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A SECOND LOOK AT THE GREEN REVOLUTION

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A SECOND LOOK AT THE GREEN REVOLUTION *

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In looking ahead at the Green Revolution I will attempt to view dispassionately what has been accomplished, what can be expected, and what cannot be expected to accrue, from this technological advance. I intend to look at what it is, what are the problems facing man, what are the needs and what tools do we have to attack the various problems be they biologic, input supply or economic adjustments. This is a broad field and any attempt to cover it in its entirety will necessarily suffer more from the sins of omission rather than those of commission.

THE POPULATION PROBLEM

It may seem peculiar to start a paper on crop production with the population problem. However, this is not only basic to the problem of food, it is an historical event unknown before but not surprising if one looks at the underlying causes.

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When man first appeared his numbers were small and he was completely subject to natural law in the same way that animals were, and are, subject to natural law. He was forced to work hard at survival. Being an inferior animal in this art he developed a social structure beginning with the family extending to the tribe and to the country and later to the very complex societies of today where national boundaries form his outer regions of defense. Like the animals with whom he has much in common he is territorial and defends those rights in order to obey the natural law of survival. Unlike the animals he became endowed with reason and an ability to protect himself against his environment. Anthropologists are not unanimous as to how this came about and it is further complicated by the religions which man has raised.

I do not intend to enter into this type of discussion except to say that these religions have at the worst embodied large components of superstition and at the best have provided hope and enshrined laws which were necessary for survival of the social institutions. In so doing they have provided the guidelines for responsible action in society.

When did man change? At the evolutionary point in history where man was truly an animal he was probably

a gatherer of plant products with the occasional addition of some animal products he oould collect with ease. He no doubt learned which he should gather from observation of products gathered by other animals as food. Then he began to invent tools. Unquestionably this was associated with consistent and continuous development of thought processes arising from cause and effect. This allowed him to have his first limited control of the environment, since he now had a leverage over other animals whom he could harvest for food. The day of the hunter had arrived and he could now become a carnivore in addition to his largely herbivorous past. He also had the tools to defend his territory which he did. This is still in process as exemplified by the various national arms races. He, however, did not yet have the means to set up complex societies.

This latter event came about 9 000 years ago when it is generally conceded that settled agriculture, based on domestication of plants he had previously collected and animals he had previously hunted, was established somewhere in the region of the Tigris-Euphrates Valley and adjacent areas of the Zagros Mountains. For the first time he was now able to grow and store food. Of even greater significance he could now grow more food than he could expect to consume. As a species he was thus able to spend

more time on technological and cultural improvement and specialization was now possible. This ability to produce beyond ones own requirement (Agriculture) has continued unabated since that time and has reached its present zenith in North America where about four percent of the people are now estimated to be engaged in direct food production in the United States. I dare-say the Canadian percentage is not far behind and the European percentage while larger is not too far away.

Returning to the theme, man developed culturally and in the complexity of his societies. However, it was a long and hard road since culture tended to be location specific and for thousands of years these centres were preyed upon by looters who still followed a nomadic existence and periodically raided these centres for spoils. This led to a banding together of centres or societies into mutual protection groups which eventually formed under kingships, rudimentary democracies and other groupings. Slavery and semi-slavery became common in order to sustain societies and men sold their freedom for physical protection. This basic element persists in modified forms to this day, in our own societies, although abject slavery has essentially disappeared.

During these early days of agricultural the production of food was very elastic. Much land was available into which agriculture could penetrate. The area was formed bounded primarily by the area which a group could protect from depredations of other groups. One exception to this might be Ancient Egypt where tillable land was finite and confined to the flood plains of the River Nile. It is not an accident that this was the area in which the Pharaoh's granary was established to tide the population over poor years.

Thus man continued to exploit new land using his new found technology. This continued through European expansion into North American as one recent example. The present exploitation of poorer semi-arid and forested areas is an attempt to continue this expansion.

Man gradually increased in numbers but he was still subject to many privations which periodically decimated his numbers. Wars were fought over rights. Starvation often depleted his numbers when these wars completely disrupted agriculture as in the 30 year war of Europe, the 100 year war of Europe and so on. Periodic plagues of disease are reported to have cut his numbers in half at regular intervals in medieval Europe. The population during this long period only

by minimal numbers through upward and downward fluctuations. Food could be grown by and large to meet needs.

One interesting aspect is that because of the severe winters, the temperate zone peoples through force of circumstances were forced to grow crops beyond their immediate need to store for the winter when no food was available and even beyond this to maintain surpluses to carry them accross unfavourable years of production. In the tropics and subtropics, however, this need was absent since people could grow food of one type or another almost year around. The same pressures that prevailed in the temperate zone, were not present. Although people were still preoccupied with growing food, storing food was not considered necessary.

Exceptions to this rule occurred in the more severe environments of higher altitudes. In the Inca Empire for example, the Inca decreed that the finest farmland be cultivated for religion mainly to provide vast quantities of food and textiles to be burned as offerings. The second share supplied government storehouses with grain for use in war or famine. The remainder was allotted to the families; just enough land to raise food.

Because of the slack winter periods the temperate zone peoples had time to think and plan. I firmly believe this was a major contributing factor to their present preeminence in technology. This is a major force which has led to the present disparity in development both agriculturally and industrially in the so called developed countries which are in the higher latitudes. The heat factor which saps energy and other environmental influences are no doubt contributory to lesser development in the tropics but this, I consider of major importance. This laissez-faire approach to food needs in the tropics has led to the present predicament.

Let us now look at how populations increased.

It is estimated by Piotrow that at the time of the Roman Empire life expectancy did not exceed 20 years. It was not until the nineteenth century that this reached 40 but is now about 70 in the United States. Thus, the falling death rate has been a major factor in the population explosion. From bible times to about 1750 the population remained relatively stable. In table I is shown the advance of population since that time.

Table I* World Population Increase since 1750

Year	Pop-in millions	Period	Annual ave. growth rate %
1750	791		
1800	978	1750 - 1800	0.4
1850	1,262	1800 - 1850	0.5
1900	1,650	1850 - 1900	0.5
1950	2,515	1900 - 1950	0.8
1965	3,281	1950 - 1965	1.8
1973**	4,000±	1965 - 1973	2.0

* Source John Durand - Ann, Am Acad. Pol. and Soc. Sciences 1967

** Estimated

At the present rate of increasing growth the population is expected to be at least 6 billion but more likely will be seven by the end of the century if projections are made of the trend. Within the table presented the lesser developed countries showed virtually no increase until 1900 while the developed countries were growing at a rate of about 1.0 percent. From 1900-1950 both populations advanced about the same rate, and since 1950, the lesser developed are growing at a much faster rate than the developed.

This then, presents the conundrum which man as a species faces. In the areas where food production technology will provide food for the population, the increase in numbers is following a decreasing trend. In the areas where both, technology and land availability are lacking

the population increase is at its greatest. Failure to solve this problem and control numbers will endanger the survival of the species and Malthus prediction will be fulfilled:

In 1798, Malthus wrote:

> "I think I may fairly make two postulates. First, that food is necessary to the existence of man. Second, that the passion between sexes is necessary and will remain in its present state.
>
> Assuming this, my postulates as granted, I say, that the power of population is indefinitely greater than the power in the earth to produce subsistence for man.
>
> Population when unchecked, increases in a geometrical ratio. Subsistence increases only in an arithmetical ratio. A slight acquaintance with numbers will shew the immensity of the first power as compared with the second.
>
> By that law of our nature which makes food necessary to the life of man, the effects of these two unequal powers must be kept equal.
>
> This implies a strong and constantly operating check on population from the difficulties of subsistence. The race of plants and the race of animals, shrink under this great restrictive law, and the race of man, cannot by any efforts of reason, escape from it. Among plants and animals its effects are waste of seed, sickness and premature death. Among mankind misery and vice. The former misery, is an absolute necessary consequence of it. Vice is a highly probable consequence. I see no way by which man can escape from the weight of this law which pervades all animated nature..."

Most writers refere to Malthus hypothesis as "gloomy" I call it realistic. Man has so far escaped from its inevitable conclusion but there can be little doubt that it is inevitable unless man with his reason can see this early enough and take steps to bring the equation to equality.

Man has come to this situation because he did not

obey the natural law that plants and animals face. They are fully subject to environment as man almost certainly was. But with the development of reason and invention of tools and immensely aided by agriculture, later control of disease and social development, he has increasingly controlled nature and its diminishing effects. This is the basis of his real predicament and one could say that without the full application of reason, man will have to pay up for his failure to obey the fundamental law of nature-compliance with environment- when the bill finally comes due. One could also say that the Malthusian principle will come true but the question really is -When?

Some writers take the view that it will be soon. Others who are carried away by the euphoria of green revolution propaganda and other technological advances say, "We always find ways to get out of these problems". Not to worry. They say the world can continue to provide food for up to 45 billion people. I say this is "hogwash" and the sooner we disabuse ourselves of this concept, the sooner we will get on the right track and control our numbers. Assuming food could be produced for this number of people and I do not for one minute agree that it can be, could we expect employment opportunities, medical care, education and all the other amenities for a decent life to keep pace? Further could political stability be maintained

or would we want to live where we were continually surrounded by legions of people. My answer would be a resounding No!

Much has been written about the Green Revolution by both the informed and uninformed. As one who has been very modestly a member of the so called "green revolutionaries" I would like to set the record straight. Firstly, the term was invented by the press not the scientists. Secondly, it was never meant to be anything but an attempt to provide breathing space in which to bring population into balance with resources. This has been stated over and over again by all responsible scientists. The effort was never designed to create utopia or to cure all the social problems in the countries to which it has been exported.

I agree with Gabor when he says:

> "It is an ethical imperative to feed the starving, and to feed them well, even if it were proved beyond a shadow of doubt that a hundred years hence we shall run into a Malthusian limit. But it is equally imperative that those born a hundred years hence shall not starve! The conflict can only be solved by lacing the food with sterilizing agents, or by other means to the same effect. If this is

> rejected as interfering with sovereignty or racial insult, there may be no solution".

What Gabor is saying is that man cannot live without hope. Responsible scientists say we can buy a little time but it is going to become increasingly expensive to produce food.

There are many other aspects of excessive population such as shortages of all products, depletion of natural resources, pollution and a thousand and other ills which affect the physical environment and the mental attitudes of people that live in it. Time will not allow reference to these aspects which bear directly on whether the human population can or would want to persist. The time already devoted to the subject may seem excessive but this is done since it is the overriding problem of man. I consider it to be of the utmost importance and potentially has the gravest consequences.

I will now turn to the real burden of the present paper. What is the green revolution? What has it done? What are the needs and what tools do we have in the arsenal to meet these needs?

WHAT DOES THE TERM "GREEN REVOLUTION" INFER

As I said earlier the term was not invented by scientists but because it has been so widely

publicized we are stuck with it. Essentially what is inferred in a spread of the Green Revolution is:

1. A new set of varieties which are genetically capable of increasing production through greater response to fertilizer and more widely adapted by virtue of their independence of daylength response.

2. A package of technological practices which if fully applied can greatly enhance the productive capacity of the agricultural areas of the world particularly those in the lower latitude where production and applied technology have been chronically low.

I do not wish to indulge in history since the past is only valuable in looking to the future. The advances that have been made are well documented in many papers on the subject, for example see Chandler (8) An experiment in applying new technology to wheat production in Mexico which was increasingly short of wheat was successful. Mexico because it could not afford the foreign exchange drain occasioned by wheat shortages decided to ask for technological help. With the introduction of higher yielding varieties, resistance to disease epidemics and application of a new set of technology, Mexico became self sufficient and modest exporter. In the past two years it became a net importer of wheat because of rising population and economic policies favouring other crops. At the same time, however, yields per hectare

were in 1973 at an all time record.

The Mexican experience led to a modest spread of the varieties and technology to Latin America. It encouraged a similar experiment in rice which has ultimately benefited many countries particularly in South and South East Asia. Wheat technology was also extended to South Asia and later to East and North Africa with some notable results. India's production rose from a pre-green revolution level of 12.3 million ton record crop in 1965 to a 1972 high of 26.5 million, somewhat more than double. During the same period yields per hectare were nearly doubled. Similar but more rapid advances were made in Pakistan because of greater percentage of wheat land under irrigation. Rice advances in The Phillipines, Indonesia, Korea and other countries under the influence of shorter more responsive varieties were dramatic.

A number of retarding factors ---the so called "Second Generation" problems--- interfered with more rapid advances in both crops. These still persist but they were not caused by the advent of new technology. The new technology did, however, highlight these problems when they were thrust to centre stage as soon as the first generation problems were very modestly removed.

The cry of the rich getting richer and the poor getting poorer has been widely publicized. It is perfectly true that a man who has more land and can

take more risks will initially benefit more. It is perfectly true that the man farming a barren, rocky hillside will make less gains on technology than a man farming bottom land in a river valley. It is true that a man on irrigated land, providing such land has not been salinized through improper drainage, will profit more than one depending on scanty and irregular rainfall. On the other side, we are faced with great need for production if people are to be saved from starvation. This is the first directive. It is also true that any attempt to start a new trend and introduce new technology must start with the man who has the will and the means to take a risk or a departure from the status quo. Any attempt to begin a movement by spreading technology to the disadvantaged will cost enormous sums in money and effort and, in any event, it will spread to those who are better able to risk. Why, then, not start where it costs the least and allow it to move in natural fashion to the disadvantaged. To do otherwise is pure folly.

One of the advantages of the new technology is that it is farm size neutral. That is it can benefit both the large and the small farmer. It is social institutions and the laws of nature and economics that prevent the small farmer participating equally with the large. Does not a large manufacturing industry producing many items have an advantage over the small

firm producing a few items. Certain fixed costs are equal so the large firm can take a lower margin profit per unit and undersell the small. Similarly the large firm attracts the more capable managers. Why should the agricultural industry be considered to be different? It is not. Those who believe the Jeffersonian creed which says that "all men are created equal" know nothing about biology. Men and women are genetically different just as plants and animals are genetically different. Further they have no control over their difference since as Ardrey[1] puts it they are an accident of the union of one egg and a random sampling of one of several billion sperm and most often this occurs in the night when any particular sperm has difficulty finding its way. Beyond this, the individual is subject to his environment and opportunities from the time the foetus forms in the womb until the entry to the grave. To say the environment is the same for individuals is unrealistic to the point of madness. Thus the green revolution cannot be made responsible for natural laws that govern its application since the laws themselves were laid down with the appearance of man on earth even if they, only recently, were elucidated by Darwin, Mendel and such men as Sewall Wright now living.

THE NEED

The exploitation of land (expansion) can proceed for some time in certain countries of Latin America,

the Soviet Union and parts of North America and Africa. The rest of the world has little expansion room left so that the food expansion must be vertical (more production/ha/year).

In 1971, the cereal production in the world reached an all time high of 1,106,000,000 tons. This sounds like a massive pile of grain and it is. Borlaug [5] puts this in perspective when he says this constitutes a highway around the world at the equator which is 18.5 metres wide and 2 meters deep or if placed as a footbridge to the moon it would be 3.7 meters wide and 1 meter deep. In spite of the massive dimensions of this yearly production, in 1972 with a shortfall below the 1,106,000,000 of only 42 million tons the market was fully disrupted, in order to make up the difference. Percentage wise the difference was 3.8 percent. Yet this used up almost all the reserves available. Are we or are we not close to the wire? Each year the highway referred to above has to be rebuilt. In addition, there are about 77 million more people. At present consumption rates for people and animals, there is an additional need for 27,000,000 more tons. This represents an extension of the highway around the earth of 613 miles of the same kind of road-bed (1000 kms), or 6130 miles of the footbridge to the moon. Is this or is this not a gargantuan task? Is it any wonder that responsible scientists say we will have

to move ever more rapidly to direct consumption of cereals rather than animal products when we consider that the conversion rate is 10:1 for beef, 5:1 for pork and 2:1 for poultry? Can the world change and if so what can we do? I would like to retrace a step or two to look at the possibilities and see what moves we can make.

THE MOVES TO ALLEVIATE FOOD SHORTAGE

In its present crisis the world has certain advantaged areas such as the U.S., Canada, Australia and Argentina where food can for the foreseeable future be supplied to their populations. They have the further advantage of relatively low birth rates. Then there are those where land expansion is still possible, e.g. Brazil and although populations are exploding they are not in imminent peril. Finally there are those extreme cases such as India, Bangladesh, Egypt and Indonesia that have already passed the peril mark and birth rates are still high. These countries differ in their reasons for peril. Bangladesh has few resources other than agriculture and about 80 million people. They cannot afford to import food even if it is available. India probably has 560,000,000 in a land area 40 percent the size of Canada, Indonesia has 103,000,000 mostly concentrated on Java. All three countries are capable of expanding food production very

materially but this can only be done in the first two by massive increase in fertilizer use, multiple cropping and further exploitation of groundwater. Indonesia can do this with development of other islands and migration to them. Egypt has 36 million people on 6 million irrigated acres or 6 people per acre and while there may be some expansion of irrigation from the Aswan Dam, this will be outdistanced by population increase before it can be developed. Otherwise it will have to depend on increase/ha/year and they already have raised yields to a high level. These countries are in real peril and a catastrophe in food could overtake any one of them at any time. In any year from now forward India and Bangladesh could lose as many as 100,000,000 people to famine. Being realistic it may take this type of calamity to force the governments of the world to enforce population control. These are harsh decisions but inevitable. In the second eschelon of countries, Pakistan, Phillipines, Nigeria and most of Latin America as well as other countries will follow.

I have said that considerable advances have been made in a number of these countries. I think it is no accident. I have a theory which my experience will support. All governments are short of money and it is on those things which are most pressing that moneys are expended. Man being a territorial animal wishes to

defend his particular territory. Countries, therefore, have traditionally given first priority to the purchase of military hardware to defend their borders unless they are under the protection of another country in whom they place their trust. This infers a certain resignation of political autonomy. With the breakup of the colonial system this largely disappeared and armament expenditures have risen worldwide. This is the reason that the lesser developed countries spend 26 billion on armaments each year but cannot find the money to spend 2.8 billion on fertilizer plants, Ewell[10]

Onto this scene steps shortage of food, It is only under the pressure of absolute survival on this front that governments are activated. India and Pakistan are prime examples. The wolf of famine came to the door, they were becoming increasingly dependent on foreign food aid and only then did the problem assume top priority. Under this threat to survival, moneys were placed in research, imports of seed were made, extension was revitalized, fertilizer was purchased, floor prices were established, storage was provided, markets were improved and the largely agrarian population advanced in buying power. People were saved from starvation. All of these things came not at once but in turn as the need arose. Thus, one of the Ministers in India prior to the first large 1968 crop said "I know we need storage but how can I go to

Parliament and request funds for this when we have three million tons storage without a single grain and are operating on a ship to mouth principle". Politically, he was right. The need had to be present. When the crop was harvested the necessity for storage became evident and storage facilities in record time, rose to 9 million tons. This I refer to as the "vacuum theory". The vacuum is created and the vacuum is filled. It necessitates loss in time and loss of product but this is a necessary loss under present social institutions where forward planning is limited by limited resources.

I am very much afraid that countries other than those mentioned will follow much the same path. It is heartening, however, to note that the success achieved in the first mentioned countries has stimulated others to move ahead with agricultural programs and they have now begun to develop young scientists to man their national programs. This interest has been increasing year by year. We now distribute CIMMYT materials to 71 countries in wheat alone and since 1966, we have trained in wheat and maize, about 385 young scientists drawn from 50 countries.

In the wheat section approximately 60 additional were trained between 1960 and 1965 under a Rockefeller Foundation funded, FAO training program. There have been about 35 visiting senior scientists and innumerable

short term assigned scientists. Although this is small in relation to need, there now exists a beginning cadre of scientists in many countries. Other international centres are carrying similar applied training programs.

WHAT TOOLS DO WE HAVE TO INCREASE QUANTITY AND QUALITY OF FOODS IN THE WORLD?

I would like to open this subject with a quotation from Borlaug (4)

"What is food worth when you don't have it?"

This simple statement sums up the need to bend every effort to the increase of food before the problem reaches us. It is a very basic question and because people cannot survive longer than three weeks without food, it means that at that point where it doesn't exist, all of one's chattels are useless and will be sold or given away to procure it. Social chaos of course would be the net result long before this was reached and economies would be completely disorganized. I intimated earlier in this paper that in those countries now in peril the increase of food supplies will largely result from vertical increase - more production/hectare/year. This cannot be accomplisehd in any other way than through the massive input of fertilizers, extension of irrigation and drainage, multiple cropping, the increase of technological

knowledge and its extension into practice. All of these must be brought into play and all of the ancillary social changes must be made to allow their full expression.

In the following sections I will deal with what can, in my opinion be done. Quantity can be undoubtedly raised, quality also, greater stability of production is attainable both from the standpoint of disease and the standpoint of resistance to environmental variations. Weed control can be exercised. New and different crops can be developed. The list is impressive but it will take concentrated effort, availability of inputs, and economic and organizational development far beyond anything we have yet witnessed in the world. Power supplies to provide the basic infrastructure is an urgent need. This problem is now coming into sharp focus in these days of oil and fuel shortages.

QUANTITY OF FOOD

In a previous section I gave something of the magnitude of the need for cereals. I will not go into any detail on other crops but in some ways the advances in breeding of oil seeds, pulses and other crops as well as those needed for fibre are equally dramatic if not on the same scale. Because of the breadth of the subject as a whole and based on my greater familiarity

with cereal crops I may be excused for using wheat, barley and triticale with whose improvement I am directly connected as illustrations of some of the points.

In the first instance I would like to lay to rest some of the cliches that have become so popular in the public press and among some of the economists and biologists who are not conversant with the fact. It is stated that the Green Revolution has only had a limited impact and only then in the more productive irrigated acres; the new wheat varieties are unsuited to dryland areas, the new rices are unsuited to deep-flooded conditions. Wheats are not able to invade the winter wheat regions of Turkey, Iran, Afghanistan and so on. No attention is being given to the rainfed farmer. The new varieties are less resistant to disease than the native varieties they replace. The new wheats <u>require</u> massive inputs of fertilizer and water. They are inferior in quality to the native strains. They are less hardy than native strains. The list of criticisms could be extended indefinitely. It appears on the surface to be an organized effort to discredit what modest gains have been made.

Let me comment on these in turn. I would agree that the impact has been modest and the greatest gains have been made on irrigation under higher levels of fertility. Could anything else be expected? In common

with all biological organisms, these crops yield more when better fed just as I gain weight when I eat adequately and even more when I overeat (a condition becoming more and more of a problem around the waist). Some of the dwarf wheats have done very well indeed on rainfed areas and have now taken over very sizable acreages in such countries as Iran, Turkey, Tunisia, Algeria, Syria and Iraq to name a few.

In certain countries where dryland farming is practiced, their spring wheat areas now grow a majority of these wheats. Dwarf rice varieties were never meant to be used under deep flooded conditions where up to five and six feet of water are encountered. Long-stemmed fast growing varieties for these areas are being bred and introduced. In a similar fashion does any biologist consider that dwarf spring habit wheats or for that matter any spring habit wheats are likely to be grown under severe winter conditions. In regard to the dryland farmer and our lack of interest I can only reply that 80 percent of the nurseries we distribute are for selection in rainfed agriculture in countries where virtually no irrigation is available. Their failure to do as well under erratic rainfall is not really legitimately blamed on these or any other varieties. "The new varieties are less resistant to disease than those being replaced". In regard to rust this is an outright fallacy since I do not know of a single case where this has been true. In fact,

in many countries including India they were the first resistant varieties in commercial production. In the case of resistatnce to Septoria tritici we fully admit that the first varieties distributed in the Mediterranean area where this is a problem were largely susceptible. However, among them were resistant ones which are currently being grown. They are not in the top group in potential yield but remedial measures were immediately taken. Our present program perhaps leans too heavily toward incorporating resistance to Septoria. With regard to hardiness, it is a most peculiar thing that most countries are introducing these strains even under extreme conditions of drought and finding they are equal to or better than the native strains - even there.

The complaint about quality is largely one of colour of grain being different for some varieties in India and Pakistan. These areas only grew red-grained varieties until about 40 years ago when a new group was released with amber grain. People became used to this colour and there is a reluctance to change. It is significant, however, that even in India, a considerable quantity of the red-grained variety PV18 is still grown and that the first introduced variety to spark change there was Lerma Rojo and in Pakistan Penjamo 62, both red-grained varieties.

Perhaps we are remiss in not answering many of these critics. Unfortunately, we are just too busy trying to improve the adaptability of material to different areas to spend our time on defense like those writers who have full time at their disposal to downgrade the advances made. Were we to do so, it would certainly greatly increase the truth of their statements. Ours is a very modest effort but we will do what we can.

I have already devoted too much time to this topic. The question really is how can we improve yields? In the broad sense plant breeding is capable of pushing up yield potential in all crops. Stability of yield is another question but one which the taking of certain measures can enhance.

Let us first consider wheat although the same principles are applicable to other crops with suitable variations. New yield potentials in wheat can be achieved through several channels. In general, new potentials for yield will arise out of crossing between genetically different populations. One must temper this generalization,however, with a consideration of what type of environment with which one is concerned. We have several approaches.

CIMMYT through association with many country programs is in a unique position to receive germplasm

from many countries. Each month a large number of small seed shipments are received. These are incorporated in our next sown nurseries. Such strains are identified by national breeders as having one or more desirable characteristics. Other are identified by CIMMYT personnel visiting country programs. These are evaluated in our nurseries and the more promising are immediately incorporated into our breeding program in which more than 5,000 crosses are effected in wheat each year. In return successful materials are circulated out to National Programs and selected under their environments. The best of these are recirculated to our program for further crossing. The system operates in an endless cycle and has the effect of incorporating and pyramiding successful genes in the general background.

One item I should mention is the principle that one wastes one's time in trying to improve native strains. One must take the opposite tack and improve genetically superior strains by incorporating superior genes from native varieties. Thus the system is one of pyramiding the output end by continually degrading the input end to provide the variation from which to select. We use the top and double cross system almost exclusively except in creating original F1's which are used for crossing. We find the payoff is much enhanced.

Another program with which we have recently become involved is crossing between winter and spring

wheats. This program involves three institutions - CIMMYT, Oregon State University and the Turkey National Program. These two types of wheat have been only marginally combined. Thatcher is one of the familiar derivations of such a cross. We are exploiting these crosses for both winter wheat improvement and spring wheat improvement.

The spring wheat side is conducted principally at CIMMYT and we expect to get from the winter wheat added genes for yield. In addition we anticipate greater drought tolerance based on long term observations of such varieties as Thatcher and preliminary performance of some of the newer crosses under drought conditions in other countries. There has been a long established belief that the qualities of drought resistance and winter hardiness are related. We are not sure why, but expect it may be due to better water binding capacity of the tissue and a deeper set crown. The latter probably provides an earlier and stronger development of the secondary root system. We also expect to select from these crosses a variety of maturity dates which will allow for greater flexibility in suiting varieties more closely to the needs of specific conditions of growth.

On the winter wheat side, most varieties are lacking in disease resistance primarily for the rusts. Spring wheats excell in this feature and resistance can be readily transferred. Similarly the yield

potential should be enhanced through crosses between these unrelated and seldom crossed populations. In this instance exploitation will be done primarily through the collaborative efforts of Oregon State, the Turkey National Program and programs of the collaborating countries which include Eastern Europe.

In the meantime short statured Russian wheats- Bezostaja, Kavkaz and Aurora are being successfully grown over wide areas of the winter wheat regions of Turkey, Iran and Afghanistan.

Stability of yield is of great importance. For the most part lack of stability is the result of variations in climate, weed control, and associated cultural practices and the depredation of periodic cycles of disease.

Weather is something over which we have little control. However, we can mitigate its effect by using cultural practices which can conserve the moisture received. In irrigated practice, water shortage may be reduced in its effect providing power for pumping and dam installations are adequate. Under rainfed culture, maintainance of moisture assumes major importance. I am sure that most agriculturists are familiar with normal fallow-cereal rotations for moisture conservation and weed control I will not go into this although active work is being done on this aspect by many organizations including our own in several

countries, using various cultivation techniques. Where rainfall is adequate in the non-cropped season and inadequate or absent in the cropped season, small holding ponds can be used to provide one irrigation in the early part of the growing cycle to firmly establish the root systems for full use of the water present in the soil profile. Monsoon countries have this possibility. Areas where river floods occur can use this in a similar fashion.

The weed problem extending throughout North Africa and the Near and Middle East is of prime concern not only because of its effect on crops through competition, use of fertility in a non-return function but also on removing water particularly during the fallow season. After a crop is harvested in such areas, sheep are pastured until the land is prepared for cropping in the second year. Non-edible weeds flourish and through being allowed to produce seed perpetuate the problem. In the North African region we are endeavouring to introduce a forage legume-wheat system similar to that operated in dry areas of Australia. The subterranean and burr clovers used there came from the Mediterranean area and thrive under winter rainfall conditions. Tunisia and Algeria have already embarked on this program. It reduces weeds and at the same time provides much enhanced forage for an animal-cereal operation and N for the succeeding grain crop. Other

countries are showing real interest in this system. Other methods of weed control include chemical investigations and rotations using row crops for weed reduction. The introduction of such techniques in this region as a whole could increase the cereal production by at least one third and probably by one-half in many areas.

Stability in relation to control of insects is of fairly minor importance in wheat as compared to most crops. On a country basis, however, certain insects regularly reduce the crop. In Morocco, Algeria, Tunisia and some countries of the Middle East, sawfly and Hessian fly are important. In Turkey and adjacent countries the Sunn Pest which attacks developing grains can cause localized havoc. Breeding work and cultural practices must be provided as control measures. On the whole, however, the diseases in wheat are much more important.

Stability in relation to control of disease is extremely important. It is even more important when a good technological package of fertility is employed. A susceptible variety grown under these conditions can build a disease epidemic of greater proportions than if it is starved for fertility and water. In the latter case the wheat starves and the disease organisms starve. Our program in common with others places great emphasis on producing resistant varieties.

However, the organisms are forced into a position where their mutants for virulence are selected and every variety can be expected to succumb in the long run. This has been the case with virtually all varieties released. What then can be done to remove this hazard?

One way is to continue to produce varieties with resistance at a sufficiently fast rate to keep replacements coming. The problem has always been that we can't foresee the build up in some cases with sufficient warning to make seed supplies of resistant varieties available in time.

Another way is to incorporate the so-called "horizontal resistance" which carries resistance factors capable of offsetting the virulence of many physiologic variations of the disease. Our present knowledge does not provide techniques for ensuring selection for such factors in the field. We have, however, an indirect approach to this through testing potential varieties over a wide geographic range. This is done in such nurseries as the USDA's International Spring Wheat Rust Nursery, the CIMMYT screening nursery, the Regional Disease and Insect Screening Nursery distributed from Lebanon and the Latin American Disease and Insect Screening Nursery from CIMMYT. These and others identify the best new lines being developed in National Programs both for resistance to

rusts and other diseases on a very wide base. Those varieties which retain resistance over the wide range of virulences represented, are likely to have horizontal resistance. These then can be used in future crosses.

Still another method for control is to introduce alien germplasm from wheat relatives into wheat. This was thought at one time to be the final answer but the work of Samborski[18] showed the fallibility of this approach with the Aegilops umbellulata gene for resistance to leaf rust. The organism can and does adapt.

We are placing considerable emphasis on the multi-line approach as enunciated by Borlaug[6] and others many years ago. There is only one multi-line variety in wheat currently grown viz: Miramar in Colombia. It has with modification controlled Puccinia striiformis for many years. At CIMMYT we are building a multiline in the background of the various varieties derived from cross 8156. These varieties have the prerequisite of very wide adaptation and inherent resistance to such diseases as mildew and the smuts as a group. In putting together the multi-line we are not concerned with exactness of type and hence are not using the traditional backcross approach. From our nurseries we have been methodically selecting out 8156 phenotypes. These vary in height, maturity

grain colour, chaff colour and other minor variations. This year we distributed some 285 lines and Dr. Rao of India added 65 additional lines to 31 locations throughout the world. These are to be rated on height, maturity, glume colour, grain colour and disease resistance in these countries with the object of determining which lines can be composited in the different regions to form different multiline varieties with this background. We are only interested in similarity for the four-mentioned specific characters and will accept considerable variation in attitude of head, leaf angle, and so on. In developing such multiline varieties we feel confident that rusts can be held at bay.

I am sure that most of the readers are aware of the advantages of this approach and how the system works. For those who are not, what we are doing essentially is simulating an out-pollinated crop system in a self-pollinated crop. Each of the lines and others developed are grown each year within the specific country to see which ones in the composite are developing susceptibility. These are removed from new seed stocks and replaced by others that are resistant. In the commercial fields if one line goes susceptible only plants of that line in the composite are attacked. Further, the chance of building up epidemic proportions of the spores is very much reduced since the lines

continuing in resistance do not contribute any inoculum. A variety of this type, of course, does not advance yield levels but it does give a defence line behind which plant breeders can investigate new ways of adding to yield potential.

Reference was made to the Regional Disease and Screening Nursery (RDISN) and the Latin American Disease and Insect Screening Nursery (LADISN). These are a part of regional activities being conducted in the Eastern and Western Hemispheres, respectively. CIMMYT has a pathologist stationed in Beirut who is in charge of pathology assistance throughout wheat growing countries in Africa and Asia and in a minor way parts of Europe which are adjacent. He is assisted insofar as possible by another CIMMYT pathologist, resident in the Turkey Program. In addition to fielding the pathology problems in the various countries two nurseries are operated. One is the RDISN mentioned and the other is a Regional Trap Nursery (RTN). The RDISN is comprised of varieties which are known to have broad resistance. In addition, plant breeders of the region are encouraged to submit their lines which are in an advanced state for widespread testing. This nursery is sown in many countries of the region at locations where disease is known to be prevalent in most years -so called "hot spots" of disease. This provides information to the various breeders

on how wide a geographical range the resistance of their varieties is displayed. Presumably, those which are resistant over a wide range can be expected to retain resistance within their country for a longer period of time. Secondly, it may show that a biological form of a rust, for example, may be present in a nearby country which poses a potential hazard to the variety were it released. Thirdly, it builds up a body of information on the movement of airborne pathogens from one area to another. Thus, if a specific variety is susceptible in Lebanon but resistant in Iran and the subcontinent, and the next year it becomes susceptible in Iran and the third year in the subcontinent, we can be reasonably sure that the virulence has moved across this route and we have a related area. Fourthly, it is a vehicle by which the superior material of collaborating national programs can be distributed to other countries where this material may be directly introduced or used as further breeding material. This nursery carries 2000-2500 entries.

The RTN comprises one or two nearly universally susceptible varieties and the principal commercial varieties grown in the Eastern Hemisphere. About 70 varieties are included. The purpose of this nursery is to work out how and when the commercial varieties

succumb to new diseases. It gives direct information on the movement of specific virulences from country to country over time. It is hoped that this information will provide an early warning system to advise countries on the need to change varieties before epidemics occur.

The principals behind the LADISN, operated from Mexico, are the same as those for the RDISN except that nurseries are grown throughout North and South America. In each case one or two RDISN nurseries are grown in Mexico and similarly the LADISN in Beirut. We hope to exchange the best varieties of each on a continuing basis between these two nurseries so that all the plant breeding programs will be in mutual assistance on a global basis. We feel that these nurseries can greatly assist the various national programs.

We, along with many other centres are investigating the contribution of such characteristics as upright leaves, long peduncle, better root system and so forth, to yield. We are confident that certain characters are definite plus factors and other are minus in their effect on yield. This of course is true in general but we are trying to identify the ones which are contributing.

In discussing another aspect in expanding the quantity of food I will refer briefly to the "multiple cropping" system. While this is not possible to do in

the temperate zone, it is very feasible in the tropics and sub-tropics, and provided fertilizer and water are available this is quite farm size neutral. As the size of farm is reduced, the family labour available per unit area increases and hence the possibilities of greater intensity of production is increased. In Taiwan, in the Phillipines and in certain parts of India, I know of as many as five crops being taken each year on small areas of land by interplanting succeeding crops between rows of the growing crop before it is harvested. Thus when harvest comes, the new crop is already firmly established. This is the extreme case but 2-3 crops can readily be taken in almost any area where moisture is sufficient. Over vast areas of the subcontinent, rice and wheat are taken in rotation and a short season crop may be grown between these two seasons. One of the dangers in this system is that one or more of the component crops may be grown outside its best period of growth. This becomes a problem in particular when one is dealing with daylength neutral crops. Thus, in the best production area of India -The Punjab- the late maturing rice variety IR8 has been placed in rotation with wheat. This results in a two-week later sowing of the wheat which, in turn, lowers the yield of the crop because it is incapable of reaching its maximum yield. The hot weather at the end of the cycle may

cause premature ripening and it is exposed to a longer period of disease attack when the latter is at its strongest development. The concept, however, is summed up in the maximization of production through kgs/hectare/year. This multiple cropping approach promises tremendous gains in overall food production in the humid tropics and subtropics, provided adequate fertilization is available.

QUALITY AND NUTRITION

Quality is a much abused term since it is so dependent on the product for which the grain is to be used. I prefer, therefore, to use the term in relation to nutrition properties and not in the industrial sense.

In the developed nations where almost all cereals for human consumption are marketed, and the finished product purchased by the farmer, it is quite easy to fortify the foods with essential nutrients. The diet in itself is well-balanced with animal products, fruits and other varieties of food so that fortification is only marginally necessary. It is perhaps peculiar but certainly animal feeders are very cognizant of the need for nutrition for animals from an economic standpoint. They know that if more of the ration can consist of cereals rather than soybean and

fish meal, and still give equal nutrition, the economic gains are appreciably higher.

Why then have we neglected improving human nutrition at no extra cost and become instead obsessed with industrial quality in the cereals?

In the lesser developed nations, the farmers make up 50-80 percent of the population. There is some variation in food to balance diets - e.g. maize and beans in Mexico or wheat and rice with chickpea, pigeonpea, lentils, etc. in India. The effect of these should not be underestimated and breeding work should be active in these crops to make them fully competitive with the cereals. The fact ramains that the diet is cereally based and animal products are often scarce. Further, the cereals are largely consumed at source under primitive preparation. Additives, therefore, are out of the question except in urban centres. It is imperative under these conditions to raise the nutritional level of the cereals which provide the bulk of caloric and protein intake.

Rice and wheat the two major cereals are low in nutrition. In rice the amino acid balance is reasonably good but the percentage of protein is low. Wheat is much higher in protein but it is low in certain essential amino acids such as lysine, tryptophane methionine and others. Much work has been done to screen for higher levels in wheat with only marginal success.

Some improvement in rice may be possible by increasing endosperm dispersion of protein.

The nutritional value of the gene opaque-2 was discovered in maize in 1965, by a graduate student Lynn Bates at Purdue University[14] Incorporation of this gene in maize essentially doubles lysine and tryptophane. Its value in nutrition has been demonstrated with humans to be increased very markedly[17] Progress has been slow since that time in putting this gene in commercial hybrids or varieties but Colombia has released material with this component. In its original form the Opaque-2 materials suffered from a soft kernel that caused increased losses to storage insects and a somewhat lower yield is reported. CIMMYT scientists are developing composite materials with a hard endosperm using modifying genes and are meeting with fairly rapid success. Yields are also being brought in line. Popularization of these materials in commercial production in Latin America and Africa can vastly raise the nutritional intake of both people and the animals which they raise.

Recently, Swedish workers[15] have identified genes for high lysine in barley. Additional genes have been isolated in a mutation program in Denmark and still further natural occurring genes have been screened from varieties at Montana State University. Barley is generally thought of as an animal feed and

for making beer. However, it is an important human food crop on the approaches to many of the deserts of the world and in high altitude locations where there is a need for a short season crop. CIMMYT is attempting to develop high yielding, disease resistant varieties incorporating genes for high lysine in both hulled and hulless types. The hulless types we feel would have a better application in the field of human use and either would be satisfactory for animal feeds. Since the areas where barley is grown constitute areas of greatest human deprivation, we feel that high lysine barleys can materially improve their lot.

Triticale, the first man made cereal, arising from crosses of wheat x rye also offers very interesting nutritional possibilities. Preliminary work suggests that protein additives in the ration of swine and chickens can be materially reduced by using increased amounts of triticale with its better balance of amino acids. Breeding work is being vigorously pursued in a joint program of CIMMYT and the University of Manitoba with financing supplies by IDRC and CIDA of Canada.

Similar opportunities exist for improving sorghum which is of such primary importance as a cereal for drought-plagued dryland areas. This is now being improved at the International Crop Research Institute

for the Semi Arid Tropics (ICRISAT) in India.

Meanwhile the search continues for ways to improve the nutritional value of rice and wheat.

At CIMMYT in collaboration with Lynn Bates at Kansas State University, we are investigating the possibilities of making wide crosses among the various grass genera. In this program the plants are being treated with chemicals prior to flowering in an attempt to overcome sterility barriers so that pollen of one genus can effect fertilization of another. Our preliminary results indicate that rye x barley and barley x wheat crosses can be made. We are attempting sorghum x maize and hope to cross rice and wheat. If this can be accomplished, it would open all kinds of possibilities in transferring genetic material from one genus to another, making completely new crop plants using wild grasses and improvement of both yield and quality are not too far fetched to consider. This could be a much more direct and directed method than the somatic-fusion process to effect alien crosses.

THE FERTILIZER AND CHEMICAL SITUATION

Throughout this paper I have made repeated reference to the need for fertilizer if we are to

continue to produce food for the world. If we are to fully use the land surface in production, we will have to feed the plants so that they may make full use of the supply of water and solar energy. Let me emphasize there is no alternative. The soil's parent material is incapable, in most areas where long time agriculture has been practiced, to provide the necessary nutrients at the off-take level expected.

Generally such soils can be classified as very short in both N and P_2O_5. Some are short of K_2O but this tends to be more location specific at present. Under a concentrated crop cycle such as that inherent in multiple cropping, the trace elements can be depleted and their level should be constantly checked. Large areas worldwide show Zn and S deficiencies. Others in East Africa e.g. are short in Cu. We can expect this to occur with these and other trace elements with increasing frequency. There are large areas of the tropics where soils have developed which fail to respond well to fertilizers, e.g. there are many acidic laterized soils which tie up phosphorus as ferric phosphate very rapidly - this can be improved by liming and banding of phosphorus during application; the volcanic soils of the Andean countries are virtually devoid of

available phosphate and no crop can be grown unless it is added; vast areas of Brazil have acid soils which provide a high level of free aluminum which is toxic to wheat - liming on a massive scale has been done to raise the pH but even then varieties resistant to toxicity must be used since liming only extends to the plow depth and once the roots penetrate below, toxicity results. Within all of these regions there exists a host of other variations so that agronomic research is to a considerable extent location specific.

Assuming the need is great, where do we get the supplies. They can be provided by chemical or organic manures. I will deal first with the chemical.

Nitrogen can be produced by a number of methods which includes the use of natural gas, naptha, fuel oil, coal or compression from the air. This element is very widespread and virtually inexhaustible. The derivation from fossil fuel, however, is exhaustible and it is likely that the power and fuel needs of the world will force man to eventually turn to the air as a source. The liquefaction of N as NH3 requires tremendous input of energy since it requires hydrolysis of water for H and O_2 in the process, in addition to compression of N itself. This is the reason that N from fossil fuels is favoured. Again, however, it can be done.

Phosphate is undoubtedly the world's most exhaustible needed fertilizer. It exists in economic concentrations in a few areas of the world as phosphate rock in combination with many other chemicals. There are deposits in quite a large number of countries but these vary in their percentage of P. The principal known deposits occur in North-Western Africa, including Spanish Morocco, Morocco, Algeria and Tunisia, in Jordan, in the U.S. and the USSR. If one looks at the continental drift, it appears that many of the large deposits were laid down in much the same area when the continents were joined. The quantities available are, however, finite although some believe it can be profitably mined from the continental shelf and the sea. Phosphorus, however, remains on the critical list when viewed from the standpoint of the long term need.

Fortunately, potash is in fairly high supply in many of the soils of the earth and its need is correspondingly reduced as a fertilizer. Supplies in Canada are very large. Canada now has about 35 percent of the world's market in K_2O. Other sources are the brines of the world's salt lakes where there has been considerable accumulation and these are presently supplying some of the needs. The Canadian deposits were laid down after the evaporation of shallow seas.

The need for these three major elements can

be expected to be tremendous in a period of vertical increase of production on the same land area.

Ewell[9] forecasts that fertilizer use on a nutrient basis will go from the 1970-71 figure of 68.2 million tons to 133.5 million tons in 1980-81. This means a growth rate of 7.1 percent each year for the decade. The actual growth rate in consumption was 8.8% in each year from crop year 1964-65 to 1970-71. One of the problems in most of these forecasts is that they are based on previous trends and there has been a very sharp use in the needs of developing countries. This has led to an exponential growth rate rather than one based on an arithmetic increase which is more typical of the developed countries. In his paper Ewell shows that for N the developed countries grew in fertilizer use between 1964-65 and 1970-71 at 10.1% and developing countries at 16.7 percent, similar figures for P_2O_5 are 5.2 percent and 14.7 percent, for potash were 6.6 and 14.7.

I would contend that we are seeing only the beginning and that growth rate will have to be increased even more if we are to catch up with need. All of the countries with which we deal, with large populations, have fallen greatly behind their needs and are becoming increasingly dependent on fertilizer imports. Thus just as they were politically dependent on sources for food in the 1960's they are becoming

politically dependent on sources of fertilizer in the 1970's. It, therefore, behooves each country to make every conceivable effort to become as independent as possible in fertilizer supplies. To do anything else for such a basic commodity as food is to surrender autonomy and invites disaster on a mass scale. There are no alternatives. We are all well aware of the crisis in petroleum products which are basic to much of the N fertilizer industry; recently in October Morocco announced a price rise for phosphate rock from $12.00/ton to $42.00. Obviously, this is capitalizing on the short supply situation but can we look for much else? In one way it is announcing to the world that we better look at exploiting other sources. Of course, the price rise will undoubtedly make exploitation of other sources of lower grade rock more attractive. In a similar way it will increase the profitability of extracting petroleum from shales and tar sands, which in North America contain many more times the fossil reserves now presently known in the oil fields of the world. In the long term this may be beneficial to mankind. In the short and medium long term and perhaps for ever it will mean increased prices for fertilizer and food and a greater percentage of consumer income spent on food.

The nations now undergoing the Green Revolution now have some idea of their fertilizer needs. Wheeler[21] speaking before the Ninth Latin American Food Production Conference in El Salvador in November 1973 states:

> ..."Except for unforeseen weather conditions they (Green Revolution nations) should within reason be able to project their future requirements as to fertilizer, pesticides, planting and harvesting equipment, etc. If they really want to supply these demands to be in a position to supply their farmers - they should quit buying on a last minute basis..."

In the past with fertilizer in surplus supply delay in purchase was used as a basis for beating down price. This can no longer be done in the present fertilizer short situation and the sooner domestic supply is built, the more stable will be that country. They will have to depend on imports for some time but cannot afford to continually fall farther behind.

Before leaving fertilizer I would like to briefly mention non-chemical sources. The greatest of these of course, is organic matter wastes. It is quite true that considerable N P and K and minor elements are present in such residues but for the most part they are a small part of the C:N ratio. In order to use them with any success it is necessary

to compost the wastes in order to break down the excessive C present. Usually this will require addition of chemical N if the breakdown is to be made in reasonable time. The fallacy of applying raw organic matter just before sowing a crop is known to agronomists all over the world. The plant yield is determined largely by the fertility absorbed in the first 1-2 months of its life or in a winter crop effectively the same length of active growing time. It is during this period that the organic matter is also being broken down and the microorganisms concerned are in competition for the nutrients available. Hence yield is reduced unless additional nutrients are provided. On the death of the organisms the products of breakdown are released for plant use. These may increase protein percentage but have no effect on yield. In one experiment in the tropics equal amounts of fertility by chemical determination in organic matter were compared with chemical fertilizer. In each of the seven years in which these plots were compared and in each year the same treatment was repeated, the organically manured plot was uniformly lower in yield. At that point the experiment was concluded with the remark that they couldn't wait any longer for the beneficial effects to appear.

Recommendations for the use of organic matter to replace chemical fertilizer are largely an invention

of government agencies in developing countries to take the heat off for not arranging for the supply of needed amounts. They have been given false hopes by organic gardeners that this is a way out of their dilemma. In countries perennially short of food this approach will not work.

The use of legumes as suppliers of N should not be overlooked because in rotation they can add each year enough N for a modest rainfed cereal crop.

I should like to turn now to the question of pesticides including herbicides, insecticides and fungicides to name the principal ones. If the world is to eat and be clothed, these tools cannot be removed. There has been a growing lobby of environmentalists, who on the basis of ignorance of even the basic concepts of food production or biology proclaim the disadvantages of the use of protective chemicals in food and fibre crops, let alone forests. To most of them food grows in the supermarket, it has been cheap and the countryside should now become a hunting and fishing preserve for the exclusive use of the urban population. This of course is politically expedient since in the U.S. where the greatest movement arose, only four percent of the people inhabit the farms and they have become as Carew[7] puts it "the unimportant minority".

All sorts of outrageous claims have been made. DDT affects eggshell thickness on birds. It and other chemicals kill the fish and contaminate all the food chain. I do not wish to go into this but in the case of DDT an excellent rebuttal has been written by Beatty [3]. In spite of a federal inquiry which resulted in the presiding judge finding that no case could be made against DDT in that beneficial effects far outdistanced the potential hazards, DDT was withdrawn from use except for a few crops where nothing else was effective. If this kind of legislation stopped at the U.S. borders one could say that the damage would be limited. Unfortunately, many other countries follow suit and Canada is one example. The Bertha Armyworm attacks rapeseed fields. I am told that because DDT could not be used, more toxic chemicals were employed and many farmers were hospitalized. In the last two years thousands of acres of Douglas fir have been denuded by the Tussock moth in Oregon. The concern of the environmentalist backers is best summed up by their considering this to be beneficial in that accipitine hawks and owls could better see their prey and woodpeckers would have better nesting sites [12]. Such mentality avoids even the smallest vestiges of sanity. The use of fertilizers is also in jeopardy from the claims of a few people that it is causing pollution in streams

and rivers. This is nearly impossible if one knows anything of the action of N in the soil. An agronomist grows plots with a 200 kg/ha application immediately next to plots with a 0 kg/ha application under irrigation and gets absolutely no movement from the plot with high application to that with the lower. Similar observations can be made with the other elements.

Suffice it to say that these people will change their tune when the food basket price rises inexorably as a result of their activity. Assuming that they have become so entrenched in their own thought processes that they see no light, public opinion as was the case with the Alaskan pipeline will change it for them.

I should not like to leave the impression that the environmental movement is all wrong. None of us are happy about pollution and the move to cleanse the atmosphere and rivers is meritorious. Let us, however, base our charges against chemical use on scientific fact not on public frenzy built up under the whip of an ill-informed minority.

WATER DEVELOPMENT AND CONSERVATION

There are substantial areas of the earth which can and should be developed for irrigated farming.

It is clear for example that Argentina could develop large irrigated tracts through drawing water from the Rio Paraguay. It is not equally clear how much land could be developed in the Amazon Basin. With the fresh water available Canada and the U.S. could no doubt irrigate substantial tracts. This would mean, however, a massive financial input in moving water across the continent. Similarly, large tracts of land in Africa and Asia could be developed for irrigated purposes

Unfortunately, many of the large irrigation projects such as those in the Indus and Gangetic system were installed as a drought protective measure and failed to incorporate adequate drainage. Although some relief has been given through the use of wells and a consequent draw down of the water table, substantial areas are salinized and effectively out of production. Any new irrigation schemes must include drainage if the production is to be sustained.

Groundwater development has added substantial areas to the irrigated acreage of the sub-continent. Much more can be done. In its use, however, care should be taken to employ it judiciously and on crops which will give the greatest return in production. Rice grows well in monsoon climates where other crops are depressed. To grow paddy rice under irrigation in the winter season, on the other hand, requires

about 60 inches of water (150 cms). Wheat requires about 18 inches (45 cms). Simple calculations show that more than three times the area can be covered for wheat with the same amount of water. Why then do some countries persist in incurring the energy expense required for pumping water to grow rice instead of wheat and get about the same yield per hectare? I submit it is habit and further that this habit is expensive to maintain.

I referred briefly to small scale impounding of water as another means to increasing production through the supply of one drought protecting, yield enhancing irrigation. This is feasible and is worthy of consideration in future developments.

In an earlier section, reference was made to the need for cultural practices such as weed control, better mulch cover and maintenance of the moisture to prevent evaporation. These practices are essential if the best use is to be made of water in the dryer regions.

POWER NEEDS

Power has become one of the essentials not only to our way of life in the developed countries but to maintaining life in our present world. The

demands for power in the agricultural sector have increased tremendously. At the farm level the efficiency of production is based primarily on the mechanization of cultivation. Without this much of the agricultural land would be devoted to feeding animal power and much less would be available for food production. The need for mechanization in the longer term is an essential since we are increasingly short of land. In the agro-industry sector, immense provision of power is required for fueling the various manufacturing processes be they the manufacture of fertilizers, the making of machines, pumping of water, transport of agricultural products and so forth.

I have said that countries should produce their own fertilizers. They cannot do this without substantial increases in domestic power supply. Further, the sources must be diversified. In 1972, for example, India suffered a monsoon failure. Much of its power was fed from hydroelectric dams. Because of low rains the reservoir levels were low, canals were low and greater dependence was placed on electricity for pumping. The electricity was in short supply because the water storage was low. You can see, therefore, that the three formed a vicious circle that lowered all parts of the equation.

Where is all this power to come from. I think man should take stock of the alternative power sources

for forward planning. Electric power produced from any form of energy, could conceivably power cars, trains and other land transport. It is highly questionable that this could ever be used for tractors or aircraft. We should consider then whether or not we should conserve fossil fuels for these purposes and as raw materials for the chemical industries beginning now. It would have the additional desirable effect of lowering the smog level in our cities. Assuming our other industrial activities were harnessed to electrical energy where do we produce it and how. Firstly, of course hydro energy should be employed wherever possible since this is cheap. Coal burning-thermal plants could be operated at pit heads and the electrical energy transmitted to other parts of the country -this, however, would raise the smog problem but outside the cities. In the long term there seems no recourse but to use fission - generated energy and when it is available fusion - generated energy. Either of these is based on inexhaustible fuel sources abundant in the world.

In reference to fission-generation, Gabor states that at present prices, granite having a uranium content of 0.1 to 0.3 percent can be ground for recovery of uranium at a price about two times the cost of extraction from high grade ores. At four times the present cost from these ores, uranium

could be recovered from sea water where it is present at the rate of 3 mgs/cubic meter. This reservoir is truly inexhaustible as the rivers bring more into the sea in a year's time than what would be removed. In a recent article in the press, South Africa[2] reports that they have a new breeder type reactor which will reduce present costs of producing nuclear fuel to less than one half that of the U.S. process. With a concentrated effort there is little doubt that man could effectively reduce costs below those incurred in the more traditional forms of power generation. If fusion power can be harnessed again this is a truly inexhaustible source since both atmosphere and water have endless quantities of hydrogen.

If power were sufficiently reduced in cost, one could anticipate the use of desalinized water for irrigation of deserts on a broad-scale. This would modify the entire climate of the earth and open large land areas for production.

All of this development will require tremendous expenditures on infrastructure but would it not be a more profitable human endeavour than the present arms races that absorb so much of our time and talent. We would have to at the same time silence those in our society who are more concerned about the effect of cooling atomic piles on the temperature

of the water, hence the sport fish habitat, than they are in developing power to make a better life for humans.

GOVERNMENT POLICIES

Governments have a tendency to look for the easy way out and the simple solution. In this they are generally fooled. There are no miracle varieties to solve problems. There is much hard work and planning necessary after superior varieties are produced if these are to be translated to production. Research and extension must be stimulated. The whole infracture must be revamped. Hard work is the price for solving problems. There is no other way.

If we are to produce adequate food even in the short term, we are faced with the necessity of having forward-looking sustained governmental policies both from the economic and organizational standpoints. Hard decisions will have to be made. I earlier referred to this in relation to population control. With reference to agricultural organization, governments will have to give concrete support to agricultural research and extension. It has been my experience that this is given a much too low priority. Too much is spent on research for research's sake. Every man who gets a Ph.D. is not necessarily of

research or extension calibre. The human element always intervenes. Yet in some countries, where they are fortunate in having many trained people, everyone is placed in the service irrespective of whether or not he is suitable. This leads to an accumulation of "dead wood", and I know of cases where this has developed to an advanced state. This in no way reflects adversely on those dedicated and productive scientists in such institutions. It does, however, greatly hamper their activities since the cutting of the expenditure pie leaves them with a less than adequate share.

In many other countries there are virtually no scientists and very little investment in their development. This must be remedied as early as possible. In so doing, they are going to have to look for the superior people. Unfortunately, in these days of ever lowering standards in the universities of the world, the process of uncovering unusual talent is obscured. There is no room for mediocrity in this race for survival.

We from the developed nations must assist as best we can in providing education for a cadre of people who take over the manning and leadership within the lesser developed nations. It is true that the first people trained in any country are usually upgraded to positions of authority. If they are good

this is not a loss in that they direct dynamic programs. If they are mediocre the program normally reflects this condition. This makes it doubly important that sound initial choices are made. The process must be continued to get research and extension scientists to man the infrastructure.

Let me now turn attention to needed economic policies in relation to crop production. The first assumption that must be made if productivity is to increase, is that the farmer must make money. This can be done by lowering cost of production through higher yields, lowering costs of inputs, raising price of product or protecting the crop against loss or providing markets and transport. Without some combination of these factors virtually nothing will happen.

Governments have and continue to wrestle with these problems, I should like to cite some of these. We could begin by assuming that the genetic part of the picture is already a fact and higher yields have materially lowered production costs per unit land area. On the question of inputs, some governments have taken the view that subsidizing fertilizer, farm machinery, water development and so on is the method best designed to get the farmer to use inputs. The aims are undoubtedly at least partially successful

but there are very odd side effects. The farmer adopts the mentality that the government must look after him; if countries adjacent to a country with this policy do not have a subsidy, fertilizer is often smuggled and sold across the border into the non-subsidized market. By contrast to this system, I consider that it is much better to establish a sound market floor price that ensures a good return to the farmer, then allow the input price to reflect the market and adjust the floor price periodically to compensate. If subsidy is to be paid at all it should be at the consumer end through government selling of the produce directly on ration to the consumer. Such a system reduces bureaucracy and more surely protects the farmer and consumer. A stable floor price announced well before seeding will allow the farmer to decide what level of expenditure he will incur and still have an assurance of a reasonable return. Another anomaly which is observed is the setting of a support price which is unreasonably low in one country as compared to its neighbours. This encourages and results in an unnecessary smuggling of grain across country borders. This low support price is usually associated with a subsidy on inputs so that the country loses on both scores -the fertilizer flowing out and the product flowing out.

Credit to buy inputs is a two-edged policy.

It can be argued that credit at reasonable rates will encourage the small farmer to use inputs. I think it does, if the institutional credit - government backed- is given with a minimum of red tape. In some countries the traditional credit source was the money lender who exacted a 20 percent interest rate. Yet I have seen poor farmers take this credit either because they were poor risks for other forms or the red tape was so complicated that they could not get credit in time to use it effectively. There is always, with institutionalized credit, a tendency to provide credit to the risk-worthy client. Yet it is the man who is least risk worthy who probably needs it the worst. There is yet no known solution to this problem or the associated one of poor record on repayment.

Land tenure in many countries works against production. In a system where the landlord takes half or, in one case of which I have knowledge, as much as 75 percent of the tenant's crop, one cannot look for much increase in the use of inputs unless the landlord provides it - and this rarely happens. Many answers have been tried but there seems to be no universal solution. These range from continued fractionation of land to provide each farmer with a small plot to the immense state farms of the advanced socialist systems. Continuous subdivision of land leads to economically inefficient plots with the

operator unable to afford the necessary infrastructure for efficient farming. The large state farm tends to become less productive because few systems provide the necessary profit incentive. One of the better systems I have seen is one where the government rents the land to the tenant at a very low rate but maintains title so that land-fractionation by inheritance does not occur. It is significant I think that in India, those districts in which land fractionated by centuries of inheritance was amalgamated so that a man in place of having five or six one acre plots had one block, are among the most progressive. The man could now put down a small well because he can water his contiguous land. He could not do this before on dispersed land.

No matter what system is devised it is generally true that the land owned by an absentee landlord is not productive; that farmed by an owner-operator is generally more productive irrespective of size. Land reform in many countries is long overdue if better production is to be realized.

As I indicated earlier storage is essential to preserve the crop once it is grown but this is unlikely to be built at market centres in anticipation of increased yields. On-farm storage is probably of greater importance since such a large part of the produce of developing countries is stored and consumed

at the farm level. Many cheap structures have been designed with a 1-5 ton capacity. These give flexibility to the farmer in his ability to hold some stock in anticipation of rising prices as the next harvest approaches. This is an area that has been sadly neglected and various insect pests, weather and molds annually account for significant losses. There have been various estimates made of such losses ranging from 10-25 percent. The actual figure probably lies between these two percentages but on a local basis the figure may indeed surpass the upper level. This is an avoidable loss. Governments should remedy this situation by granting credit for on-farm storage construction and distribute ampules of methyl bromide to be applied each month by the farmer for insect control. I have personally seen marketed grain which was nearly 50 percent weevils and frass by weight entering Indian markets in the pre-harvest period.

Associated with marketing is the question of market access. In many countries very good highways have been contructed between main centres to facilitate movement of supplies to those centres. Ethiopia is one such example. At the same time there are virtually no access roads. Farmer marketing under these conditions, consists of carrying a few kilos of grain on a donkey for up to 50 kilometers to trade

for such staples as sugar, salt, tea, etc. These small lots are dumped in a bag. The receiving merchant delivers a bag when full to a trucker who collects from other merchants. When he has accumulated a truck load he takes it to one of the cities for sale. The idea of a fair average quality is far from achievement. The product cannot be described above fair but whether it has quality can be left to the imagination. Ethiopia is presently negotiating loans in order to improve its secondary road system and place farmers at not more than 30 kms from marketing opportunities. Action is much overdue in many of the LDC's. As a corollary, if fertilizer inputs are to be used road systems for delivery are a prerequisite.

I have already pointed out the need for fertilizer as an absolute essential if increased production is to be met. Its need cannot be overestimated and governments in any country where unexploited water power potential is available should think very seriously of investing money in economic-sized fertilizer plants located at convenient points. Some countries are holding back because their domestic consumption has not reached this level. In such cases, plants should be located near port sites where the fertilizer can be exported

in the near term using what is needed for domestic consumption. Where domestic consumption is high the location should be near the area where that product is to be used. It if is a product suitable for rice - the rice area; if suitable for wheat - the wheat area. The need is so great that any country with potential for manufacture faces an almost inexhaustible market which would compete favorably with fertilizer produced in the developed countries where freight charges would give the nearer site a distinct advantage. I have often recommended to Nepalese officials that they produce their own N and export the surplus to India. They have a vast potential of undeveloped water power and a virtually unlimited market for a very long time into the future. Ethiopia is similarly endowed. I would, therefore, recommend to the governments of all the LDC's that they look seriously at development of fertilizer manufacturing capacity as a means to supply fertilizer to their farmers at a lower price and at the same time increase their foreign exchange earnings.

Water development was discussed in general terms. Each government should plan forward to increase the effectiveness of their countries' water supply. This includes irrigation cultural practices and efficient use. Poor land levelling under irrigation can account

for 30 percent less yield with the same inputs. Rice farmers tend to treat upland crops, in their multiple rotation, like paddy and use excessive water. In this way they not only waste water but lower yields. Education of the farmers on proper practices is essential.

I have not mentioned supply of high quality seed as one of the essential inputs. I shall not enter into a discussion of the merits or demerits of public vs private seed production. It is fair to say, however, that in most of the developing countries seed production is largely a preserve of public institutions. In many, these are in their infancy; in others that have been fairly well developed there are still major problems. Most of the bottleneck to successful seed production occurs at the link between the experiment station and the seed production unit. Too often the seed producing organization is expected to show a profit and is reluctant to take new varieties on a pre-release multiplication basis with the possibility that they will not be released and the product will have to go as grain with a monetary loss. Yet, this is a necessary function of seed organizations if varieties are to be available in quantity at the time of release. Government action is required in several fields. Where seed organizations do not exist, these should be brought into being; where seed organizations are operative they should be granted financial

backing for any losses incurred on pre-release multiplication of varieties which are not released - this should be viewed as an investment and considered in the light of the potential gains to production as a whole within the country; as the program matures seed laws should be set up, but, the law should not be unduly restrictive and should be based on a common-sense assessment of what is possible within the context of country development -laws can be amended and it is ridiculous to try to bring in a copy of the law passed in a country with very sophisticated agriculture. The associated seed laboratories should be constructed to do the necessary germination and purity work.

On the international scene there is a real need for governments collectively to set up international granaries of food in strategic locations such that food shortages due to weather vagaries can be met expeditiously to avert famine. It is not the responsibility of exporting countries to maintain such granaries, but should be the responsibility of all countries under some international body such as the U.N. This should not take the place of buffer stocks established within national boundaries.

There are many other governmental activities which need enactment as agriculture becomes more fully developed but I think that those enumerated are

ones which each government must consider carefully in drawing up plans for future development.

THE GREEN REVOLUTION IN THE BALANCE

World population is in a period of explosive increase with increased mouths entering the world at something more than 2.0 percent (77,000,000/year at present). Birth rates are highest for those countries least able to provide food because of their stage of development but with great agricultural potential, through increase of food/hectare/year. The question of whether or not agricultural change should or should not be made is only academic. It must be made. Whether or not it brings with it an exacerbation of other problems such as displacement of tenants, a highlighting of second generation problems and so forth, the need for food is so imperative that attempts to alleviate some of these must be made under the cover of increased food production at any cost.

Birth rates must be brought to balance with death rates at the earliest possible moment. In some countries the population size has outrun the economic ability of countries to provide education, opportunity, medical care and living accomodation. These countries do not need a 0 population growth rate but a rollback of population under a negative growth rate. Other

countries are possibly at optimal size but there is little evidence that any country should increase its population. In economic terms, the more people the less to divide, the greater is the pollution and the poorer is the quality of life.

Agricultural change can only provide a breathing space in which population pressure can be controlled. There is no question that food quantity in itself can be at least doubled and with proper investment and husbandry can probably be quadrupled. Nutritional quality can be markedly improved. But man cannot exist on bread alone. Existence can be very dreary if that is his only preoccupation.

It is unlikely that populations can be controlled in the near future, barring an unforeseen development in sterility factors that can readily be introduced into food and accepted as a social necessity. It follows, therefore, that we must look to agriculture to provide as much food as cheaply as possible to humanity in the transition period.

There is documentary proof that in its initial thrusts the new agricultural change has resulted in benefits of considerable magnitude in an appreciable number of countries with India and Pakistan as prime examples in wheat and these together with the Phillipines in rice. While these gains are impressive they pale to insignificance in relation to the need.

If change is to continue and be maintained in the lesser developed countries, the governments of those countries with the help of technology and finance from the more advantaged nations will have to take concrete steps to provide the necessary inputs. Fortunately, these will tend to increase employment. A tremendous effort must be mounted to provide fertilizers. This is presently the greatest need. Associated with this are questions of power development to power factories, exploration and exploitation of sources of feedstock for these fertilizer plants and development of and conservation of water resources both for irrigation and for dryland farming. Drainage projects can reclaim large salinized areas that have developed in poorly organized irrigation systems. The infrastructure must be laid for sound seed production programs. Cultural and chemical protection against weeds are essential. Marketing and storage for the preservation of the food produced can add several million tons. Economic policies designed to encourage production must be carefully manipulated. Underpinning this structure will require adequate investment in research. This input, if emphasis is placed on applied technology can provide tremendous additions to the GNP. To achieve these ends will take tremendous resources, sound planning and able execution.

As the change proceeds and becomes more complex the need for leadership and decision taking will expand. Herein lies a great danger. The

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As the change proceeds and becomes more complex the need for leadership and decision taking will expand. Herein, lies a great danger. The lesser developed countries for the most part are just emerging from a colonial period in which officers of the colonial power took decisions. Is it any wonder that there is now a shortage of decision takers? Many will criticize the delays and inaction in the developing nations. They should place themselves in the position of these newly emerged leaders. They are gaining experience. The supply and expansion of effective leadership must be maintained. Otherwise, the few leaders that are available have to expand activities beyond the ability of the human being to cope. It is essential, therefore, that unusual talent be nurtured, advanced and encouraged through decentralization of authority as rapidly as possible.

In the short term we will be obliged to depend on surplus food transported to deficit areas to avoid famine. This can be much more effective if an international granary system is developed with stores, stocked near potential disaster areas. This will mean making the necessary financial arrangements for food distribution in years of poor harvest. I do not believe that everything produced in the world should be divided equally. Some utopians espouse the principle of unlimited migrations of people from over-

populated to under populated areas. This is no solution. It can only lead to depressing the life standard of all to a less than animal existence. The problems of each country must be solved by that country. The more richly endowed countries can, however, protect the populations of the lesser endowed while solutions are made. To do otherwise would be an affront to humanity.

In the early stages of agricultural change, there is no doubt a widening in the disparity of the incomes of more and lesser advantaged groups of farmers. This tends to be transitory, but no manner of research or technology can eliminate all the disparity. Multiple cropping and increased yields can partially reduce the difference on good land and can be labor intensive. Wage rates in real terms have increased in most countries where change has occurred. In the context of labor intensification, mechanization should proceed slowly and be applied first to those activities which will enhance production and preserve product. Thus, seeders which ensure solid stands and mechanical threshers that reduce loss of grain to weather and rodents are obvious candidates for the first change. Others can wait. The rate of mechanization will not be the same for all countries. It should be governed by the ratio of rural population to land

available.

I should not like to be classed as a prophet of doom The situation on the food front is serious. The situation on the population front is infinitely more serious because it involves the general deterioration of the environment of the human race in broad terms. I am confident that given the necessary support and decisions we can meet the food needs for the near and medium term. It would be an enigma without parallel if man, the greatest of the animals and the one animal with reason should be the one who is unable to solve the single problem of his numbers. If he does not political chaos is likely to ruin him before he starves to death. I have faith that his reason will prevail in the end and instead of our ever-expanding market concept we will be able to redivert our energies to making the world a better place in which to live.

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