening tests sent out probably are most valuable of all. They carry a great deal of germ plasm and expose it to the critical eye of collaborators where the best-suited material can be selected. It is our feeling that each of our scientists in the core program, whenever time allows and I assure you they do not have much time, should travel out to the national programs and see what the problems are in the countries in situ. We have done this on a rotational basis. We consider that each will then carry in his mind's eye the problems of the various countries or regions. He can say, I was in Algeria and I was at Algiers and I can remember the tremendous Septoria epidemic, the snow on the high plateau and so on. Then I know that these represent problems we face in breeding for these kinds of conditions. This will continue and our scientists will have an opportunity to interact with many of you here. I hope they do not come as an adviser but as a friend and colleague because I know this is how they feel about everyone of you who are here.

On regional activities, the value of the tests have been demonstrated by the replies Mr. Hanson got to his question yesterday. Here we have in the making one of the greatest strengths of all our activities. These regional trials represent the materials that have come to the top in the breeding programs of the various countries. These are being distributed to the different countries for screening. Thus, the combined power and strength that has gone into production of those materials is brought to bear on all of the national programs collaborating in these nurseries. This is very important. You biological scientists know that many varieties are thrown out in one country which do not quite reach the mark, largely from locational effects. Yet, that very variety may be the ideal variety for Floyd Bolton's operation in Turkey so he can plant in November. In this exchange of material, you have the opportunity to select from all the best materials developed in the region.

Seminars such as this and others held regionally have much value. It brings us together as scientists from widely dispersed points. We are able to talk and meet with one another. We can exchange ideas and come up with a synthesis of ideas that as individuals we have not considered. We can translate these ideas into a general plan of action which may cover an entire region. I attended one of these last year in Beirut organized by ALAD. They concentrated on two areas: (1) the agronomic practices which we have discussed here and (2) yellow rust and Septoria. These were rated as the principle problems of the Mediterranean Basin. This focused on these problems and each person went away with ideas on certain ways these problems might be mastered.

In the area of increasing the base yielding capacity of varieties, each of us has his own ideas on what such plants should look like. Dr. Borlaug does not agree that a certain type is necessarily best, declaring

that it is yield that counts. However, I am hopeful that this yield can be made better. Yield, after all, is made up of the sum total of all characters. Some characters are plus and some are minus. Among the plus we see certain ones which are often present in successful varieties. This area of research is one from which we can expect to get information leading to the production of a more efficient plant type. The winter-spring program I alluded to in relation to drought. There are other benefits to be expected from this program. We set a high priority on this and expect to expand it appreciably. The winter wheat program that Dr. Demirlicakmak, Dr. Wright and the Turkey group are conducting will yield big dividends as cooperation develops in Iran, Afghanistan, Algeria and Eastern Europe. Dr. Ramirez in Chile, I am sure, will also be interested. He has already exchanged materials with that program. We already have a global exchange of winter wheat in Dr. Virgil Johnson's trials sent around the world to about 40 countries, which must represent all the wheat growing countries. Thus, we do have a proliferation of exchange of materials at the international level. I would very much support the continuation and increase of this type of activity.

We discussed training needs but this was discussed just before lunch and everyone is very familiar with what is being done and what are the needs. Suffice it to say that CIMMYT considers training its most useful contribution to national programs. This is even more important than supply of materials since scientists can exchange materials perhaps in a more limited way but effectively. People are more important than materials.

DISCUSSION

Finlay

After hearing these two summaries, things may have come to mind that we have misinterpreted or other items which should be considered. The meeting is open for discussion. Mr. Hanson said he would like a statement from tropical Africa on their position and needs. He specifically mentioned Ethiopia, Kenya and Zambia, which have representatives here.

Taha

I believe the representation of Zambia at this conference is evidence of the effectiveness of CIMMYT. There is no wheat grown in Zambia. The need for Zambia to produce wheat is evident when we consider that it imports every grain brought to the country. It is also evident from the increasing consumption of wheat through the villages of Zambia. We have also shown high yields in our trials. Neighbouring countries also show high yields so that Zambia should be able to do the same. Kenya, Ethiopia, and Rhodesia all grow wheat very successfully. I am here to inaugurate a wheat production program in Zambia. I am sure that CIMMYT will be a great help to us.

Oggema

I will speak more of Kenya than tropical Africa, although eastern Africa--Kenya, Uganda, Tanzania, Lesotho and Malawi--has drawn very much on what we have been doing since 1908 at Njoro, Kenya. Our problem in

Kenya is that all our wheat is grown under rainfed conditions. The three rusts constitute our major problem. But up to the 1960s, we have been using materials from Mexico, Peru, Ecuador and so on as our varieties. But since CIMMYT began we have been unable to use any CIMMYT variety directly as one to be grown in our country. We can only use them as breeding material. Regarding staffing, our station is well staffed with undergraduates, but the Canadian Aid Team is working closely with us. They train our staff in graduate work. We also have had a few trainees from CIMMYT. One of them has already gone to the university. Speaking in general on cooperation of Kenya, Tanzania and Ethiopia, we supply stem rust-resistant materials to Ethiopia. They in turn test materials for Septoria resistance. We also have a training scheme for Ethiopian scientists. Every season before they start their major planting, they come to Njoro to work with us. We show them how to score rusts and other diseases and breeding characteristics. That applies also to Tanzania. It depends almost 100% on materials bred in Kenya.

Tessema

Unfortunately, Ethiopia does not have many scientists and the country is suffering from the lack of personnel. Ever since CIMMYT started training, only four Ethiopians have been in Mexico. Only two of these are presently in research. We have been cooperating with CIMMYT, FAO and others. With the number we have, I think we have made good progress, but if this is to continue, we need to keep the supply coming. I hope CIMMYT can help us.

Kingma

Certain things were not referred to by the two speakers. I would summarize these points under the general heading of "communication as a problem". We are getting a great deal of information from the region and we are faced with the problem of late and untimely return of data. We need these data early. I am sure I am also speaking for CIMMYT since their ISWYN reports, for example, usually appear 2 or 3 years after the tests are conducted. I think we lack a good, clear summary of which are the best wheats under test. Similarly, we need a summary of which names are synonymous. Sometimes they go as a number to a country. After 1 or 2 years, they get a name and sent to regional and international nurseries. This brings in duplicates. Also, while I was still here we had a CIMMYT newsletter regularly. I haven't seen it in three years. It was helpful to us when we were outside to hear news of CIMMYT. Almost all countries of our region produce an annual report. This is usually for the country, but I am sure we could all learn many things from these reports. This would make the information of wider use. I would suggest that somehow we try to get the information in these reports out to a wider circle. Finally, we do get lots of yield trials but they are very variable. We need standardization in reporting. If we can improve communication, it will help our international collaboration.

Anderson

This question of communication does really divide us. There are

many pieces of information. Some come as one line in a letter. Another is one page. All of these are bits and pieces which, if put together, could give us a much better picture than we have. Mr. Hanson has been working on the production of a scientific newsletter. In the initial stages, this letter would deal with a particular subject, for example, opaque-2 maize or triticale. This letter would be circulated to the CIMMYT collaborating group. There is probably also a need for a newsletter of a pot pourri type which would garner together these pieces of information coming from letters or short reports. This kind of thing could be done. We do have problems in trying to meet our commitments. We will, however, do the best we can.

We apologize for late circulation of ISWYN reports. Our problem has been a lack of continuity in staff, but we are trying to get up to date. Some problems in programming, some in printing and so on have put us behind. We hope our difficulties are nearly overcome. All of you who are cooperating in CIMMYT nurseries will be receiving an outline of the times for reporting and cutoff date. Up to now it has been our fault; then it will be yours.

It would be highly desirable if each of you could send in a summary report of your annual activities. A number of countries are presently doing that and we include this in our annual report. Any country in collaboration can submit such a report. We can very rapidly edit these reports. Our job becomes inestimably easier. Otherwise, we have to put one together piecemeal. We need this by November 1.

Tahir

I would like to give 2 or 3 pieces of information in regards to Mr. Hanson's report. One is the exchange of germ plasm with the Peoples Republic of China. They were not a member of UN so FAO was unable to assist them. They have now shown an interest in becoming a member of FAO and the Director General is now visiting with them. In his brief we have outlined the exchange presently taking place, including CIMMYT, Nebraska, etc. I have assured them that on a reciprocal basis the materials can be sent to them. We hope this will develop.

The second point is about the relations of East and West Europe. I am sure most of you are familiar with the fact that there is a European organization known as Eucarpia. It is a plant breeder's association and includes members from both East and West Europe. They meet regularly on various crops and exchange materials. They have joint nurseries and considerable collaboration exists. The Nebraska nursery also, for example, is distributed in both.

Everyone complains about duplication of nurseries. We distribute several nurseries through our headquarters. I find there is little duplication. We have the Nebraska Nursery, several CIMMYT nurseries, Eucarpia nurseries, and ones with other organizations. I do not feel there is duplication. Usually, if the country doesn't want the nurseries, they can write and say so. However, people who say there is duplication usually are the duplicators themselves.

Recently, there have been complaints that too many visitors have been coming to see them from too many agencies with the result that technical people are tied up too long looking after visitors. But at

the end of the year, we have complaints that we didn't visit. When we are planning a visit, I think we should have a clear objective in mind and it should be with the consent of the country.

Paarlberg

The way in which CIMMYT has to work henceforward and has for sometime been so working is through national institutions. In the U.S. we have several of these national institutions with which CIMMYT has been working and could perhaps work more. One of these in the USDA, where I am employed, and the land grant college system with which you are all familiar. Some things have been happening that cast some doubt on the manner in which these institutions have in the past been able to make their professional contribution to international agricultural development. It isn't altogether clear whether Congress will continue to fund development at the same level or in the degree that these programs deserve. We need to find ways in which our capability in agriculture can be enabled to come to the service of the less-developed countries of the world. I believe that CIMMYT and other centres are outlets through which our technical capability can increasingly be supplied to the nations and people that so badly need these. I don't know how these channels can be deepened and broadened, but these are things we might discuss. This is not on our part purely philanthropical. We know we have gained much through the work of this organization. Your germ plasm is already being used on American farms. The technology that has been developed is also being used. It seems to me that working with national institutions as we have spoken of here is a thing that applies to both developing and developed countries.

Finlay

We already have a number of collaborative programs. I agree with you that USDA and universities represent a tremendous area of expertise of extremely sophisticated people, equipment and research. All of these people are looking for a relevant outlet for its value. I believe the international centres can act as vehicle for this type of interaction. The other day you saw one case in Dr. Lynn Bates' collaboration. Here is one man working in a university who has something of potential value internationally. But there is no way for a man on his own to get science to work except through publication and this is quite inefficient. There is still a big gap between publishing and getting information into use. By linking one man to an agency with linkages we would hope this will pay off. The grant is small but in the long term your work could give a big boost to international agriculture. We are interested in exploring with anyone who sees possibilities of linkages that would not overload us and is relevant to our work as well.

Saari

I would like to comment on communications. I think CIMMYT should have a wheat newsletter. In addition, there is scope for an open newsletter to which anyone could contribute. We had a regional trap nursery and Dr. Prescott sent out information as it came in. This was useful, but the newsletter has considerable scope. It would be sent to the heads of national programs for reissue within country. I just returned from Kenya and found Kenya Kanga attacked by stem rust. How do I circulate

such an observation? This could be very useful in the region.

With regard to visits, I am one of the most guilty in visiting everyone. If I don't visit I am also guilty. This becomes a problem since I often visit and spend time in the field with associates. However, if I don't visit upstairs someone may feel badly and if I do I am causing them to lose time. This dilemma is hard to resolve.

In the Near East, we did have duplications over the past few years in the nurseries. This has been much reduced since we joined hands with FAO in distribution. There probably is still further scope.

We were speaking of training. I observed that about two years ago the group had a workshop on plant pathology to focus on a specific subject. This could be an intermediate step where the national programs cannot afford mounting a full-fledged program.

Ramirez

I believe Mr. Hanson wanted someone to speak on Chile. As many of you know, we are under a foodstuff crisis at the moment. Preliminary forecasts predict that Chile will need about one million tons of imported wheat and corn. The world market is not good for importing countries. I will not refer to causes of the problem. There is a real need for bringing in fertilizer. During the last 2 or 3 years there has been an accelerated land reform and, as in other countries, the transfer is not an easy problem with many disturbing factors. This is likely to be temporary. This difficulty in transfer is aggravated by the fact that the education level of the people to whom the land is transferred is not high enough to provide equal productivity on the same lands. CIMMYT's cooperation has been very satisfactory on both sides. This is a follow up of the extensive cooperation we previously had with the national programs of Mexico, Colombia, Ecuador and Chile under the time of the Rockefeller Foundation. We have had a very satisfactory exchange of germ plasm during the last 5 to 10 years and I also believe we will continue this to the maximum extent.

In connection with this, I comment on the words of Dr. Anderson on the winter-spring crosses. I feel we have material to contribute to this program because Chile is one of the places in Latin America where winter wheats are grown successfully. We have had experience in this type of program. I would like to pay tribute here to Dr. Rupert who emphasized this program some years ago. There is a lot of germplasm to exchange with other countries and, as Dr. Anderson said, we are already doing this.

Chile also has a shortage of trained personnel and I feel that our program advance will be hastened by increased training of our people. We need augmentation of facilities for this. On the other hand, we must emphasize the efforts of CIMMYT in its attempt to increase the regional developments such as exist in the southern part of South America where they have similar problems to solve.

Smith

I comment on Dr. Paarlberg's question of cooperation with USDA and land grant colleges in the U.S. as it relates to getting some of this

information to centres such as CIMMYT. In the Crop Quality Council, we have a winter seed increase program at Obregon. The material in the program is from North Dakota State University, South Dakota State University, University of Minnesota and USDA. There is also material from the Canada Department of Agriculture and the University of Manitoba, University of Saskatchewan and University of Alberta. The purpose of this nursery is to speed varietal development by advancing generations of bread and durum wheat, and barley. When we come to Obregon we provide this germ plasm to anyone who would like to have it. There is a completely free exchange of germ plasm. I think personally that one of the most important parts of the program is that each year scientists from these institutions come to Obregon and have an opportunity to exchange ideas and notes in the field. This then is one of the ways in which exchange is being done. The program started in 1954 and we have been very grateful to the Mexican Government and INIA for this close cooperation.

Oggema

I would not like to say that nurseries are duplicated. In Kenya, we receive materials from all over the world. When I study this material carefully, I find about 20% is the same material. This happens because of the proliferation of new names. Still, they want the same tests done for stem and stripe rust. If there was a way to distinguish these lines by passing them through a screening process and then perhaps through that newsletter CIMMYT is trying to initiate, we might be able to cut down the duplication.

Reporting of data is another point I would like to raise. In Kenya we have nurseries ranging up to 3,100 metres. We have one site at low altitude, mainly for stem and leaf rust, and have a high-altitude location for stripe rust mainly. We do not sow these two sites at the same time. At low altitudes, planting is done in May and at high altitudes, seed is sown late in July or August. We cannot, therefore, report the data simultaneously. For example, harvesting was just being done from the higher location when I left Kenya. The other nursery data has been ready for some time.

Anderson

This is the same situation we face in growing nurseries in the two hemispheres. This is a real problem. We might overcome this by publishing data late from the southern hemisphere. It so happened that the land masses where wheat is grown are predominantly north of the equator. To make data most useful it should be available as early as possible. We might put the southern hemisphere data in the next one as an appendix. The high-altitude location data could also be put in an appendix.

Stakman

The nursery site in Kenya was once supported by the Rockefeller Foundation and commended by Dr. Rodenheiser and other people because there is a combination of very virulent rust races in Kenya. This is the most virulent combination known in the world. In addition, conditions every year were ideal for stem rust development at elevations of 7,200

feet and as you go above 2,000 feet, it is almost ideal for stripe rust development. Consequently, up on the mountain there is a beautiful chance for having the plant breeders send the most rust-resistant material to this nursery to get the ultimate test or extreme uncton, one of the two. It was a special nursery for a specail purpose which was established to take advantage of a special situation. Whether it should be revived or not I don't know, but if it is we should get all out of it that we possibly can. If we are to do this, there must be expert people there to take notes. These have to be analysed and properly evaluated and by communication sent to where they belong.

I would like to comment on communication. There are certain international political situations that must be considered as well as certain international scientific cooperations. We tend to confuse these. I would like to suggest this to the people who complain about communications and the people who want good communication. I would say they better do a good job themselves or there will not be good communication. All my life I have had to be an editor and I say this particularly to Americans-- I wouldn't presume to say this to anyone outside my own country and then only with great reluctance and a certain amount of caution-- if you want good communications, you make them. Learn to write intelligently and succinctly and correctly. I have gone over some of these reports and I want to tell you that 250% of the gray hairs I have were obtained because of this problem of communication.

Finlay

Dr. Borlaug mentioned yesterday that he has thrown away or burned more textbooks than most people. One of the other things CIMMYT has done and deliberately-- and it is arising now in criticism a sense, but we feel it is worth doing-- is this question of release of materials. We send out material which is then selected by different countries and the same lines are given different names in different countries. We have 8156 with about 20 named varieties. It is essentially the same line. The reason behind this, and CIMMYT actually encourages it, is that they should have pride in their own workmanship. When the particular scientists make selections, we would prefer that they name them. The national farmers, we feel, identify this variety with their program. This is not a Mexican wheat, nor a CIMMYT wheat. That breeder has done the final job of selecting under their environment, and fitting it to it. We feel they should have the right to name it. Perhaps we could do better in keeping a list of the names put on it, but basically we feel we would like to continue with the present policy.

Hafiz

I told you previously that in the Near East we are publishing an information bulletin which is three issues a year. In this we try to give the results of the various nurseries, which we call regional, which are prepared jointly by ALAD and FAO. Apart from this, this year we started giving preharvest information to the breeders. We have sent information on wheat and barley nurseries through getting results from the various nurseries, getting means and pointing out which are top varieties. We indicate also that they should look at these particularly and make use of them. Thus, we are sending out about 700 copies. These

go to all cooperators in the region and certain places out of the region as well. The last of the 1972 issues will be available shortly. We would like any information--a simple note, even three lines. As Dr. Stakman has said, the outstanding thing you wish people to know about either inside or outside the region, please send it in and we will publish and circulate it.

I think there is a competition between Dr. Saari and myself on which one does the more visiting. But I have decreased my visits some. In 1953, I met a soothsayer in Pakistan who came to my house and asked to see my hand. I told him I was also in the same business, "so you show me your hand." He came to my house and persisted in his request to see my hand. "I will not charge you anything," so I agreed. He said, "This year you are leaving Lyallpur and going to Karachi by the end of this year. You will only be there one-and-a-half years and then be promoted in the same place where you will stay nine years. Then you will go outside and will have your briefcase in hand and take aeroplanes." This is just what happened and what I have been doing since --living in a suitcase or out of a suitcase, I am not sure. But now I have had to cut down trips because I know some competence has developed and young scientists capable of taking data are in position. We have to encourage these people or they will become discouraged. We must just guide them and let them take the data themselves. They develop confidence in their abilities.

Duplication has been discussed. There has been duplication. What happened earlier was that FAO started this work in 1952 and this was done up to 1962 by Dr. Harrington. I then took over; the volume of nursery work increased and number of countries increased. Then another organization came into operation in 1969 in Beirut and other nurseries were sent out from there. The next year I received a letter saying I was duplicating the nurseries. I wrote back to say that surely we were not entirely responsible since we had been delivering the nurseries earlier. It was suggested that this could be simply resolved by cooperation. Since then we have worked out the problem and there is very close cooperation. No doubt varieties are repeated in some of the nurseries as Dr. Oggema has said, so we have to be careful. We are working for humanity and cooperation is essential. There is no need to blame anyone. It is the only way we can help to build a better life for coming generations.

Finlay

I was thinking as you were talking that perhaps CIMMYT should get your friend to hold its hand and tell us where we are going.

Hutchison

I find that most of you attending this conference are more of a real economist than I. I am very interested in helping you in any way possible. I work for the USDA Economic Research Service, International Division, and work on commodities. We are looking at long-range projections and what is happening and what is likely to happen, in other words, putting a frame on what is going on. We are gathering and assessing a lot of statistics. All of you are using statistics in presenting your results. If any of the data we have in the USDA could be useful to you, please

drop me a line and if it is published I will try to get it to you. If it is data we can put together quickly for you we will try. If it takes longer we will still try. Just write a line and we will send material to you.

Bronzi

There is one problem that has not been analysed. This is the problem of CIMMYT's staff. More and more demands have been made on CIMMYT people. I think that human capacity for work has been reached. This is a problem that should be discussed in relation to the future.

Hanson

CIMMYT made a commitment along with some of the other centres to the donors at the last annual meeting that we thought our professional staff was reaching a plateau and that we would not be expanding significantly beyond the present level. We were speaking of 50 people on professional staff, of which 15 are now in place in each of the two crops. Another 10 or so are in administration and about 10 are under special grants that do not come from the same donors. There is one element of flexibility that Dr. Borlaug might want to touch on when he makes his roundup remarks. I think we have found flexibility in what Dr. Sprague calls postdoctoral fellows. These do not show as positions because we hire postdoctoral fellows for one or two years and on a term appointment. If we then find that we need them for assignment in Asia, Africa or Latin America, they are known to us, they know our system and they are extra-numerary to our staff. We are trying to build to 10 postdoctorals at any one time. Some will stay with us, some will go to other centres and some will go back to universities from which they came. Thus, Mr. Bronzi's comment is correct. We have reached the limit of hours in the week that this wheat staff can put in and we have been close to breakdowns because of excessive hours of work. But I do think we still have some flexibility.

Saari

My comment concerns the duplication of varieties coming back from other places so that some of us do not leave with the wrong impression. Frequently, varieties come back to haunt us under different names, but they have often been reselected. You would be surprised that even in 8156 there are considerable differences, sometimes very subtle. They can be detected in the pathological sense. It is actually to our benefit to have a few lines from different crosses since they may carry particular genes for which they were not selected at other locations and we have benefits in the long run.

Rao

I do not know the date when the epic Mahabharata, the classical epic of India, was written, but historians say it was something like 2,000 years ago. One of the epics within it is the "Gita", the sacred book of the Hindus in India. One of the things mentioned therein is when the hero of the epic tells the God Incarnate that the three people in this world he respects are: (1) the person who never shows his back in the battlefield; (2) the person who educates me; and (3) the person who gives food to the needy.

I am reminded of this tale after attending this conference for the past week. CIMMYT is doing yeoman's service for suffering humanity and the underdeveloped countries. On behalf of all the delegates assembled here and for the wonderful work they are doing, for the kindness shown to us during our stay, we are indeed very grateful.

Going back a little in our experience in the second most populous country in the world, India, we wondered how it would be possible to feed this tremendous population year after year-nearly 12 million more each year and this rate increasing. How can they be fed? A number of prophets of doom have predicted that India is a lost case and that it is useless to feed the hungry millions. But other prophets have come into the Indian scene. They have generated new enthusiasm. They have given ideas. They have given materials with the result that our food production has gone up substantially. I do not want to repeat what has been said, but just want to mention that in the short period of five years, wheat production has risen 138%. The story is probably very similar in many other countries wherever CIMMYT has gone. It has done a great deal of work for humanity and CIMMYT is manned by people who have a feel for humanity. In this connection, going back to Gita, I offer my sincere salutations to the people who are doing such good work for the different countries.

On behalf of my fellow workers, I would like to sincerely thank the organizers for hospitality and kind treatment tendered us during our stay. We thank you also for inviting us to be with you and giving us the opportunity to meet fellow workers and exchange ideas.

Borlaug

The shades of this conference are about to be drawn. I feel that from my own and the CIMMYT staff view that this has been one of the most successful wheat and allied cereal grain conferences that I have attended. I enjoyed all presentations and the open discussions. I was particularly pleased to see the good participation, especially by the young members of the delegates who were here. I would like to thank the organizing committee and especially Dr. Alfredo Carballo for the grand work he has done in the arrangement and conduct of the conference. I would like to thank Gil Olmos for the preparation of the demonstrations you have seen on the first floor, Miss Linda Ainsworth for transport arrangements, Ing. Madrid for the many ways he has helped in easing the conference over rough spots, Ana Laura Sobrino for travel arrangements, the secretaries of CIMMYT for all their help in keeping you tuned in to what is going on at different hours of the day, and the translators who, I am sure, have had much difficulty. Last but not least, I would like to tender thanks to all of you delegates who have come here to make this seminar the success that I feel it was. I hope you will go away feeling it was beneficial. I would like to say to Dr. Bradfield that he has developed a 444-day year. I think that in some cases you will feel we are trying to outdo him and in some cases we probably have. If we go on at the rate we are presently going, I think we would have a 548-day man-year for each man and perhaps getting up to 700 man-days per year per individual for those who like to go to night clubs. So you, Dick, can further intensify your cropping and we will see if we can't keep all the people at conferences such as this stimulated so they get into the spirit of long days.

In closing, we of CIMMYT thank you for your contributions. God speed and please pass on our salutations to our colleagues in your home countries. We hope to see them on a future trip. We hope also that, whenever the opportunity is presented, you will visit us in one of our nurseries.

Hanson

My closing remarks concern the health of CIMMYT for the rest of the 1970s. I would paraphrase Norm Borlaug's remarks this morning, "I hope they will not burden us with paper work to the point that we are distracted from our scientific work and can't get done those things that people in this room would like to see us do." I am sure he was being careful of saying "they". I would identify "they". This starts with donors, trustees and management, and I accept responsibility for that. For the first 20 years Norm Borlaug was in Mexico, he and his colleagues enjoyed the luxury of an intimate relationship between the Rockefeller Foundation in New York and a group of scientists here in Mexico, with both sharing the closest ties with the Government of Mexico. If you needed money you wrote a letter, if you were in a hurry you telephoned New York. There was no long budget justification written a year in advance and reviewed by various people to decide whether you would get money in those days. When visitors came from New York, they knew the program and you didn't have to waste time telling them the background facts. It was, we might say, an "Old Boy's Club".

Now look what history has done to us. The Rockefeller Foundation reached the limit of its financing of this operation about 1966. They invited in the Ford Foundation and the two of them operated in the same intimate manner as in the past. Next came the U.S. Government as the third donor. By 1970, the cost of this and other centres had grown beyond the willingness of those three donors to finance them. The World Bank was asked for help. It organized what is now known as the Consultative Group of 27 donors. We are only in the second year of operation under that group and are in an evolutionary process which has been a very hectic one for Norm Borlaug and everyone in CIMMYT this past year.

Let me give you some examples. Between January and the end of March last year in 13 weeks we had 13 delegations of donors, each one asking to interview the scientific staff and find out what they were doing. Some were from the same donors. I spent virtually every one of those 90 days with donors. I was new here and trying to find out. I tried to spare the staff as much as possible, but all said, "Where is that Nobel Price Winner? We have to see him." So if Norm was busy with visitors, it was part of the pressures on all of us. Next, the donors decided they wanted an international panel to come and review our program. They came in April. One was from Canada, one from India, one from Egypt and one from the U.S.A. It took us two months to write the briefing book that we gave them and they took five continuous days of interviewing our staff. I think this was a productive effort. I think we satisfied a lot of people and a lot of questions. But it took most of the first quarter of 1972 to accomplish.

Next, our trustees and donors thought we should have an external review of our administration and we had one man from the Philippines, and two from the U.S.A. It took our spare time of four months to write the briefing

book and one week to satisfy their questions. Again we learned from the exercise but hope we do not have to repeat this for the next five years. It was, however, time consuming for those involved.

Our trustees decided they did not want another external review of the kind we had, but wanted an in-house review in which the CIMMYT scientists would look at each other and decide whether they approved of this. This required five staff days in September and October and we have yet to finish the report. I think it was interesting that when you put 15 maize scientists and 15 wheat scientists in the same room and they start asking questions, they are like a group of strange dogs who have just met each other for the first time. Norm will recall that the first day was spent trying to explain why the wheat team was choosing what they called bulls, which were their best breeding material for the next generation, and why the maize people were picking a row of corn and not an individual plant. This was part of the process we will not have to repeat a second year.

Like the group here in this room who want more publications, so do the donors and so do the trustees. They probably don't want the same publications. They want something a little more boastful of how good we are so it will persuade their national legislatures or treasurers that this is a good place to put money. Nevertheless, when we speak of a newsletter that has been delayed it is an issue here where we are trying to satisfy the diverse clients we have that want more information from CIMMYT. Also, the scientists know we have tried to relieve them of as much paper work as possible. We have never found a way in which the scientist can be relieved of writing his first manuscript himself. Then a rewrite man can take it and turn it into a newsletter. I have a feeling that more publications inevitably leads to more paper work for the scientist. I am not discouraged. I find that a secretariat in the World Bank, who took a great deal of our time one year ago, is now satisfied with a two-minute telephone call when information is wanted. I don't think that some of the donor groups who came here last year and took 3-5 days will come back this year and take that kind of time. There is permanent progress in what was invested last year. I would like to give this kind of assurance to the scientific staff and collaborators involved. We have tried to apply the principle that the scientist should stick to science and the administrator should take the administrative load off their backs. We have also tried to use the principle that Don Paarlberg used on Monday that the scientist should be allowed to do their own planning. As I understood it, he said, "Don't transfer the decisions on what research you are going to do to someone else and expect the scientist to put his heart into carrying out another's plans."

In fact, CIMMYT does follow the principle that the scientific groups should make their own expenditures. They should have the right to choose their own personnel. When they are given these rights, there goes with it some burdens and we are trying to relieve these as much as possible. They must be called into budget meetings and personnel meetings. We want them to retain control of progress in the work they are doing. There has been a great deal of change in all these problems in the past year and I feel confident that as long as we have a few active worriers on this subject, we will not find ourselves an organization devoted to paper reports.

With that assurance, I give you our best wishes as you go back to your countries. I hope a few of us will have a chance to come and see you in your own research fields soon.

Cummings

I want to express my sincere appreciation for the opportunity of attending and participating in this conference which has been a great inspiration and a great help to me. Some have expressed surprise at seeing me here. As some of you know, for a short time during the last six months I was serving as Director of IRRI and dealing with a crop about as far removed from wheat as you can get. Then, for an equally short period, I had the almost impossible task of trying to be Director of IRRI and ICRASAT both. But now I have only ICRASAT. Mr. Hanson extended an invitation to me to attend this conference while I was still at IRRI and he renewed it after I had gone to ICRISAT. The schedules and demand have been so overwhelming that several times I was tempted to say it just is not possible to fit this in.

But I looked at the program and I looked at the list of those who were to be here and I decided I could not miss being here because in building a new institute, one needs to draw all the lessons he can from the experience of others and take advantage of those experiences which are useful and of those which he should learn to avoid. It has measured up to more than I could have expected from the conference.

Over a period, I have had reason to be associated one way or another with another of the international institutes in addition to the two that I have mentioned. I have developed some convictions with respect to international agricultural research institutes. I don't think all problems are amenable to solution through this route. But I think there are some in which these institutes are uniquely equipped to cope with. If one can find problems that are of utmost importance to a large number of people around a variety of nations, where there are similarities and common elements, and where there is a need for a depth of penetration and a concentration of resources beyond that possible to put into this for any one or any grouping of existing institutions, I think that this is a place for the international institutes to enter the picture and perform a useful role.

Another conviction I have is that if one is to have truly interdisciplinary teamwork, one must first choose a group of scientists of real ability and insight, but that is not enough. One needs leadership to establish goals that are sufficiently important that they can challenge the best that all of these scientists can put into it and that they can see how their respective disciplines can contribute to the contributions of the other scientists toward the solution of that problem. Now we are dealing with a constituency that is very large and for which increased food production is a desperate need and requirement. I have seen in this conference this week a group of people who are without doubt very able in their respective fields, who are dedicated, who have their sights on these goals that they have recognized as important; they are putting their full talents on this, they are articulate, fired up and are doing a job that is really unique in history.

Dr. Rao referred to the experience in India. This is one which I feel is worth emphasizing again. I think one would have to search a long time to get another example in which good production for a commodity **grown** on this large an acreage is increased by 138% in five years. There were many things that come together in this. No one of them can claim the full credit. There was a very fortunate conjunction of the stars, so to speak, to bring this about. India did have a desperate need. At the beginning of this period, India had gone through two years of very severe drought and this curtailed food. The country was scraping the bottom of the barrel and importing heavily. There truly was a desperate need. There was a good and well-trained scientific establishment intact and over the previous several years there had been a good deal of sound technical information built up in which they had confidence. They had already had the best germ plasm of this program which had been introduced and tested and had begun its increase. India was prepared to supplement its own seed supplies with rather massive imports to speed this up. India had an enlightened administration in government. They were willing to provide the necessary inputs in fertilizers and direct these to the areas where an impact could be rapidly made. Beyond that they were willing to establish prices on marketing so that an assured price could be paid. This has been consistent over a period of years. When you go from a maximum of 12 million tons on about 13 or 14 million hectares up to 27 or 28 million tons on a somewhat larger acreage over a period of five years, that is truly a phenomenal experience.

This has sparked many other things in the society in terms of increasing intensity of production and production practices, and in the intensity of land use in these areas. It has sparked an increase in tube wells and virtually doubled the acreage of wheat under irrigation in that period and it has become sufficiently profitable that wheat has moved into areas which were not formerly wheat areas.

Things that have come out in this conference have convinced me that the job is far from done. It seems to me that you have been reaching for the challenge, not just taking stock of where you are, but the challenge of the future. This irrigated acreage, representing about 9.5 million hectares as I understand present estimates, needs to have constant vigilance to maintain present gains. You need to stabilize this and make sure you have the wherewithal to continue this.

It is almost a surprise to me that wheat has survived and remained one of our important foods. But when you see the versatility and the changeability of its pathogens and the devastation the pathogens can wreak on this crop time after time one wonders how, when there was no scientific establishment, the crop survived. It will take the best you can do to broaden and deepen this spectrum of resistance against these pests if you are to protect your present gains.

I sense that many of you are looking even within that sector for the next plateau. I think we have plateaued for the moment with respect to that sector of wheat production. Are there other breakthroughs that we can get by applying the best of modern science so that we can reach a new plateau and improve the potential?

The other half of India's wheat acreage is still suffering from the vagaries of an uncertain moisture supply. Fluctuations occur from year to year. If that is half the acreage in India, it is a good deal more than half the acreage in many other countries. I suspect in Turkey wheat under rainfall would be 90% and if one went across the Middle East and North Africa, it would be a very high percent of the wheat grown under conditions where moisture supply is not under your control. To get into this area and improve the dependability of production on those acres and reduce the extreme fluctuations that come from year to year is a real challenge. I know you are working on this. I will not dwell on the kinds of techniques you are using. All of these and more you will be exploring.

Barley, the other crop grown in association with wheat, is grown throughout most of this wheat area and is an extremely important food crop. You pointed out two areas where the crop is highly deficient. It is even more susceptible to diseases than wheat and you need lodging resistance to allow the crop to respond to the more favourable environmental situations. Barley does fit in many places where wheat does not. It is early, more resistant to drought and saline conditions, and so on.

Durum wheats have been discussed and you are just beginning your work on this, it seems to me. The field seems to be wide open to make tremendous advances in the next several years with this crop.

In the triticales, this is the first food crop to come from wide crossing. It is just in its infancy. It has only a very narrow base. The potential germ plasm can be drawn from the constituent species. You do not yet know all of the potential uses that may be made of this, of the yield potentials, or what all the problems are going to be in production. But I am sure this will constitute a very exciting chapter.

If time permitted, I could cover many things. I simply wished to point out a few of those to say that I am convinced that you have one of the greatest challenges for which you might wish. I am further convinced that you have goals that are worthy of challenging the best you can put into it and will allow you to keep your teamwork going to develop this continuing community of dedicated and able scientists coming along in the future. It has been a great inspiration for me to attend this conference and again I do want to thank you sincerely for the privilege of being here.

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