REGIONAL WHEAT WPRKSHOP

Eastern, Central and Southern Africa, and Indian Ocean

Njoro, Kenya.
September 2-5, 1985

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CIMMYT
P.O. Box 25171
Nairobi, Kenya.

NPBS
P.O. Njoro,
Kenya.

CENTRO INTERNACIONAL DE MEJORAMIENTO DE MAIZ Y TRIGO

INTERNATIONAL MAIZE AND WHEAT IMPROVEMENT CENTER

P.O. Box 25171
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P R E S E N T A T I O N

I am pleased to present these Proceedings to the attention of those interested in learning about food production problems and progress in Africa. These Proceedings reflect the working spirit of the peoples of Eastern, Central and Southern Africa and the Indian Ocean countries. Hundreds of workers had to go into the mud for thousands of days to amass the information contained herein. Even before that, imaginative and well documented projects had to be prepared, corrected, discussed, approved, funded, and implemented at different levels of the research organizations in each country. Then, their execution could take place, under the supervision of skilled national scientists seldom too abundant. This systematic approach, it must be emphasized, has taken place even under the omnipresent threat of acute food crisis and the no less common stress of chronic dietary deficits for much of the population.

I can witness to the dedication of these scientists, working under precarious conditions, with limited facilities, often with insufficient moral and economic rewards. Still, they have opened sound tracks to generate technology for wheat production and utilization suited to their countries' possibilities. CIMMYT is proud to be a partner to these courageous workers. Their job is far from finished, however, and the challenge is still here. May these Proceedings be a useful medium to help others in understanding and solving some of the constraints (spoken as well as unspoken) to increased wheat production.

These Proceedings are dedicated to all those wheat scientists whose efforts made the Workshop such a resounding success: its dignitaries and officers, its participants and those whose presence was prevented by higher duties at their home countries.

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C O N T E N T S

Foreword

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It is well recognised that the rate of development in agriculture, is greatly influenced, among other factors, by the quality of national institutions responsible for research and development programmes. The availability of well trained technical staff, and its utilisation in appropriately planned multidisciplinary activities enhances productivity and stimulates investments in agriculture. In the East African region comprising Burundi, Ethiopia, Kenya, Lesotho, Madagascar, Malawi, Rwanda, Swaziland, Tanzania, Zambia and Zimbabwe, it is deemed essential to facilitate internal and external scientific communications as a means to developing scientifically sound practical programmes focused at solving farming constraints and at introducing innovations.

CIMMYT realises this need and has sponsored a one-week long workshop, as one of its many endeavours to contribute to improved human welfare. The Workshop brought together scientists from within the region and distinguished resource personnel from outside as well. The main objective was to share the technical information accrued from their national and international experience and research.

Wheat Workshops have evolved in this region from narrow-based, single-discipline orientation, with a trend towards a broader base, covering topics of general interest regionally and internationally. This 1985 Workshop was markedly ambitious in its scope: the subjects discussed included developing varieties for different areas, purposes, and circumstances; innovative uses of wheat in blend with other flours; wheat production under small scale technology, on acid soils and under the constraint of the so called minor diseases which hitherto were given the lowest priority and yet continue to cause silent cumulative crop losses and quality degradation.

The proceedings herein included contain the full text of all papers presented and a balanced summary of the discussions. As such, they should be of substantial interest to researchers, extension agents, donor agencies, and other international research institutions. It is the onus of individual government, and particularly their agencies specialised in developing infrastructures, or providing services and financial assistance to the agricultural sector, to take cognisance of the facts and recommendations herein presented, and thus help farmers in their respective areas of influence to expand or improve the wheat enterprises.

Opening address

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Introductory Remarks

I am very pleased to have the opportunity of addressing this distinguished group of wheat researchers and administrators. The importance of such a forum for the exchange of ideas and information cannot be overstated. Rarely, does there gather a group of individuals, such as those represneted here today, who can have so strong an impact on agricultural research and development, and hence, on the quality of life enjoyed by literally millions of people in Eastern and Southern Africa.

My task here today is to set the tone of the discussions to follow. In so doing, I will not dwell upon the major themes to be addressed during the workshop; rather, my primary aim will be to describe in general terms the issues and challenges before us. I also wish to stress the need for the continued spirit of cooperation that transcends national borders and ideolgies. The food production problems of the region are critical, and these problems are clearly transnational in character.

Let me begin by providing a brief overview of CIMMYT's responsibilities in Africa. I will then discuss in broad terms the food production situation in Africa generally, and then more specifically the food situation in the Eastern and Southern Africa region. Following that, I will turn to wheat and triticale production in the region describing CIMMYT's activities to date, and our plans for the future. Finally, will try and share with you a brief overview of the constraints to increasing wheat production in the region constraints that should provide the focus for research and funding in the future.

CIMMYT Responsibilities in Africa

CIMMYT has global responsibilities for the development of improved bread wheat, durum wheat, and triticale germplasm. This mandate includes the Sub-Saharan region of the African continent, and the countries represented by the participants in this conference. The principal goal of CIMMYT in Eastern and Southern Africa is to assist national programs in developing their capabilities to increase the productivity of resources devoted to the production of bread wheat, durum wheat and triticale.

The Food Production Situation in Africa

Throughout the 1960s and 1970s, the average growth rate of agricultural output by all developing countries combined was just under 3% per year -- an impressive figure. However, the populations of these countries also grew at an unprecedented rate, however, resulting in a much less impressive 0.3% per year increase in per capita agricultural output.

The situation was worse in Africa, where the annual growth rate of agricultural output declined from 2.7% in the 1960s to 1.3% in the 1970s; and the rate of population growth accelerated. These trends combined to depress per capita agricultural output to 0.2% per year during the 1960s, and a negative 1.4% per year throughout the 1970s. Part of this decline was due to a slowdown in the production of nonfood agricultural items (tropical beverages and fibers), but growth in food output per capita was also transformed from a slight increase in the 1960s to a decline of 1.1 percent per year in the 1970s.

The Eastern and Southern Africa Region

Some 170 million people live in the countries of Eastern and Southern Africa, and these countries are among the poorest on the African continent: regional per capita GNP is less than US$350 per year, 45 percent of which comes from the agricultural sector. Despite a very high urban growth rate, over 80 percent of the labor force is still employed in subsistence-type, labor-intensive agriculture. Cultivated cropland in the region is scarce, comprising only about 6 percent (36 million hectares) of the total land area which is over 600 million ha. Thus, the region depends heavily upon an agricultural sector that employs largely "traditional" farming practices on a rather limited land base.

Since 1969-71, only three countries in the region have had positive growth rates in per capita food production, and these can be considered modest increases. Declining per capita food production exacts a high price in both human and economic terms. The human cost is malnutrition and hunger. In most Sub-Saharan countries, per capita calorie intake falls below minimal nutritional standards during certain periods even in "normal" years. Even if total available food supplies were distributed equally and efficiently at such times of relative plenty, there would still not be enough food to provide everyone with an adequate diet. When the weather or other constraints intervene, this precarious balance is upset and major food crises can, and have, resulted.

The economic price of declining per capita food production is a rising import bill. The traditional response of Sub-Saharan countries (including those of Eastern and Southern Africa) to lagging domestic production has been to increase food imports, primarily in the form of wheat (both grain and flour). During the 1960s, cereal imports to the region posed little financial hardship. While the volume of imports doubled, the cost rose by only 50 percent. Low and stable prices, combined with concessional sales, made imports a cheap and relatively secure way of meeting rapidly growing consumption needs in urban areas. However in the 1970s, the situation changed dramatically. The cost of cereal imports to the region doubled, and many countries experienced growing balance of payments problems; a situation that has persisted into the 1980s, and has been worsened by higher prices for oil and manufactured imports and lower prices for export commodities.

Origins of the Region's Food Production Problems

Much of Eastern and Southern Africa's slow progress in food production can be explained firstly by the level of agricultural technology applied by farmers, and secondly by the natural environment. Although land tenure patterns vary, most of the region's food is produced by subsistence farmers cultivating relatively small holdings and using few commercial inputs. For example, fertilizer use is lower than in either Asia or Latin America, and much of what is used is applied to export crops. Water control systems are not prevalent, with only five percent of the region's cultivated cropland currently under irrigation (the vast majority of which is located in Sudan). Mechanization is also at a low level and basic foodstuffs are produced largely by human labor using simple hand tools. The use of draft animals in many parts of East Africa is limited by endemic diseases, as well as by cultural and economic conditions.

However, there are transport problems that make marketing difficult, subsistence cultivators in the region have shown that they are sensitive to changes in the marketplace and are capable of producing food for sale. Yet, simply raising producer prices of key food grains is not enough to spur production. Better distribution and adoption by farmers of improved, high-yielding crop varieties is required, plus appropriate agronomic practices that will permit a more efficient utilization of scarce labor during peak production periods. Money to finance innovation at the farm level must also be available, otherwise, relative price differences will simply redirect resources from one crop to another without increasing agricultural output as a whole.

Similarly, the natural environment of the more tropical countries of East Africa seriously constrains immediate increases in domestic food production. Tropical soils tend to be fragile, losing organic matter, water and nutrients when exposed directly to the elements. Traditional cultivation practices, such as intercropping and broadcast sowing, are sound agronomic adaptations to this characteristic of the natural environment. The more complex rotation and fallow systems also help in this regard. If food production in East Africa is to undergo sustainable long-term increases, it is necessary to move to a more intensive system of cultivating key foodgrains than is currently employed. This implies a more widespread use of higher yielding crop technologies, and a transition from traditional to "improved" farming practices.

The basis for such a transition in Eastern Africa is already emerging. Maize is the single most important source of calories for the people of this region, and improved varieties of maize are now available that hold considerable promise for increasing yields and total production. But wheat is also a significant component of local diets, particularly in urban areas where rapid increases in its consumption have been made possible by imports; the total utilization of wheat in the region, (and I define utilization as domestic production plus net imports) has risen at roughly seven percent per year since the early 1970s; the second highest rate of increase in the world. The Eastern and Southern Africa region has slightly more than one million hectares of land devoted to wheat, with an average yield of about 1.3 tons/ha. Over the last two decades, wheat production in the region has grown at about 2.8% annually, most of which is due to improvements in yields. New wheat cultivars, released by national programs and readily adopted by farmers, are largely responsible for these yield increases.

Achieving sustainable production breakthroughs will, however, require more than the mere availability of improved, high-yielding crop varieties. These improved varieties must be integrated into sets of appropriate technological recommendations that have been verified as being "economic," and that are well-adapted to the circumstances of farmers in the region.

An understanding of traditional planting strategies, their perceived benefits and the labor patterns they entail is a necessary precondition to the development of appropriate and innovative recommendations for farmers. Production agronomy studies and on-farm research in the context of the entire farming system is an important step in this direction. In fact, more intensive production agronomy work and localized on-farm research may prove to be the most productive research option now available for the kind of agroclimatic diversity that prevails in East Africa.

CIMMYT's Activities in Eastern and Southern Africa

CIMMYT has a well-established regional program in Eastern and Southern Africa, currently headquartered in Nairobi Kenya. This on-going regional effort began in 1975, with the posting of a senior agricultural economist to engage in on-farm research. The economist's role has been to work with national agricultural research programs in on-farm research first of all to improve procedures for assessing farmers circumstances, secondly to demonstrate the utility of on-farm research to administrators and biological scientists, and thirdly train others in on-farm research procedures and encourage their widespread use in the region. To date our activities have concentrated on the economic dimensions of on-farm research, with the agronomic aspects of the research being contributed by national programs, by Mexico-based CIMMYT agronomists, and by various development assistance agencies in the region.

The CIMMYT program in the region expanded in 1976 with the posting of a senior wheat breeder/pathologist to carry out germplasm testing and crop improvement activities with national programs in the region. Then, in 1982 two agricultural economists (funded by a USAID special project), strengthened the on-farm research team. In late 1982, the program was expanded still further with the addition to the region of a senior maize breeder.

The emphasis of CIMMYT's wheat activities in East Africa has so far been placed on

1) providing, through our international testing network, high-yielding, widely adapted, and disease-resistant germplasm suitable to the predominant agroclimatic zones,
2) conducting on-farm research and training national program staff how to implement such activities, and
3) consulting with national crop improvement programs in their wheat and maize research endeavors.

National programs in a number of countries in Eastern and Southern Africa have developed and released a number of improved maize, wheat and triticale varieties. These new cultivars have already had a significant impact on the production of these crops in the region, and I believe, have the potential to increase production still further as appropriate agronomic practices are developed and adopted.

Impact of high-yielding wheat varieties (HYVs) in the region--As noted earlier, most of the increase in wheat production in Eastern and Southern Africa has been due to the release and adoption of HYVs. This is primarily due to improved resistance to stem rust and other diseases that can seriously constrain production on otherwise productive lands. These HYVs are also more responsive to improved agronomic practices than are the traditional varieties still grown in a number of locations.

In Ethiopia, for example, (which grows just over ½ million hectares of bread and durum wheats under rainfed conditions), about half of the wheat area has been devoted to such HYVs as Cocorit 71 and Boohai durums. In 1984/85, the Ethiopian national program released three new HYVs: Bob White 5, Sunbird 4, and Veery 17. It is estimated that approximately 90% of Kenya's 100,000 hectares of wheatland is under HYVs, mainly derivatives of Kenyan improved varieties crossed to Tobari 66 and Sonora 64. In the Sudan, some quarter million hectares of bread wheat are grown, 90% of which are given over to HYVs like Mexicani and Giza 155. Tanzania, which has about 55,000 hectares in bread wheat, grows HYVs on roughly 90% of that area. Many Kenyan varieties are grown in Tanzania, most notably derivatives of Tobari 66 and Sonora 64. And finally, 100% of Zimbabwe's 40,000 hectares of bread wheat are devoted to HYVs like Angwra and Gwebi. Clearly, the use of high-yielding wheat varieties has become widespread in traditional wheat-producing regions and the credit for this must go to you, the breeders in the national programs of East and Southern Africa.

CIMMYT's role in this shift to HYVs in Eastern and Southern Africa (and indeed, throughout the wheat-producing areas of all Africa) has been largely in the area of providing genetic diversity to national programs via our international bread wheat, durum wheat, and triticale nurseries. For example, in 1984 CIMMYT distributed 247 bread wheat nurseries, 90 durum wheat nurseries, and 58 triticale nurseries to as many as 27 African countries. International nurseries give national programs access to the best germplasm available in the international network; materials that have undergone testing at literally hundreds of locations worldwide. In addition, CIMMYT regional staff assist national programs with the exchange of locally improved germplasm through regional nurseries.

CIMMYT benefits greatly from its involvement with national programs in Eastern and Southern Africa. Relations with Kenya, for example, go back a very long way. In 1947, when Mexico was confronted with a severe outbreak of stem rust, N.E. Borlaug urged the immediate release of an adapted Kenyan bread wheat line and quickly moved the better Kenyan wheats into his crossing program. Since then, Kenya has served as an excellent bread wheat stem rust "hot spot" screening location for international network materials.

In Ethiopia, the enormous variability in tetraploid wheats has given rise to virulent races of stem rust on durums. In the last few years, breeding research at Debre Zeit has resulted in significant advances toward genetic resistance to stem rust in durums. Boohai durum wheat, for example, combines many useful traits from Ethiopian, Mexican, and Argentinian durums.

Yield testing of international wheat and triticale nurseries in the region has been going on for more than 20 years and, in addition to very useful yield data for highland areas, the recording of disease reactions has proven very helpful to breeders at CIMMYT and around the world. In particular, the Njoro station has provided many consecutive years of invaluable data for the evaluation and crossing of experimental materials.

Future CIMMYT Activities in the Region

As noted earlier, achieving the biological potential of these new wheat varieties requires that farmers not only adopt the improved germplasm, but that they also use appropriate agronomic practices. Moreover, studies in the region and elsewhere have clearly indicated the limited success of agricultural technologies developed solely on experiment stations, without the benefit of testing and modification under farmers' circumstances. The reason for this limited success rate is deceptively simple: if the recommended technologies do not "fit" the prevailing production circumstances and constraints, as perceived by farmers, then these farmers will not be inclined to adopt such technologies; technologies developed in the "vacuum" of the experiment station are all too frequently inappropriate for the "real-world" circumstances confronting farmers.

Thus, CIMMYT advocates intensive agronomic work and on-farm testing with verification of technological alternatives or "packages" of recommendations. As indicated earlier, a vital component of these recommendations are the agronomic practices appropriate to farmers' circumstances. Various combinations of practices and cultivars must be tested in farmers' fields before appropriate recommendations can be made with confidence, and the research conducted on experiment stations should reflect the results of this verification process.

Furthermore, a cadre of trained national program agronomists is needed in the countries of the region to facilitate the development and adoption of appropriate high potential technologies. CIMMYT has long acknowledged the need for training national program personnel. To date, 42 national program scientists from the countries of Eastern and Southern Africa have passed through the wheat in-service training programs in Mexico. In addition, from 1982 to 1984 the CIMMYT Economics Program (in conjunction with the Wheat and Maize Programs) conducted in-country training in on-farm research that reached an estimated 400 individuals in the region of Eastern and Southern Africa. Even so, the Center's total training capacity has not been able to meet the demand. While CIMMYT's current headquarters-based in-service training programs are generally considered effective for developing country personnel, we are currently "at capacity" in Mexico. Our experience (and that of other institutions), with in-country training leads us to believe that this approach offers some significant advantages as a supplement to our Mexico-based training efforts.

The principal benefits of in-country training are fourfold:

1. Since most agronomic problems are highly location-specific, they are therefore better studied _in situ_ within the context of local farming systems;

2. In-country training can be arranged so as to occupy shorter periods of time, thus allowing more people to fit the training to their schedules;

3. In-country training provides an exposure to, and interface between, trainers, trainees, and decision makers in national programs, which should in turn, result in increased opportunities for training to be institutionalized, and thereby maximize chances for long-term success;

4. In-country training is an effective method for achieving the desired multiplier effect.

Given the prevailing agroeconomic situation in East Africa, the need for agronomy, on-farm testing and verification of agronomic practices, as well as the need for trained agronomists throughout the region, CIMMYT has obtained special project funding from CIDA, Canada, to support the addition of three senior agronomists to our East African regional program. Specifically, we have added a small grains (wheat and triticale) agronomist, a maize agronomist, and a maize agronomist/trainer to the regional team. In addition, a maize agronomist and an agricultural economist are to be posted to Southern Africa through the extension of a USAID special project. These additional staff members are responsible for conducting on-farm and on-station agronomy trials, in close cooperation with national program scientists and regional economists. The trials will be designed to derive, test and verify packages of production recommendations appropriate to farmers' circumstances. Heavy emphasis will also be given to human resource development through in-country training programs.

Constraints to Future Productivity

Let me close my presentation by briefly sharing with you my thoughts on the research challenges that lie before us. They can be classified into four broad areas: human resource development, agronomy, germplasm development, and market policies.

Human resource development--Experience in Eastern and Southern Africa, as well as in other regions, clearly indicates the fundamental importance of human resource development in establishing and maintaining effective national research programs. The need for well-trained scientific staff will increase over time, both because of turnover in national program staff, as trained individuals are advanced, and because of the need to increase the number of research staff who will have to deal with expanding research agendas. I believe that even with an expansion of in-country training efforts by CIMMYT and other institutions, the demand for trained individuals will continue to outstrip the available capability.

Agronomic problems--As noted earlier, many agronomic problems are site-specific in nature, requiring research *in situ* for their resolution. Such general problems as land preparation, stand establishment, plant nutrition, water conservation, weed control, and harvesting methods are deserving of more research resources. Again, the emphasis of this research must be on developing technologies appropriate to the circumstances faced by farmers, particularly resource-poor farmers. Efforts should be made to identify opportunities for enhancing the productivity of small holders, and this carries with it implications for the allocation of research resources.

Germplasm development--There is much that can be and is being done to enhance the yield potential of wheat (and triticale) in East Africa. Research underway by CIMMYT in close cooperation with several national programs in the region and elsewhere, is focusing on the development of adapted germplasm having the traits needed to perform well in selected environments. Such characteristics as improved tolerance to drought and to acid soils, greater resistance to leaf diseases (especially those caused by *Puccinia*, *Septoria*, and *Helminthosporium* spp.), and improved resistance to preharvest sprouting will help increase the production potential of new varieties in selected areas.

Market-oriented difficulties--Agricultural research scientists have, and can do, much to enhance the productivity of the resources used to produce wheat and triticale, but less has been done to enhance utilization. Research at CIMMYT, Mexico, shows that blends of up to 50% triticale flour and 50% wheat flour results in very acceptable leavened bread products. Given the superior production potential of triticale under many East African conditions, as well as the grain's higher protein content, these results should bode well for East African consumers. Yet, the market potential of triticale remains largely unexploited. This is but one example of how policy decisions can impinge on advances in agricultural technology.

Concluding Remarks

In conclusion, I would say that the movement to HYVs has already made an impressive contribution to increasing the productivity of resources devoted to bread and durum wheats in Africa - thanks to the wheat breeders in the national program in Eastern and Southern Africa. However, I believe that improved germplasm is only a part, albeit an important part, of the production challenge before us. I think that the emphasis CIMMYT is now giving to the agronomic aspects of the production puzzle, which represent the key constraints to increasing production, will show significant results in the not-to-distant future. I would especially emphasize the need to carefully evaluate the potential of triticale in Eastern and Southern Africa. An impressive range of triticale germplasm is currently available that holds tremendous potential for the region's more marginal areas, especially those highland areas with acid soils and disease problems that limit the production potential of wheat. Millions of resource-poor farmers in the region could benefit from commercialization of this crop, but for this to happen governments must be willing to adopt market policies that will encourage not only the production of triticale, but also its utilization.

And finally, let me stress once again the need for us to work together in confronting Africa's food production challenges. CIMMYT will do the utmost it can, to assist national programs in Eastern and Southern Africa, but the ultimate responsibility lies with national program scientists. Experience has shown that progress in plant breeding and agronomy occurs much faster when information is freely shared; for only in this way can each of us profit from the mistakes and successes of others. CIMMYT is confident that you, our colleagues and collaborators from the national programs, will rise to this very important challenge.

Synopsis of Session 1

Country reports

Chairperson: E. RUBAIHAYO, Kwanda Research Station, P. O. Box 7065, Kampala, Uganda

Rapporteur: J. IVARA, National Plant Breeding Station, P. O. Njoro, Kenya

1 From the papers presented, it is clear that the various Governments in the region are concerned about wheat and wheat production; it is also evident that efforts are being made to increase production of wheat and other small grain cereals.

2 All reports point to insufficient production relative to requirements. A number of constraints are indicated:

i high disease incidence, and development of new races of pathogens capable of overcoming the resistance available in commercial varieties;

ii general dependence on rainfall, which is often erratic and therefore inadequate;

iii insufficient supply of high yielding, disease resistant varieties;

iv existence of problem soils (mostly with low pH);

v pest outbreaks, particularly insects and birds (notably *Quelea quelea*);

vi shortage of fertilizer, or lack of information re its most effective utilization;

vii lack of a systematic body of agronomic technology.

Superimposed over the above constraints, food and economic policies set further limitations to cereal production. These include:

a Wheat pricing: most countries reported that price of wheat is very low, and therefore farmers are not given adequate incentive to expand their wheat enterprises.

b Dependence on international bodies for germplasm:

Admitting that CIMMYT is playing a very important role in providing wheat germplasm for evaluation, faster results could be achieved if varieties already adapted in some countries were made available to others in the region. The limited cooperation among researchers is a hindrance to progress.

c Use of triticale: this can be an advantageous cereal in specific countries or areas of the region. The production of this crop is limited due to lack of pricing and utilization regulations.

Smallholder wheat production and research in Malawi

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SUMMARY

Wheat is successfully grown in high altitude areas ($>$1, 500 m a.s.l.) during the cool season (March to August). Total production is small ($<$ 1000 metric tonnes per year) due to lack of high yielding adapted cultivars, poor agronomic practices, diseases, insect pests, rodents, birds and climatic conditions. Consumption has increased rapidly over the last decade and it is estimated that over 26,000 metric tonnes will be imported in 1986 at a cost of approximately MK 6,000,000. Because of the difficulties in procuring wheat the Malawi Government has decided to expand wheat production. As an incentive to increase wheat production, the price of wheat paid to smallholder farmers has been increased from 11 to 30 tambala per kilogram. To be self sufficient in wheat it has also been proposed to establish about 10,000 ha. This can be achieved if large scale wheat production under irrigated conditions can be encouraged.

INTRODUCTION

Wheat production was probably introduced in Malawi by the early missionaries at the turn of this century, but its cultivation has been limited to the highland areas ($>$ 1,500 m a.s.l.) where it is grown as a rainfed crop during the cool season, March to August, that gradually merges into a hot dry harvesting period, September to October. The majority of the farmers keep their own seed which is mixed and of low quality. The flour is considered to be inferior for bread making. As a consequence, production has been low and static. Wheat fields in these areas vary from 0.25 ha to 2.5 ha in size with a mean of 0.5 ha. Mean yields are low averaging about 700 kg ha^{-1}.

There are about 1000 ha of land grown to wheat at present, but a survey conducted in the Tsangano area in 1977 revealed that 20,000 ha could be developed for rainfed wheat production. The soils in these traditional wheat growing areas are highly weathered and acidic (pH 5.5) in nature. Annual rainfall varies between 1500 - 2000 mm according to the altitude and falls between November and April. During the cool season light showers (Chiperoni) are frequent.

The demand for wheat and wheat products is increasing steadily due to increasing income, urbanization and changes in eating habits. Local production is small (about 1000 metric tonnes/year) and it is estimated that over 26,000 metric tonnes of wheat will be imported at a cost of MK 6,000,000 in 1986 (1). Considering the costs and difficulties associated with wheat importation and the fact that Malawi can grow most of the wheat grain that is imported, the Malawi Government has decided to attach greater importance to wheat production. The aim is to be self-sufficient in wheat, in order to save foreign reserves. This objective can be achieved by expanding wheat production both as a rainfed crop on smallholder farms and as an irrigated crop on estates (large scale farms). The target is to establish about 10,000 ~~100,000~~ hactares of wheat.

FACTORS LIMITING WHEAT PRODUCTION

Some of the factors which limit wheat production in Malawi are

a) inadequate soil-water during the reproductive growth period,

b) lack of adapted cultivars for specific areas,

c) late planting,

d) poor stands per unit area,

e) low fertilizer application,

f) poor harvesting methods,

g) diseases, and

h) insect pests.

Diseases do not develop into epidemics since wheat is grown under low humidity condition at the end of the main rains. However, these diseases might become important if wheat is sown during the main rains. Bird scaring (by children) is an important aspect of wheat cultivation especially from July to October.

RESEARCH OBJECTIVE

There is one main wheat research centre, Tsangano Hill Station. However, some trials are carried out at Bembeke, Chitedze and Bvumbwe Research Stations. Several smaller trials are conducted on farmers fields. The main objective has been to increase wheat production in Malawi by

a) selecting high yielding cultivars that are ecologically suited to Malawi conditions, possessing a high level of resistance to major wheat diseases, and which have grain of suitable quality for bread making. Resistance to lodging and other diseases are also important aspects,

b) determining fertilizer requirements under both irrigated and rainfed conditions,

c) determining the best time of planting,

d) developing new production technology, and

e) introducing wheat as a rotation crop in Tobacco Estates.

WHEAT IMPROVEMENT AND ACHIEVEMENTS

Screening Nurseries

Wheat hybridisation is not undertaken at the moment. Instead our efforts are concentrated on introductions and yield nurseries received from Mexico, Kenya, Zimbabwe, Zambia, Tanzania and other areas in Southern Africa. Over the years it has been observed that materials from Kenya, Mexico and Southern Africa show good adaption in our main wheat growing areas, while materials from other areas tend to be more susceptible to leaf rust (2).

National Wheat Cultivar Trials:

A large number of promising wheat cultivars from Mexico, Kenya, Tanzania and other countries in Southern Africa have been tested in Malawi to assess their performance under both rainfed and irrigated conditions. Results from these trials have revealed that

a) Triticales are superior to bread wheat in grain yields and disease resistance,

b) both Triticale and wheat yields vary from year to year depending on rainfall distribution during the growth period,

c) in good years Triticale and wheat yields achieved under rainfed conditions in the Tsangano area are higher than those recorded under irrigated conditions in low altitude areas,

d) wheat can be successfully grown in paddy fields as an alternate crop to rice during the cool season, however, yields achieved have been low (< 2500 kg ha^{-1}) due to poor water management,

e) under Malawi conditions leaf rust and Helminthsporium are the most important wheat diseases, and

f) there are a few cultivars which show promise under Malawi growing conditions (Table 1).

Table 1: National wheat cultivar trials conducted in 1984 (Yield in kg ha^{-1})

Cultivar	Mwanza	Mpompha	Bembeke	Tsangano	Mphachi	Bvumbwe	Nthungwa
ZA	5139⁞	2133⁞	3299	2094⁞	1406	2372	2900
Tesia	4678	867	3711	1544	1311	2111	3144
PF70354	4542	1767	3989⁞	1533	1650	2705⁞	2884
Chova"s"	4458	1356	3389	1511	1294	2650	2133
IAS 54	4417	1728	3711	1465	1444	2700	2878
T4 (R)	4403	1283	3344	1322	1950	2550	3489
Elrina	4389	967	2778	1211	1311	1244	2033
69/12 AL	4333	1555	2883	1356	1422	2000	3367
Veery S-17	4028	1400	2778	--	2800⁞	2122	4272⁞
Ciano 79	4028	1394	3445	1811	--	2483	3745
Bobwhite	3945	1722	3322	1789	1311	2133	2994
Kenya Nyati	3819	1611	3567	1678	1233	2177	3172
Kuz-K4500	3625	1217	3289	1355	1450	2272	2828
SST33	3667	1550	3455	1256	1317	1772	2916
Jachuara 77	3111	1711	3267	1511	1639	1817	1722
B 7408	3028	1833	3044	1674	1244	2467	2633
TCL 65	--	--	--	1700	--	--	--
Mean	4100	1506	3329	1551	1526	2224	2944
S.E.	±364	±339	±375	±170	±289	±159	±400
C.V. %	15	39	20	19	33	12	24
Significant	*	NS	NS	NS	NS	**	*

ZA = ZA 75-PRN '5' cm 36681
* and ** = Significant at 5% and 1%, respectively
⁞ = Promising cultivars

SOME PROBLEMS IN INCREASING WHEAT PRODUCTION

Small Scale Wheat Production

Small scale production of wheat has taken place for many years and the system must be regarded as economically viable, otherwise, the farmers would go out of production. No cash inputs are involved so that the only risk a farmer takes is poor returns to his efforts.

The recommended time of planting wheat in Tsangano and Nsambi, mid-March to mid-April, falls when the maize crop is still in the field. Wheat is grown as a relay crop after maize has reached physiological maturity. This results in late planting of wheat by most farmers. Yields obtained by smallholder farmers range between 500-700 kg ha^{-1} (3). Farmers also grow vegetables and European potatoes in Dimbas which compete for labour.

There is no land shortage for increasing wheat production, but the capacity of local farmers to increase output is likely to be a limiting factor. The injection of capital to increase the scale of operations would need careful assessment in view of climatic conditions. As an incentive to produce more wheat the price of wheat for smallholder farmers has been increased from 11 to 30 tambala per kilogram.

Large Scale Wheat Production Under Irrigation

It seems likely that, if any large proportion of Malawi's wheat requirements are to be produced locally, this would have to be undertaken on large irrigation schemes, probably on a large scale mechanised basis. This would also require the use of very high yielding cultivars ($>$ 4000 kg ha^{-1}) to cover the irrigation expenses. Although gravity fed irrigation schemes could be cheaper than pumped irrigation schemes, an assessment of the economic viability of wheat as an irrigated crop can only be made in accordance with conditions of each individual farmer. The high experimental yields of some 4000 kg ha^{-1} achieved under irrigation at Nthungwa and Estate 68 in Mchinji indicate a high potential for growing wheat under irrigation in Malawi.

REFERENCES

1. Malewezi, J. 1985. Person Communication.
2. Annon, 1977. Annual reports of the Department of Agricultural Research, Malawi.
3. Lungu, N.F. Country Report: Cereals research in Malawi. _In_ Manda, D.R.B. (ed). Proceedings of the fifth Eastern African Cereals research conference held in Malawi, March 10-15, 1974.

Progress on research for rainfed wheat production in Tanzania

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1.0 INTRODUCTION:

In Tanzania all the wheat is produced under rainfed conditions. It is grown in the northern and the southern highlands of the country as a result of elevation rather than latitude. Whereas the potential wheat land in southern Tanzania has reliable rainfall of over 1000mm of rain distributed, December to May, the Northern highlands which are currently producting over 90% of all the marketed wheat has marginal and erratic rainfall of (500mm - 750mm) at an elevation range of 1300m - 2000m above sea level.

However these highlands have long and undulating slopes which lend themselves for large scale mechanized wheat production. (Presant 1974).

Wheat research in Tanzania has therefore focused on the factors limiting production under these two different environments. The wheat research program at Tanzania Agricultural Research Organization (TARO) Research Centre at Arusha is responsible for the research geared for rainfed dryland farming, while the Uyole Agricultural Centre at Mbeya is responsible for the research and production studies on crops including wheat for the southern highlands.

2.0 WHEAT RESEARCH GOALS AND OBJECTIVES:

The general goal and objective of the wheat research program under T.A.R.O. is to raise wheat production through the application of appropriate scientific and technical knowledge, to local conditions especially modern knowledge married effectively with accumulated environmental experiences of the local farmers. (Tanzania Agricultural Policy 1983).

The specific objectives of the wheat research program have remained basically the same during the 1983 - 1985 reporting period. That is, (1) to identify, select and evaluate suitable bread wheat, durum wheat, triticales and malting barley varieties for use under the specific ecological zones of the Tanzania highland regions; (2) to identify suitable management practices through problem solving oriented research projects to ensure continued and increased production in the present and potential wheat and related crops growing zones of the country; (3) to evaluate the soil management and soil fertility requirements for wheat in those areas as well as monitoring of their fertility status for sustained production; (4) to evaluate suitability of current farm implements for mechanized wheat and allied crops production in rotation or in alternate farming systems, while maintaining economic returns and protecting soil structure against physical deterioration and erosion; (5) to monitor cost benefit analyses of mechanized wheat production to ensure economic viability and level of mechanized farming under Tanzania conditions.

3.0 HIGHLIGHTS OF WHEAT RESEARCH PROGRAM (1983-1985):

In Tanzania the wheat research program is still in its developmental stage at both research stations at Arusha and at Mbeya. The program relies on other regional and international centres for coordinated wheat research improvements programs. Namely, the International Maize,ans Wheat Centre (CIMMYT) Mexico, the International Centre for Agricultural Research in the Dry Areas (ICARDA) in Syria. The Regional (CIMMYT) centre in Kenya and the National Plant Breeding Station at Njoro Kenya from whom the wheat research program continues to enjoy a steadly flow of early general materials for evaluation, and selection under the different wheat growing ecological zones in Tanzania.

4.0 RESEARCH ACHIEVEMENTS AND TECHNICAL PACKAGE RECOMMENDATIONS TO FARMERS IN TANZANIA.

During the 1983-1985 progress has been made in various research disciplines of the wheat program. In the Cereal Variety Improvement, a bread wheat variety, Tanzania Viri (W9075), a medium early maturity (124 days) under Basotu conditions (1900m elevation, Lat 4^{o} 30'S, & Long.35^{o}05'E and 35^{o} 12'E in Hanang district:) ; white glumes, white, good straw strength, good resistance to endemic diseases of stem rust *Puccinia graminis tritici*; leaf rust, *Puccinia recondita*, stripe rust *Puccinia triformis*, leaf bloch, *Septoria spp.*, Mid large white kernel seeds. High grain yield potential of 8% -10% more than best commercial variety T.Mbuni (W 26-73).

In Durum wheat, a new variety was released by wheat research program at TARO Selian Research Centre Arusha namely Tanzania Duma (D9364). A late (130 days) maturity under Basotu conditions; light purple colour in straw and glumes, fair resistance to epidemic leave diseases and large amber seeds.

A new Triticale variety Tanzania Tembo (T6026) was also released for commercial production under contract for pasta products. Characteristics - medium to early maturity (124 days) under Basotu conditions - white glumes, white straw, good straw strength medium tall (104 cm.) good resistance to epidemic diseases, mid-large, medium red seeds (but with the shrivelling characteristics of Triticales), high grain yield potential 20% higher than T.Mbuni.

During the same period two bread varieties Tanzania Mamba (W3676) and Tanzania Trophy (W3503) were efficially deleted from the list of recommended varieties for commercial production because of their consistently mediocre grain yields and their susceptability to the common rusts including stripe rust in the case of Trophy, and susceptability to 2-4-D and MCPA spraying and enhanced lodging for variety T.Mamba.

4.2 PROGRESS IN WHEAT AGRONOMIC RESEARCH:

Progress has been made in grass weed chemical control and the following herbicides are now recommended for commercial wheat production in Tanzania for the control of grass weeds in wheat particulary lovegrass (*Setaria verticillata*) and *Eragrostis spp*. These are (i) Arelon (isoproturon) applied at 1.5 kg ai/ha,(ii) Illoxan at 0.71kg ai/ha; (iii) Dosanex (Metoxuron) at 4.0 kd ai./ha.

The current herbicides for broadleaf weed control in wheat and related small grain cereals in Tanzania for post emmergence application are Fermine, 2-4-D Amine at 0.5 - 0.8 kg ai/ha and Agroxone (MCPA) applied at 0.6 - 1.0 kg ai/ha. The use of Fernasta (2-4-D Ester) has management limitation in its use. Other agronomic management research recommendations as detailed in the wheat bulletin-Wheat production in Tanzania (1977)-are still in current use in Tanzania.

Experience has shown that the recommended post-harvest tillage operations in wheat for weed control has led to increased soil erosion on the onset of the season rains. Studies have now demonstrated that in areas where there are no after-harvest weed growth tillage operations may be delayed until the onset of the rains.

The costs of fuel and farm machinery have recently become real economic factors in machanized production and hence the recommendation for reduced tillage in wheat production in Tanzania.

5.0 WHEAT PRODUCTION TREND IN 1983-1985:

In Tanzania the greatest beneficiary of the impact of wheat research achievements and package recommendations has been the large scale mechanized corporation farms under the National Agricultural Food Corporation (NAFCO), who produces about 90% of the marketed wheat in the country.

Wheat grain yield averages have risen steadly from 1975/76 at these NAFCO farms from 0.5t/ha to triple the yields to 1.6t/ha by 1981/1982. The total marketed wheat to the National Milling Corporation (NMC) from the NAFCO wheat farms was 38,000 metric tons in 1983/1984 as shown in table 1. The estimates for 1984/1985 are reckonned at 50,000 metric tons.

Table 1: Wheat grain production in 1983/84 at theNAFCO wheat farms in Hanang District in Arusha region.

Wheat Farms	Hecterage (ha)	Production (m.tons)	Average yield (m.t/ha.)
Basotu	4240	7353.3	1.73
Setchet	3540	5302.6	1.50
Mulbadaw	4200	7099.6	1.69
Murjanda	3996	7499.2	1.88
Gawal	3709	5967.6	1.61
Gidagamowd	2520	4714.1	1.87
Warret	(NEW)	NA	NA
Total	22,205	37,936.4	1.71

In the southern highlands where wheat is a staple diet only limited marketed production has been reported except from the Tanganyika Wattle Company (TANWAT CO.) farms in Njombe in Iringa region. However, district and regional production figures in the areas indicate that wheat is intercropped with other crops like beans, peas and bamboo for"Ulanzi" (a local brew).

Table 2: Estimated wheat production in Iringa region in 1983/84.

District	Hecterage(ha)	Production (m.t)	Average Yield t/ha
Iringa	1,740	1,958	1.14
*Njombe	760	855	1.14
Mafindi	350	394	1.13
** Makete	11,500	7,763	0.68
Total	14,350	10,970	1.02

* Njombe district data doesnot inclde TANWAT CO.

** Makete district has no suitable land for large/medium scale mechanized wheat/barley production.

REFERENCES:

1. Anonymous (1977) Wheat Production in Tanzania,Wheat Agronomic Research Project bulletin.
2. Anonymous (1983) The Agricultural Policy of Tanzania, Ministry of Agriculture Publication.
3. Anonymous (1984) National Wheat Development Strategy 1984-2000, Ministry of Agriculture Publication.
4. Beamish et al (1968) Feseability Study on wheat production in Tanzania, Consultancy Report.
5. Massengo,S.(1984) Problems of wheat production in Iringa Region.
6. MOSHA,A.S. (1981) Status of wheat research and production in Tanzania; Proc. of Regional Wheat Workshop March 1981 pp.15.
7. MOSHA, A.S. and MUNISI E.N. (1983) Focus on research for wheat production in Tanzania; Proc.of Regional wheat workshop June 1983.
8. Presant, E.W. (1974) Report on the soils of the Basotu farm Tanzania Wheat Agronomic Research Project Publication.
9. Raike,P.L. (1968) Peasant wheat production in four districts of Tanzania ERB Paper No.70.3
10. Raike,P.L. (1970) Historical development of wheat production in Northern Mbulu District. ERB Report.

Wheat breeding and pathology in Tanzania

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ABSTRACT:

During 1983 - 85 a total of 3011 lines of common wheat, durum wheat, barley and triticale were introduced for selection and evaluation. The lines were seeded at the research farm at Arusha, West Kilimanjaro farms and at the NAFCO wheat farms in the Hanang Wheat Complex in single row 3m plots or as replicated tests with the local cultivar Mbuni as a check variety. The lines were assessed for grain yield and resistance to rusts, tan spot, spot blotch, leaf and glume blotch, black point, scab, powdery mildew and root rot. A total of 135 lines were found to have good agronomic characteristics and were selected from the different nurseries for further testing.

INTRODUCTION:

In the last 15 years wheat acreage in Tanzania has increased to an estimated 35,511 hectares with a potential 122,150 hectares (1). Much of this acreage is situated inthe northern highlands in the Hanang Wheat Complex. The area under wheat extends from an elevation of 1950m with 1100mm annual precipitation to those of marginal rainfall with only 600mm annual precipitation providing a diversity of climatic conditions. Such a diversity of both altitude and climatic presents a special problem in wheat variety development and requires a vigorous plant breeding program to breed and identify highly adapted, high yielding and disease resistant cultivars of good quality.

The marginal production environments, characteristic of the Hanang Wheat Complex and the high disease particularly rusts, *Helminthosporium spp* and *Septoria* dictate the need to utilize material from constraint-oriented crosses such as the Helminthsporium Screening Nursery (Helm SN), the Septoria Screening Nursery (ISEPTON) and the Drought Screening Nursery (DSN) developed by CIMMYT wheat improvement programs (2).

The wheat breeding program at Arusha-Tanzania is based on selection from plant introductions from both regional and international nurseries, thus taking advantage of international efforts in crop improvement. The introductions include early generation material, observation and yield trials containing relatively advanced lines of bread wheat, durum wheat, barley and triticale.

RESULTS AND DISCUSSION:

(a) Selections from Introductions:

A total of 135 lines were selected from the different nurseries introduced as indicated in Table 1. Eighty seven lines were bread wheat lines of which 8 lines were selected from the Helminthosporium Screening Nursery, seven lines were from the Drought Screening Nursery and eight lines originated from the Septoria Screening Nursery. These lines are of special interest to the wheat industry because lines resistant to these diseases and drought are a necessity in order to sustain wheat production in the marginal environment conditions (2) such as the Hanang Wheat Complex. Twenty nine lines of durum wheat, 4 lines of barley and 15 lines of triticale were selected and kept for further testing in replicated yield trials. These results indicate that only 4% of the introduced lines were selected and 96% of the introductions were discarded on the basis of disease susceptibility or poor agronomic characteristics.

Table 1. Number of lines introduced and selected from the different nurseries between 1983 - 85.

Nursery	Origin	No. of lines introduced	No.of lines selected
Helm SN	CIMMYT-Mexico	228	8
Drought SN	CIMMYT-Mexico	126	7
ISEPTON	CIMMYT-Mexico	112	8
SNACWYT	CIMMYT-East Africa	212	21
ACWYT	CIMMYT-East Africa	15	3
IBWSN	CIMMYT-Mexico	462	20
ALUMN SN	CIMMYT-Mexico	271	14
ZAMBIA SN	ZAMBIA	39	3
RDTN	ICARDA-Syria	200	3
IDYN	CIMMYT-Mexico	30	6
IDSN	CIMMYT-Mexico	612	15
IDTN	CIMMYT-Mexico	200	8
IBYT	CIMMYT-Mexico	25	4
ITSN	CIMMYT-Mexico	479	15
	Total	3011	135

(b) Variety Evaluation:

The performance of the commercial varieties and lines in the various advanced line yield trials indicated that most lines carried varying degrees of resistance to the prevailing diseases in the wheat growing areas.

(c) Disease Incidence:

A light to moderate disease pressure was observed at most locations in the 1983-85 growing seasons. The three rusts: stem rust (*Puccinia graminis tritici*), leaf rust (*Puccinia recondita*) and *Puccinia hordei*) and yellow rust (*Puccinia striiformis*) were recorded in various degrees in the different test areas. Leaf rust (*Puccinia hordei*) occurred on barley fields in West Kilimanjaro. Stripe rust (*Puccinia striiformis*) was severe at West Kilimanjaro site.

Tan spot caused by *Pyrenophora trichostoma* F (*Helminthosporium tritici repentis* Died), Spot blotch caused by *Cochliobolus sativus* (*Helminthosporium sativum* P.K. and leaf and glume blotch caused by *Septoria tritici* and *Septoria nodorum* respectively recorded high at West Kilimanjaro and the Hanang Wheat Complex. Scab caused by *Fusarium spp* was recorded at both West Kilimanjaro and Hanang Wheat Complex on susceptible lines while powdery mildew (*Erysiphe graminis*) was noticed in some introductions at West Kilimanjaro site. *Phoma spp*. *Alternaria spp*. as well as common root rot occur to some degree in these locations (3).

The occurence of the above array of diseases dictates the kind of germplasm to be retained. The wheat breeding program through introductions and screening has been successful in selecting suitable material making available new and useful locally adapted germplasm. The above program meets but one of the two elements in crop improvement as pointed out by E. Torres (2) due to the lack of any local crossing program. There is therefore need for the combination of desirable newly introduced gene pools with locally adapted germplasm through crossing in order to address site specific constraints and to complement international efforts with a local component.

REFERENCES:

A. S. Mosha and E.N. Munisi 1983 Focus on Research for Rainfed Wheat Production in Tanzania. Reg. W. Workshop for East, Central and Southern Africa Arusha, Tanzania June 13 - 17, 1983 pp. 20- 25.

E. Torres. 1983. What does CIMMYT have to offer East and Central Africa vis-a-vis Increased Wheat Production Reg. Wheat Workshop for East Central and Southern Africa Arusha, Tanzania June 13- 17, 1983 pp. 61 - 65.

Tinline R.D., 1982. A Report on Assessment of Wheat diseases in Tanzania for the Tanzania-Canada Wheat Project.

DISCUSSION

(M. W. OGGEMA):

Experience shows that continued wheat cultivation is damaging to soils. In Kenya we have experienced soil acidification, and it has taken a long, tedious process to bring back the original soil fertility. What is your strategy to avoid the same effects?

> Ans. Our agronomists are working on rotation schemes. Still our soils are rich and there is no fertilizer response.

(J. E. BRANDLE):

Why do you need early maturing varieties?

> Ans. To facilitate growing two crops as was the original intention of the schemes. We plan to introduce wheat into the rice schemes. With 100 days to maturity it is a feasible operation.

(L. M. M. MURIITHI):

Stem rust used to be the main disease of wheat in Kenya, but now yellow rust has taken a lead. What is the situation in Tanzania? Do you have varieties with adequate resistance?

> Ans. Our situation is identical. Yellow rust is now appearing in areas with warm climate. New races also appear that attack previously resistant varieties.

(W. C. JAMES):

Could you tell us about the current situation in the diagnosis of the Basoto soil problem?

Ans. There has been little progress. Now we are not even sure it is a soil problem. The current approach is to modify our technology.

Screening and evaluation of wheat and triticale varieties in the Southern Highlands of Tanzania

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The Southern Highlands plateaus of Tanzania comprise these parts of Rukwa, Mbeya and Iringa regions of an altitude of more than 1500 meters above sea level. These plateaus are situated between latitudes 5°S and 10°S and between longitudes 31°E and 37°E. The plateaus cover approximately an area of 40,000 square kilometres and consists largely of volcanic derived soils. Rainfall pattern is mono-modal with a single rainy season extending from November to May and dry season extending from June to November. Average annual rainfall varies from 1000 mm to 1500 mm. Higher rainfall occurs generally at higher altitudes above 2000m with increased reliability.

Wheat was introduced into the Southern Highlands in 1898 and into the Northern Highlands after 1900. The Southern was the main wheat producer until 1940 when the northern areas begun to increase wheat acreage because of demand of wheat flour after the outbreak of the second world war. Wheat varieties introduced by German Missionaries in 1890s are still to the present day grown by some farmers in the region although average yield of these varieties is as low as 400kg/ha. Wheat research in the region is conducted by two institutions: the Agricultural Research Institute at Uyole in Mbeya region and at Tanganyika Wattle Company (TANWAT) at Njombe in Iringa region.

TANWAT is largely financed by the British Commonwealth Development Corporation and is based on the production of tanic acid for tanning leather, but has been diversifying into large scale arable crop production since 1966 in which wheat was aimed to be a major crop. Wheat varieties grown in the Southern Highlands from mid 1960s originated from the Kenyan and Tanzanian national wheat research programmes. While these varieties were excellent with regard to their rust resistance, their resistance to other foliar and root diseases were unsatisfactory. Decline in yields since early seventies was associated with:-

(i) Increasing area under wheat which has made it possible that the management of the crop has suffered with regard to timeliness and effectiveness of cultivations, planting, weed control, etc.

(ii) Increasing age of most arable land under cultivation which has resulted in possible soil structure loss, lower organic matter content, lower nutrient levels, especially nitrogen and build up of weeds especially grasses.

(iii) Increasing period during which most arable land has been under wheat with the consequence that the disease inoculum has built up considerably and in turn has been associated with the possible loss of varietal resistance due to high disease pressure.

Thus, seen in the light of the above possible effects, screening and evaluation of wheat and triticale varieties in Southern Tanzania is currently directed towards:

(i) Selection of wheat and triticale varieties with improved disease resistance and higher yield potential.

(ii) Use of nitrogen to identify responsive varieties with good resistance to allow early planting. Most high yielding CIMMYT varieties should get yield response if seen in comparison to hybrid maize response.

Agroecological similarities throughout the Southern Highlands has made it possible that varieties selected anywhere in the south are well adapted across all locations.

Screening and Evaluation Methods

Selection and evaluation procedure is carried out in five phases: early selection in the screening nurseries, initial screening and yield trials and commercial variety evaluations. Seed multiplication is started in breeders seed plots as soon as superiority of a particular variety is recognised. Newly selected varieties for commercial production are tested for nitrogen response before final recommendation for release.

WHEAT-TESTING FLOW CHART

SCREENING NURSERIES

e.g. IBSWN
ISEPTON
AL. SN
SNACWYT
ITSN

SELECTIONS AT TANWAT

e.g. Selections from original F_2 segregating material and selections from existing varieties e.g. Veery 'S' and Fink 'S'

INITIAL SCREENING TRIAL

OTHER YIELD TRIALS

e.g. ISWYN
ACWYT
TWVT
ITYN

EARLY AND LATE PLANTED SCREENING TRIALS

(entries must have been tested for 2 years. Seed multiplication started in breeders seed plots)

EARLY AND LATE PLANTED FOUNDATION VARIETY TRIALS

(Varieties must have been tested for at least 3 years while seed multiplication is on progress. Outstanding varieties tested for nitrogen response)

EARLY AND LATE PLANTED COMMERCIAL VARIETY TRIALS

(all commercially grown varieties included each year)

Disease problem

The most outstanding observation in early seventies were severe infections by Septoria spp. and Puccinia recondita tritici (leaf rust) - Nilsson 1972. However a multitude of other diseases per samples analysed in Mexico in 1982 were devastating (Zillinsky 1982). Ophiobolus graminis and Helminthosporium sativum affect root tremendously. Septoria nodorum, Xanthomonas translucens, Fusarium spp. Cercospora apii and phoma spp. were taking a very severe toll.

Source of varieties

Cooperative international screening and yield nurseries are now obtained directly from CIMMYT Mexico and CIMMYT Kenya. Valuable material is also obtained from various Brazilian research stations. CIMMYT varieties have now replaced East African varieties and are grown all over Southern Highlands (table 1). The crossing programme between high yielding CIMMYT varieties and South American progenies has produced outstanding cultivars such as CM.H.76.480 and CM.H.78.409 which are still in the foundation variety trials. Good disease resistance is afforded by entries in the aluminium screening nurseries, but these are disappointing in terms of yield.

Triticale

Triticale has emerged as a well adapted crop in the Southern Highlands and yields about 25% more than the best wheat varieties (table 1). Crop buying authorities in Tanzania have now accepted triticale.

Discussion

(K. G. BRIGGS):

What magnitud of crop losses due to Septoria are reported from your region? Also, is there any research on fungicides to complement genetic resistance in disease control?

Ans. Losses from Septoria have been found to be up to 40%. Several fungicides have been tried, but genetic resistance is of better use.

Table 1: Variety trial yields (mean of early and late planted)

As percentage mean yield of W 3697 (K4500 - 2)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
W 3454	105	32	69	93	82	79	68	95	+	+	+	+
W 3519	109	79	95	-	92	96	68	102	86	+	+	+
W 3525	112	-	89	86	92	95	75	+	+	+	+	+
W 3588	114	90	94	71	76	100	89	119	84	+	+	+
W 3679	107	100	102	95	98	102	74	89	88	+	+	+
W 3697	100	100	100	100	100	100	100	100	100	100	100	100
W 3710	-	-	-	101	89	93	73	94	91	+	+	+
W 3760	-	-	74	74	76	88	73	+	+	+	+	+
W 3815	97	-	98	109	96	94	86	81	85	+	+	+
W 3837	-	-	-	89	80	84	55	+	+	+	+	+
RBX = W 3899	105	91	97	97	98	90	81	97	89	+	+	+
W 3998	-	80	91	86	83	100	72	82	82	+	+	+
6290-17	-	-	-	114	105	98	89	93	95	106	95	95
6290-45	-	-	-	-	-	95	82	100	+	+	+	+
Cajeme 71	-	-	-	98	78	84	71	88	+	+	+	+
PM 15	-	-	-	-	-	98	82	93	63	118	100	+
PM-18	-	-	-	-	-	111	93	95	94	107	+	+
26-73	-	-	-	-	88	101	69	92	83	102	81	+
196-74	-	-	-	-	-	-	-	101	92	120	120	+
6650-2	-	-	-	-	-	-	-	96	89	104	+	+
Moncho 'S'	-	-	-	-	-	-	-	103	104	117	122	98
IAS 54	-	-	-	-	-	-	-	-	140	147	153	118

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Veery 'S'	-	-	-	-	-	-	-	-	-	118	120	180
B 7408	-	-	-	-	-	-	-	-	-	125	135	105
PF 70354	-	-	-	-	-	-	-	-	-	132	138	116
Ram 'S' (tcl)	-	-	-	-	-	-	-	-	-	150	138	115
CM 36681	-	-	-	-	-	-	-	-	-	135	104	104
SWO 176	-	-	-	-	-	-	-	-	-	115	134	+
CM 41860	-	-	-	-	-	-	-	-	-	130	157	115
Delfin 205 (tcl)	-	-	-	-	-	-	-	-	-	246	225	130
Mean yield of W 3697	3064	3869	3250	2907	3603	2601	2211	2302	2518	1985	1903	3091

+Varieties culled from the programme on the basis of yield and disease performance.

Wheat breeding in Uganda: an evaluation of the yield performance of some wheat introductions

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INTRODUCTION

Wheat, a rainfed crop in Uganda, is produced on the average on 4,000-5,000 hectares, yielding a total of 10,000-12,000 tons (Anon., 1984). Most of this wheat is grown on the slopes of Mount Elgon in Kapchorwa district where the production is mechanised. The rest is produced following traditional methods, in the highlands of Western Uganda in Kabale, Rukungiri, Mbarara Kasese, and Kabrole districts; on the slopes of Mount Elgon in Mbale district. Wheat has been reported to be grown on trial basis in Arua (Leakey,1963) and Gulu districts in Northern Uganda and Karamoja region (Anon., 1975).

No major wheat disease has been reported in Uganda at epidemic levels. Disease occurrences have been reported, however. Stem rust (caused by *Puccinia graminis tritici*) and leaf rust (caused by *Puccinia recondita*) were reported in Toro as early as 1936 (Leakey, 1963) and West Nile in 1962 (Flores,1970). Yellow rust (caused by *Puccinia striiformis*) and leaf blight (caused by *Helminthosporium* spp.) have been noted by the author. Other diseases that occur in Uganda, although of minor importance so far, include head scab (caused by *Fusarium* spp.) and glume blotch (caused by *Septoria* spp.).

Upto the break of the East African Community in 1976, much of the wheat research in Uganda was done through cooperative programmes with the National Plant Breeding Station, Njoro, Kenya. Uganda's role was mainly to run Kenyan wheat yield trials and disease trap nurseries with no particular emphasis on breeding work. This made Uganda heavily dependent on wheat seed imports from Kenya as there was no research leading to wheat seed production.

The current wheat breeding programme was initiated in 1980 at Buginyanya Coffee Research Station situated at an altitude of 2,000 meters above sea level. The programme aims at producing widely adapted varieties that can be multiplied and supplied to the Ugandan wheat growers and hence ease the foreign drain and time loss involved in importation of the seed. The initial stage of the programme has put emphasis on evaluating foreign germplasm to select high yielding varieties with tolerance or resistance to the diseases mentioned above.

MATERIALS AND METHODS

In 1980, 1,039 varieties/lines were received through cooperative programmes with the International Maize and Wheat Improvement Centre, CIMMYT (Mexico/Kenya) or at direct request to the United States Department of Agriculture. They were planted out at Buginyanya during the second rains - which is the main wheat growing season of this area. Planting was done as indicated in the instructions accompanying the seed, orelse in observation plots of 5-m single rows.

Data were taken as follows:

1. Disease scores (a) Rusts were recorded using the modified Coff's scale (Loegering 1959).

   (b) For other foliar diseases, the 0-9 scale developed by Prescott and Saari was used.

2. Yield (expressed in tons per hectare).

3. Height in centimetres.

4. Days to flowering and maturity.

5. Percentage lodging

6. General agronomic appearance.

One hundred selections made in 1980 were planted in 1981 in small multiplication plots to raise enough seed for a preliminary performance yield trial. Screening of these 100 selections gave 19 entries.

In 1982, a preliminary performance trial using the 19 lines was planted out in a randomised complete block design replicated three times with 6-row plots of 2.5 meters long and inter-row spacing of 0.3 meters.

Ten selections made in 1982 plus a local check (land race) were planted out in a repeated performance trial during the second rains of 1983 at Buginyanya. NPK fertiliser was applied at the rate of 100 kg per hectare at the onset of tillering.

In 1984 the same 11 lines were planted out in a yield trial at three sites:

Buginyanya with rainfall of 355 mm during the nursery cycle (September-December); Bugusege Experimental Farm which is at an altitude of 1400 meters with rainfall of 631 mm during the nursery cycle (March-June) and Bumbo at an altitude of 1600 metres (rainfall figures not available). The design was a randomised complete block with four replications. The plots consisted of 6 rows 2.5 meters long with inter-row spacing of 0.3 metres. Field operations were not mechanised.

RESULTS

Table 1 gives the disease reactions and agronomic characteristics of the 11 entries that were tested at Buginyanya, Bugusege and Bumbo in 1984. These varieties exhibited adequate disease resistance and performed consistently well throughout the testing season. Leaf blight and stripe rust were the most prevalent diseases.

Table 2 shows the yields of the multilocational trial in 1984.

Table 1 Agronomic Characteristics of 10 Selections made in Uganda from the 1980 Introductions. Data obtained at Buginyanya in 1984

Selections	Yield t/ha		Average Height cms	Days to Flowering	Days to Maturity	Diseases		% Lodging
	1983	1984				Helm.	Stripe rust	
Kinglet "S"	2.37	0.77	85	59	106	t	10MS	0
Koel "S"	1.71	0.69	75	54	100	3	0	0
Bobwhite "S"	2.39	0.82	85	69	100	t	TMS	0
K.Tembo/K4500.2/Inia	2.28	0.96	95	61	104	3	0	0
Brochis "S"	2.62	0.71	75	61	104	0	0	0
Ti71 Resel/3/Bb/PL/S	3.00	0.96	85	59	103	0	0	0
TC 750434-IR-IC-OS	2.97	0.84	80	56	101	3	20MS	0
Bvr/Arm (Tcl)	3.61	1.51	105	56	120	t	0	20
Musala "S"	2.61	1.14	85	61	108	0	0	0
Minivet "S"	2.51	0.52	75	72	108	t	tMS	0

t - traces; MS - medium susceptible; S - susceptible

Table 2. Average Yields (t/ha) of 11 Wheat selections at 3 Locations in Uganda in 1984

Selections	Location			Variety means (t/ha)
	Buginyanya	Bugusege	Bumbo	
Kinglet "S"	0.77	1.01	0.51	0.78
Koel "S"	0.69	1.42	0.27	0.79
Bobwhite "S"	0.82	1.31	0.44	0.86
K. Tembo// K4500.2/Inia	0.96	0.75	0.65	0.79
Brochis "S"	0.71	0.05	0.72	0.83
Ti 71 Resel/3/Bb/PL/S	0.96	1.10	0.84	0.97
TC 750434-IR-IC-OS	0.84	1.07	0.46	0.79
Bvr/Arm (Tcl)	1.51	1.40	0.69	1.20
Musala "S"	1.14	0.99	0.52	0.88
Minivet "S"	0.52	1.09	0.60	0.73
Land Race (local check)	0.98	1.39	0.46	0.94
Location means (t/ha)	0.91	1.14	0.54	0.86

The effect of crop management is also reflected in the dramatic differences in variety mean yields and overall average at Buginyanya from 1983 to 1984. The location mean yield was 2.6 t/ha in 1983 as compared to 0.91 t/ha in 1984 when no fertilisers were applied.

Yields at Bumbo were significantly lower than those at Bugusege. There were no other significant differences among location means.

DISCUSSION

Although there was no significant variation among variety means, triticale (Bvr/Arm) outyielded the best breadwheat (Ti 71 Resel/Bb/PL/S) during the 1984 trial. In 1983 at Buginyanya, the same triticale selection did outyield the same breadwheat, which was also the best among the breadwheats (Table 1). This result may be due to the tolerance of triticale to soil acidity which is a widespread problem in the area.

Yields obtained in these trials are low compared to the national average. This may be due to the peasantry methods followed in these trials as compared to the mechanised means of production that affect national average.

One reason for the low yields at Bumbo is rainfall distribution. The nursery was affected by drought from the onset of tillering to booting; from then on, it received heavy rains up to harvest time. Differences between Buginyanya and Bugusege, although not significant, could also be attributed to the weather. In Buginyanya, a dry spell which set in at anthesis may have led to poor grain filling and thus be a contributary factor for the lower yields. On the other hand, Bugusege received adequate and well distributed rainfall all through the growing period (Appendix 1).

CONCLUSION

Triticale, a new cereal in Uganda, could be multiplied and introduced to farmers especially in the areas where soil acidity is a problem.

Among breadwheats, selection from Ti 71 Resel/3/Bb// Pl/S, Musala "S" and Bobwhite "S" could be multiplied to satisfy local demand for wheat.

It is evident that, given current development conditions in Uganda, introductions could offer a quick solution to the production of wheat.

REFERENCES

Anon., 1975 Church of Uganda, Karamoja Agricultural Project. Annual Report 1975.

Flores, G. 1970. Diseases of wheat at Zen - West Nile - A report to the Chairman, Uganda Development Corporation.

Leakey, L.A. 1963. Rust Races. Reference Crp/1/D/3 - Department of Agriculture (Uganda).

Loegering, W.Q. 1959. USDA International Spring Wheat Rust Nursery.

Anon., 1984 Ministry of Agriculture (Uganda) Statistic Section. Various reports.

DISCUSSION

(A. MOSHA):

The research programe described, caters to the large scale or the small scale components in your area?

Ans. Given the high population density of Uganda, our research is geared to small scale production.

(F. C. MUNTHALI):

What factors led to low yields under peasant farming, even with fertilizer application?

Ans. The main reasons are poor seedbed preparation, low plant density, and poor harvesting methods.

Appendix 1

Rainfall distribution at Buginyanya and Bugusege during 1984

Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Buginyanya													
Rainfall in mm	4.7	30.1	40.5	185.5	271.8	200.3	191.8	187.5	80.8	99.8	85.0	45.0	1422.8
No. of rainy days	3	2	3	11	21	17	22	15	14	13	6	7	
Bugusege													
Rainfall in mm	21.7	29.2	31.5	157.7	285.7	157.7	60.5	163.9	33.3	64.0	119.0	24.1	1148.2
No. of rainy days	3	3	3	20	22	17	7	14	6	8	18	6	

Developing breadwheat cultivars for the Ethiopian highlands

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Wheat improvement work in Ethiopia started in the 1930's using indigenous collections and introductions from Europe and later from Kenya. Actual hybridization programme was initiated in Paradiso in 1956 with an objective of transferring stem rust resistance from the local to exotic varieties (3). As a result, a few wheat cultivars were released between 1953 and 1966.

The establishment of the Debre Zeit Experiment Centre in the early 1950's and the Institute of Agricultural Research, (IAR), and CADU in 1966 ushered in a period of national coordination and cooperation in the wheat improvement effort. This paper will summarize the bread wheat breeding activities to develop cultivars for the Ethiopian highlands since the establishment of Holetta Research Station under the IAR (1).

In broad terms, the bread wheat breeding programme has as its objective - the development of high-yielding varieties with desirable characteristics such as resistance to diseases, stability, resistance/tolerance to stress environments, early to medium maturity, strong straw, and good kernel quality. The major production-limiting environmental stress conditions in the Ethiopian highlands are low soil fertility, drought, frost, impeded soil drainage, and low soil pH. Hence, the programme deals with the following lines of investigation:

1) Creating a viable germplasm pool by evaluating indigenous and exotic collections;

2) Identifying valuable genotypes by using international and national nurseries, screened at stations strategically located at different agro-ecological zones;

3) Developing varieties through breeding; and

4) Carrying out national and regional cooperative variety testing and seed increase.

Evaluation of Germplasm

Both the local and exotic wheat collections have been valuable sources of germplasm. The wheat breeding programme has evaluated several accessions maintained by the Holetta Station and later by PGRC/E. The focus has been identifying genotypes carrying genes for disease resistance and adaptability to stress conditions, particularly, low moisture stress, poor soil drainage, frost, and acid soils.

International and National Nurseries

While Ethiopia is rich in tetraploid wheat germplasm, the hexaploid wheat is of recent introduction. Therefore, the country depended largely on external sources of genetic material. The international and national nurseries are used to identify useful genotypes through screening under different conditions (Table 1). For short-term needs this has been a good source of varieties. Major sources of international materials include CIMMYT, Kenya, and the Middle East. Since 1968, the programme at Holetta has evaluated more than 26,000 entries. About 10% of these materials were initially retained for further evaluations. To-date, more than 15 bread wheat varieties which were recommended for release originated from these nurseries. In addition, this activity has also helped in developing a systematic method of screening and searching for useful breeding stocks (2).

Table 1. Relatively rust resistant wheat lines, identified from the international and national nurseries, compared to susceptible checks (1982 - 1984).

	Line	LR	SR	YR	KQ*
1	HAR 402	tMS	0	0	1
2	HAR 417	n	0	0	1
3	HAR 414	0	0	0	2+
4	HAR 488	n	0	0	1-
5	HAR 426	n	0	0	1
6	HAR 409	tMS	0	0	1-
7	HAR 416	n	0	0	2+
8	HAR 410	n	0	0	1-
9	HAR 435	n	tMS	0	2+
10	Mengavi-8156	0	0	tMS	2
11	SNB 4	0	tMS	tMS	1
12	SNB 12	n	0	0	1-
13	LR-19 x Thatcher	tMS	0	tMS	1
14	KUP 703	0	n	0	1
15	Choti Lerma	20MS	40S	100S/100	3
16	Kenya 4496 L5A2	70S	10MR	60S	2-

*Kernel quality (1 - 3 scale)

Breeding

The first hybridization programme at Holetta was initiated in 1972. Since then the programme has carried out more than 2000 single, 3-ways, double and back crosses involving hundreds of parents. This local crossing work is supplemented by a large number of F_2 populations received from other national and international programmes, particularly CIMMYT.

The important elements of the wheat breeding programme include a defined goal, a rich germplasm pool, a practical and effective breeding/selection method, a workable selection criterion and time (Fig. 1). The other factors in the center of the inter-link diagram are the human (H) and resource (R) elements. Time is an essential element in a crop breeding programme. Depending on availability of resources, the minimum time required to release a wheat variety from a crossing programme is 9 years. This may be shortened to 5-6 years by using already advanced material. So far, two varieties were released out of the crossing programme and one is in the pipeline. Currently, the programme is handling thousands of hybrid and segregating populations ranging from F_1 to F_6.

National and Regional Cooperative Variety Testing

Under the aegis of the IAR and National Crop Improvement Conference, it has been possible to create an organized cooperative variety testing programme in the country. At present the bread wheat variety testing scheme consists of one set each of Extension Yield Test and National Yield Trial and two sets each of Pre-National Yield Trial and National Observation designed for the high potential areas, and several sets of specialized regional trials organized for specific conditions. For the last 19 years, several wheat varieties have been evaluated annually through this scheme for adaptation, disease resistance, grain yield, etc. As a result, more than 20 varieties had been recommended for release.

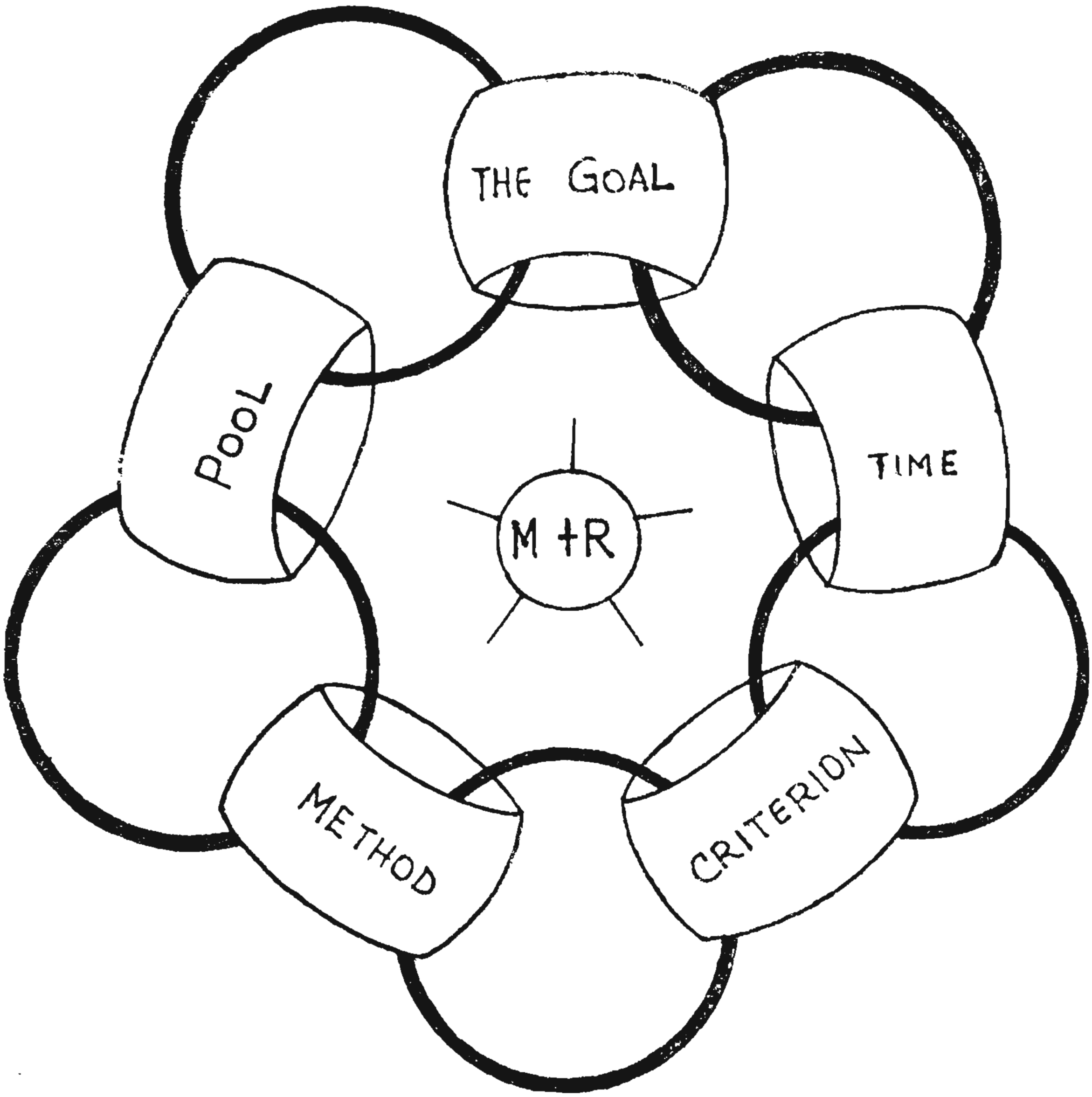

Fig. 1. The interrelationship of the important elements of the breeding programme.

Currently, Enkoy, released in 1974, occupy a large hectareage. Lately, howev it has become susceptible to leaf rust and moderately susceptible to yellow rust. Three varieties, namely, 'Dashen', 'Gara' and 'Batu' were released in 1984. Four other varieties are in the pipeline. They are HAR 416, HAR 410, HAR 406, and ET620B1. These seven varieties show resistant or trace reaction to the three rusts (Table 2). Based on a three years average across six locations, Dashen yielded 14.3% more than Enkoy, whereas HAR 416, HAR 410, Batu, HAR 406, and ET620B1 out-yielded Enkoy by 11, 9, 8, 7, and 4 percent, respectively (Table 2).

Table 2. Grain yields and disease reactions of seven bread wheat varieties newly recommended for Arsi/Bale and Shewa Regions as compared to Enkoy

Variety	Mean yield q ha^{-1}	% of Enkoy	Disease Reaction			
			Septo.	LR	SR	YR
Dashen	46.3	114.3	M	R	R	R
HAR 416	45.0	111.1	M	R	R	R
HAR 410	44.3	109.4	M	R	R	t
Batu	43.6	107.7	M	R	t	t
HAR 406	43.4	107.2	M	R	R	R
ET620B1	42.3	104.4	M	R	R	R
Gara	40.8	100.7	M	R	R	t
Enkoy	40.5	100.0	M	S	M	M

The results of 2 years dryland variety trial at three locations showed that, until better varieties are identified, 6106-9, 6290-bulk and VEE 15 can be recommended for low rainfall areas. These three out-yielded Enkoy by 32, 27 and 16 percent, respectively. On the basis of three years data, VEE 1, 6106-9, and Dashen were found to perform well under heavy black soil conditions such as Diksis. They yielded 35, 31, and 31 percent, respectively, over the check, Romany BC.

Conclusions

The Ethiopian national bread wheat improvement programme is based on an inter-disciplinary team approach. The team consists of breeders, agronomists, pathologists, soil and weed scientists. The group has made significant progress both in creating a viable wheat improvement programme and developing varieties for the highlands of Arsi, Bale and Shewa. However, it has recently become apparent that the programme should give low rainfall areas a high priority in its future effort.

REFERENCES

1. Gebre-Mariam, H., and B. Geleta. 1985. An overview of the Ethiopian bread wheat breeding programme. In Proc. Workshop Rev. Field Crops Res. in Ethiopia. Addis Ababa, Ethiopia.

2. Gebre-Mariam, H., and G. Gebeyehu. 1985. Evaluation of bread wheat genotypes for their resistance to septoria tritici blotch. p. 27 - 30. In Proc. Workshop on Septoria of Cereals. Bozeman, MT.

3. Nastasi, V. 1964. Wheat production in Ethiopia. p. 13 - 23. In Inf. Bull. on FAO/Near East Wheat and Barley Improvement and Production Project, Vol. 1, No. 3.

Grain harvesting and handling system at the Hanang complex, Tanzania

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INTRODUCTION

The Hanang Wheat Complex is essentially a cluster of seven individually incorporated and managed wheat farms operated under the overall supervision of the National Agriculture and Food Corporation (NAFCO). The harvesting operation for the wheat at these farms starts with swathing the crop into windrows at 20 - 35% m.c. (w b) followed by combining the windrows with pull type combines, handling and transporting the wheat from the farms to Arusha for processing. Both these operations are very costly and thorough investigation and analysis are necessary in order to develop more efficient operating procedures.

SWATHING (WINDROWING):

Harvesting of the wheat crop at the Hanang Wheat Farms is conducted in two operations. The crop is first of all windrowed at 20-35% mc (wb) grain moisture level and leaving behind 10-15cm high stubble using pull type swathers or windrowers.

The swathed crop is left to uniformly sun dry in the windrows for about 10 days when it is combined using pull type IHC 914 and John Deere 6601 combine harvesters.

In the so called developed countries like America, Canada and Europe, the idea of windrowing dates back to early twenties where its justification for use was mainly to overcome problems associated with straight combining, i.e. where the cutting, threshing and cleaning operations are done simultaneously by the same combine harvester. Such problems were mentioned to be (i) non-uniformity in crop maturity (ii) rain incidences during the harvesting period,(iii) avoiding green growth (iv) early frost i.e. shorter growing season etc (Dodds, 1967).

The earliest permissible stage of maturity for swathing wheat has been established to be at 35% mc (wb) and 40% mc (wb) for barley,Schneiter (1969). It was found that windrowing at such moisture levels no significant loss in yield test weight,protein content and viability were observed.

Dodds, (1967) showed that wheat crop could be windrowed seven to nine days before it was ready for straight combining at 14.5% mc (wb). Drying in the windrow took 4 days hence making the windrowing 3 to 5 days advantageous over the direct combining. A grain of 5-7 days was observed with barley and oats while oats gave similar results as wheat.

Dodds (1967) showed that delayed swathing does not benefit a farmer. Under that study it was observed that the natural losses (mainly shattering) at 35% mc (wb) swathing came up to 17 kg/ha and these losses increased to 50kg/ha when the wheat was swathed at 12% mc (wb). For minimum shattering losses, the windrowing of wheat should not be done when the crop (grain) falls below 20% mc (wb) otherwise straight combining should be given priority, Dodd, (1966).

The disadvantages of windrowing include ownership and operational costs as well as the initial costs of machinery which in 1979 was estimated to be $ 2,000 per metre of cutting width for self-propelled windrower and $ 650 for a pull-type swather.

COMBINING: (the windrows).

The vertisoils tend to develop cracks sometimes large enough to allow portions of windrows to fall in them thus creating losses in terms of crop loss or machinery parts. Generally they provide rough ground surface for good trafficability, as compared to upland soils. In the upland soils late harvesting could easily be accommodated except for the threat of grain losses due to shattering and quelea quelea birds as strafficability of these soils is generally good.

Generally the combine will take more straw when windrowing technique is used as part of the harvesting operation since the crop is cut much lower as compared to direct combining where the table cuts only enough to get most of the crop heads in. The amount of straw fed in the combine during combining is of significance as far as combining capacity and separating losses are concerned. With a harvesting rate of 8 ton/ha of wheat the losses were 1% with a straw/grain ratio 1:1 and that the losses were 6% when the straw/grain ratio was increased by 40%, Reed, (1972). Similar results were reported by Gross (1958) and Nyborg, 1968.

GRAIN HANDLING; STORAGE AND TRANSPORTATION:

Handling: (from the field to the holding area)

At the Hanang wheat farms the harvested grain is trasnsported from the field to the holding grounds within the respective farms by means of trucks and tractor drawn trailers. In most farms the ratio of the transporting facility to a combine harvestor is about 1:1.5. Moreover some of these trucks are fitted with spouts at the rear to assist in the bagging operation (unknowingly) at the expense of the combining operation-which sometimes has to halt awaiting for a grain carting facility to arrive from the holding ground (bagging centre). The grain is bagged into approx 90kg units.

Storage; (at the respective farms).

Currently there is no commercial grain storage at the Hanang wheat farms. Except for seed grain which is stored in outdoor circular bins, over 80% of the total wheat produced at the farms is transported to Arusha (185 mile or about 300 km away) for central storage in grain silos and processing by the National Milling Corperation, N.M.C.

Transportation: (from the respective farms to Arusha).

The haulage of the grain from the farms is facilitated by lorries and trucks on a rough surface road. Table 1 shows the grain handling expenses from the point where the grain reaches the holding ground (at the farm) to its arrival at the storage/processing centre in Arusha.

Table 3 Grain handling expenses (T.Shs./ton)
(assumption: 1 ton = 11.11-90 kg bags)

Item/Operation	Handling Cost (TShs/ton)	% of Handling cost
1. Bagging (filling the gunny bags + sewing) at 23.90 TShs per person per 50 bags)	5.30	0.26
2. Stacking (at 23.90 per person per 100 bag)	2.65	0.13
3. Loading into the truck (at 2.00 TShs per bag)	22.22	1.09
4. Transport charges (Arusha-Basuto -Arusha) at 4.50 TShs per milex2)	1665.00	81.52
5. Unloading (at 1.25 Tshs per bag)	13.89	0.68
6. Cost of empty gunny bag (at 30.00 Tshs. per bag)	333.30	16.32
Total	2042.36	100

DISCUSSION:

Bearing in mind the points mentioned under Swathing the operation at the Hanang Wheat Complex farms seems to meet the objective of minimizing grain looses by quelea quelea birds and avoiding green growth at the time of combining as well as shattering losses. However through experience, these birds attack the grain severely when it is soft and milky i.e. over 40% mc (wb), the time when even swathing is not worth doing if losses in grain quality through excessive shrinkage are to be avoided. In other words the swathing operation is normally done when the birds have already done considerable damage on the crop.

The need to establish the swathing, combining and direct combining costs per ha and relate these costs to the evaluated quelea quelea damage costs is of vital importance in order to establish the rationale of the harvesting operation.

When windrowing has to be done in a light croped field double swathing should be preferred to single swathing as it can make full used of the combining capacity thereby regaining the time wasted during the windrowing operation.

Regarding the handling system which is currently employed the transportation and gunny bags costs account for about 82% and 16% of the total handling cost/ton, respectively. Also the availability of the gunny bags on time is not guaranteed. All in all the present grain handling system is very expensive and something must be done to improve the situation.

In order to solve this problem handling of the grain in small units (bags) should be discouraged and bulk handling should be given an immediate priority. However, this entire venture is more or less a nation-wide issue which needs some blessings from the higher authorities in order to facilitate the suggestion on cheaper means of transporting the grain.

CONCLUSIONS AND SUGGESTIONS:

(a) The grain damage losses by quelea quelea at the farms should be accumulatively evaluated in terms of TShs/ha.

Also the swathing, combining and straight combining costs should be determined and compared to the bird damage losses for the purpose of establishing the rationale of performing the grain harvesting operation in a more economical way.

(b) Currently it is advantageous to straight combine in upland soils and areas where the crop stand is generally light. When swathing is necessary such areas should be double swathed as opposed to single swathing.

(c) More grain carting facilities in terms of quality and size should be made available in the field during the combining operation for increased combining efficiency. Also good soil management should be practiced during seed bed preparation for reduced soil erosion hazards.

(d) Bulk grain handling should be encouraged at all levels as it tends to lower the total handling per unit weight of the grain. In order to facilitate this a cheaper and more convenient way of transporting the grain from the farms to other areas, where great distances are involved should be considered. Preferably a railway line linking Arusha and Singida through the newly established Minjingu rock phosphate mines, salt deposits near Babati and the Hanang Complex wheat farms should be considered.

REFERENCES:

1. Dodds, M.E.,(1966): The effects of early windrowing on the protein content of spring wheat Can.Jour. of Plant science Vol.46.
2. Dodds, M.E., (1966): Grain losses in the field when combining wheat, Can.Agric.Engineering Vol.8 No. 1 pg. 31 - 32.
3. Dodds,M.E.,(1967) Grain harvesting with windrower, ASAE paper 67-151.
4. Dodds,M.E.,(1967) Wheat harvesting-Machine and Methods; Canadian continental wheat symposium p. 361,371.
5. Gross, J.R. et all, (1958) Performance Characteristics of grain combining inbarley; Agric. Engineering Vol.39 No.11 page 697-702,711.
6. Nyborg,E.O. et all, (1968) Grain Continue loss characteristics; ASAE paper No.68-609.
7. Reed, W.B.: (1972) Combine Operation,University of Saskatchewan, Saskatoon.
8. Schneiter A.A.; et all, (1968) Guidlines for swathing, Wilson Experimental Station, North Dakota.

Situation of wheat and triticale cultivation in Rwanda

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Although wheat was introduced in Rwanda 50 years ago, its integration into the agricultural system has not been very successful. Wheat occupies the 12th position among the 15 major crops in the country. Among the 5 cereal cross planted in Rwanda, wheat occupies the 4th place in area and the 5th in production. The constraints are technical, scientific and socio-economic: There is a lack of varieties adapted to local conditions; there is no incentive among producers regarding its economic importance and inspite of reasonable prices for wheat, farmers were not interested in this crop until 1970.

Current situation

The government is concerned about research and development of wheat and triticale production. Production increased threefold between 1970 and 1984. This steady increase has been due to the expansion in area, to the release of new varieties by researchers, and to successful efforts of extension services.

Varieties

Until 1962 there were only 4 breadwheat varieties available to producers. After independence, 7 varieties were released by ISAR, namely: ROMANY and TROPHY from Kenya, NORTENO and BAJIO from Mexico, AMAZONAS from Ecuador and two other entries from Kenya via Tanzania. Between 1983-1984 six other high yielding varieties were released. 4 of these varieties originated from Mexico material and the other 2 from Kenya. These varieties are superior in yielding capacity and feature adequate agronomic characteristics such as disease resistance, crop cycle between 120 and 140 days, resistance to lodging and good kernels.

Newly released wheat varieties in Rwanda by ISAR.

Local Name	Cross or CIMMYT Name	Country of Origin
Tamira	Gyrak "S"	Mexico
Gicinya	Veery "S"	"
Kinigi	Bb/Cno// Jar/3/Cno/7c/Tob	"
Mutura	Chova "S"	
Rustima	G.55/K. Nyati	Kenya
Buberuka	K. Fahari	"

Ecology

Wheat is grown in the highlands of the Zaire-Nile Crest, in the Northern Highlands, and in the Volcanic chain at the N.W. of Rwanda. There are two seasons, one stretching from March to August, and other from September to February.

Yields

Average yields range from 800-1200 kg/ha. Progressive farmers utilizing adequate inputs can produce upto 1,500 kg/ha. Yields at the experiment station can reach 4,000 kg/ha, and normally average 1500-2000 kg/ha.

Triticale situation

Since its introduction in 1977, triticale has proven an encouraging crop. Three varieties have been released (T65 and T74 from Kenya and Moshi from Tanzania). There are four more varieties recommended for release, Octo-Bush Bulk, Delfin 205, and two selections from W 74.103.
Triticale shows great potential for Rwanda's agriculture because of its adaptability to unfavourable growing conditions. Triticale yields from 20-50% more than wheat and is less susceptible to bird damage. Triticale can be consumed as porridge and as a slightly alcoholic beverage. A Survey conducted in 1982 showed that 60% of the sample did not favor triticale porridge because of its sweetness and soft consistency.

Current problems

The main problems for wheat are diseases (rusts, Septoria, Helminthosporium) late maturity, and susceptibility to lodging. Triticale suffers from shattering, early sprouting, grain shrivelling, lateness and susceptibility to septoria.

Conclusions

Considering the above constraints, research must continue based upon mass selection of introduced material. These introductions must be frequent, systematic and abundant. The main desirable characters are high yield potential,earliness, resistance to major diseases, resistance to lodging and good grain. Local crosses could be used to complement introductions.

Triticale is more attractive than wheat both from productivity and from hardiness. To be really a promising crop for the future, it is necessary to develop varieties with better seed quality.

Considering their nutrientvalue, wheat and triticale could also be used for porridge, or, blended with sorghum and maize meal to prepare slightly fermented beverages.

Extension of available information and motivation of producers with adequate infrastructure are essential elements for the success of these crops in Rwanda.

Discussion

(J. M. ORONDO):

How do you explain the gap between progressive farmers and research stations if both groups use similar inputs?

Ans. The main reason is a long-term soil management programme applied at the stations.

Research needs for the improvement of wheat yields on high aluminum and/or acidic soils in Kenya

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ABSTRACT

An ever increasing demand for wheat and a declining wheat hectarage is forcing increases for higher yielding varieties combined with improved cropping practices in order to realize increased yields for all areas of Kenya highlands. Among the regional constraints to wheat production are large acreages of soils with high aluminum and acidic conditions which lead to lower yields. To circumvent these constraints a sound research to determine ways and means of increasing yields in such soils should be pursued. Priority areas of such research should include: evaluating the extent of high aluminum and/or acid soils in the potential wheat growing areas, establishing appropriate soil amendment procedures (e.g. using lime), carrying out detailed genetic studies of the existing germplasm and retain the tolerant cultivars, establing the effect of fertilizers and other agro-chemicals (e.g.herbicides) with respect to increasing soil acidity, and overall breed for desirable agronomic characters in order to realize higher yields.

Introduction

Kenya covers a total area of 58 million hectares of which 6.2 million hectares (11 per cent) of the total can be considered highly productive with significant agricultural potential. This land is intensively cultivated and Kenya must look to its marginal and low potential land to feed its growing population, whose staple food is maize (corn) and recently wheat. At present, the population is estimated at 18 million and expanding at an annaual rate of 3.9 per cent; it is expected to double over the next twenty years (Briggs, 1984; Dunford, 1983).

Wheat production increased during 1982 to 222,660 tonnes compared with 203,395 tonnes in 1981, an increase of 9.5 per cent. Domestic demand for wheat continues to exceed domestic supply, especially in the urban areas. Wheat must, therefore, continue to be imported to satisfy domestic requirements, costing the country a large sum of foreign exchange. In recent years the area of wheat cultivated has declined mainly as a result of fragmentation of farms within the traditional wheat producing zones (Briggs, 1984;Dunford, 1983).

In response to this situation the Government launched a National Food Policy which aims at self sufficiency in food production by the year 1990, without decreasing the export of agricultural commodities. The main approach to achieving this objective includes giving a priority to public investment in agriculture, and especially to subsistence food crops (wheat included) and improving the efficiency of production among others. However, to achieve these (especially in wheat production) there are several production constraints which need to be overcome, among them the problems encountered in soils of high aluminum and/or acidity. This paper examines the high aluminum and/or acid soils as one of the wheat production constraints.

Definition of Aluminum and/or Acid Soils

Aluminum is one of the elements in the soil that has not been indicated to be useful either as a structural or functional plant component. Soils high in aluminum can be defined as those (soils) that have toxic quantities of aluminum in the soil solution high enough to restrict root growth, thereby reducing the plant's ability to take up nutrients and water.

Soil acidity may be partitioned into exchangeable (chiefly monomeric Al) and non-exchangeable (titratable or pH-dependent acidity) components based on extraction with a neutral salt solution such as 1M KCl (Coleman and Thomas, 1967). Aluminum is frequently the dominant exchangeable cation in highly leached acid soils (Kamprath, 1970), but approaches minimal levels when soil pH exceeds 5.5. Titratable acidity arises from dissociation of weak acid functional groups of soil organic matter (Hoyt, 1977).

On this subject, Hoyt *et al* (1982) in Alberta and northeastern British Columbia, determined that changes in soil acidity from pH 6.1 to 6.9 have little effect on crops. Hence for this region pH 6.0 is considered to be the upper value for acid soils.

Extent of High Aluminum and/or Acid Soils

Soil surveys have been carried out in different parts of Kenya and at various mapping scales, but the process of working out the distribution and extent of high aluminum and/or acid soils has not so far been undertaken. (K.S.S., 1984. pers comm.)[3] This means that if one was interested in identifying such soils of a particular area that has already been surveyed, he/she should look at relevant published reports and identify the soils, however, this information is scanty and does not give a clear detailed nature of the soils.

Among the high aluminum and/or acid soils in Kenya are the Oxisols, Humic Ferralsols and Latosols (FAO/UNESCO, 1974,classification).Oxisols are highly weathered soils ,leached and mostly red in colour. Their pH range from 4.8 to 5.3. They are characterized with high contents of aluminum and iron, but low contents of exchangeable magnesium and calcium. They are rich in kaolinite clay and sesquioxide and in which sands are essentially void of easily weathered minerals. Typically they occur under forested conditions of the humid tropics. In Kenya these soils occur between 2,100 to 3,000m

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[3]*Kenya Soil Survey, Nairobi, Kenya.*

above sea level and representative locations are: Molo, Uasin Gishu, Moiben and Olenguruone.

Humic Ferralsols and Latosols are soils that have been developed under forested, tropical humid conditions. They are characterized by low cation exchange capacity and a low content of most primary minerals and soluble constituents. They have a high degree of aggregate stability and usually have a red colour. Representative locations in Kenya are: Kitale and Endebess.

The exact hectarage of wheat under high aluminum and/ or acid soils has not been establised. However, a genuine estimate of 33 per cent of the total wheat hectarage can be said to be under high aluminum and/or acidic soils. This is based on the hectarage of wheat in areas that have soils of the taxonomic classes known to be acid in nature.

Ssali and Nuwamanya (1981; 1982) and Nuwamanya (1984) have indicated that there is a mosaic pattern of acid soils in Kenya with varying degrees of exchangeable aluminum. These workers have reported existence of acid soils in various parts of Kenya and from their work it is evident that to generalize soils either acidic or non-acidc depending on the major taxonomic soil classification may be inaccurate. Ssali and Nuwamanya (1981; 1982) demonstrated that soils above pH 5.5 had little no exchangeable aluminum. This criterion can be used to estimate the extent of high aluminum and/or acid soils in Kenya.

Soil surveys and descriptions of the soils in the surveyed areas are important tools that can guide breeders and agronomists in designing appropriate research programs which in the long run can lead to appropriate crop management and production recommendations. It is inevitable that Kenya will need to opt for intensive wheat production methods in the near future. In order to attain this a modified package of inputs should be recommended. Before, making these recommendations a guide to efficient land utilization describing the capabilities and limitations of the various soils would be desirable.

Liming Approach to Increased Yield on Acidic Soils

The purpose of liming is primarily to neutralize the exchangeable aluminum and this is normally accomplished by raising the pH to 5.5. When manganese toxicity is suspected the pH should be raised to 6.0. The factors to be considered are (1) the amount of lime needed to decrease the per cent aluminum saturation to a level at which the particular crop and variety will grow well, (2) the quality of lime, and (3) the placement method.

In Kenya there are no firm records which show the number of farmers who actively use lime neither are there records showing the total amount of lime used annualy in wheat growing regions with acid soils. This means that most of the lime recommendations that have been made are still at experimental levels.

Determination of Lime Requirement

Various methods of determining lime requirement (LR) have been cited in the literature. In Kenya the criterion used to determine LR is pH. It is recommended that liming starts when pH is less than 5.5 and that lime should be applied to a target pH of 6.5. This will require 5 tonnes of lime per hectare, which can be applied at the rate of 1 tonne per hectare per year for 5 years or at one shot of 5 tonnes per hectare to last five years before reliming (N.P.B.S, Annual Recommendations 1985. pers. comm.)[4]

A large amount of effort has been devoted to finding the best methods for estimating LR in the tropics. Part of the confusion was certainly caused by attempts to lime soils to neutrality and the use of titratable acidity as the criterion. Kamprath (1970) suggested that lime recommendations be based on the amount of exchangeable aluminum in the topsoil and that lime rates be calculated by multiplying the milliequivalents of aluminum by 1.5. The result is the milliequivalents of calcium needed to be applied as lime. Lime rates calculated by this method neutralize 85 to 90 percent of the exchangeable aluminum in soil containing 2 to 7 percent organic matter. The reason for 1.5 as a factor is the need to neutralize the hydrogen ions released by organic matter or iron and aluminum

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[4]*N.P.B.S. P.O. Njoro, Kenya.*

hydroxides as the pH increases. In soils with higher organic matter, the factor has to be raised to 2 or 3 because of the presence of exchangeable hydrogen. This method has been used in Brazil since 1965 (Cate, 1965) and is employed in most Latin American countries.

Using this approach, it can be determined that for every milliequivalent of exchangeable aluminum present, 1.5 meq. of calcium or 1.65 tonnes per hectare of calcium carbonate- equivalent should be applied to raise pH from 5.5 to 6.5.

Ssali and Nuwamanya (1981; 1982) have used Kenyan soils to determine the best index of LR and found that exchange acidity (ACe) was the best index.[5]

Other findings from Ssali and Nuwamanya (1981; 1982) indicated that methods of determining LR can differ depending on the soil characteristics, like the amount of organic matter present. In order to realize the benefit of liming and attain high yields of wheat per hectare it will be necessary to:(i) determine the amount and nature of acidity in a range of Kenya soils where wheat is grown,(ii) relate acidity with other soil properties and (iii) identify the factors which contribute to LR.

Quality of Lime

It is not easy to find fine and pure lime under natural conditions.Therefore, the selection of sources must take into account the calcium and magnesium contents of the liming materials as compared to the calcium and magnesium status of the soil. Fineness of the liming material is crucial. The higher the quality of agricultural lime the less you will use to neutralize acidic soils. Also the finer it is , the less you will have to use, but more importantly, the quicker it will react with soil. These factors are important to consider when applying lime in Kenya, because lime is not cheap considering the bulk quantities needed and transport costs involved.

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[5] *ACe consists of any monomeric aluminum or iron, as well as any exchangeable hydrogen that may be present in a soil solution, and that can be exchanged by unbuffered neutral salt solution such as 1N KCl or NaCl.*

Overall the return on money invested in liming depends upon the size of yield increase, the value of the crop, the cost of lime and the interest rate charged for money borrowed. Since most of these factors vary from one farm to another (depending on distance from lime sources) and from one year to another , it is impossible to come up with a calculation that will apply to all situations. According to 1985 market prices a tonne of agricultural lime costs KShs.250/=, excluding deliverly and application costs. To lime 1 hectare of soil pH 5.5 to a target pH of 6.5 will require 5 tonnes. This will cost a farmer KShs.1,150/=, excluding the cost of application and interest charged on money borrowed. This figure may look small on a hectare basis, but if the farmer had to lime 100 hectares this will cost KShs.115,000/=. To justify liming , the marginal revenue due to liming must exceed the marginal costs. More research is needed in this area to determine the economics of liming acid soils in wheat growing areas.

Most liming in Kenya as observed in experimental plots is incorporated into the top 15cm several days before planting the crop. Although this is usually the best way, there are instances in which deeper incorporation is beneficial, especially where sub-soil acidity is a problem.

The feasibility of deep lime incorporation depends largely on structural soil properties and available equipment. These two factors may limit deep incorporation of lime. Soils of Eldoret (in L.S.F.T.C. research plots) develop a hard crust hard for plough penetration when dry and become stick when wet (visual observations). These characteristics can limit deep incorporation of lime.On the other hand the cost of specialized equipment and the energy requirements for such equipment for deep incorporation of lime makes the whole idea of deep liming an ideal rather than a reality.

The time for effectiveness of lime treatment will depend upon the buffering capacity of the soil, manegement practices such as application of ammonium based fertilizers, and the extend to which cations (mainly calcium) are removed from the soil by cropping and leaching.

Liming may be one of the approaches to attaining higher yields of wheat per unit area of available arable land , especially in the high aluminum and/or acid soil. However, to attain the benefit of this approach much more local Kenyan information is needed. Such information should include LR if possible in every wheat farm that has been determined to have acid soils, cataloguing of other elements associated with low pH (either in toxic or defficient levels), data on lime-fertilizer interactions, and other effects of lime (for instance, the change of soil structure and increase of disease incidence like scab that has been reported by Tisdale *et al*, 1985)

Varietal Approach to Inreased Yields on Acidic Soils

The second method of contending with soil acidity is to grow varieties of wheat that are tolerant to high aluminum and/or acid soils.

The national wheat yield per hectare is approximately 2.5 tonnes (about 28 bags of 90 kg). Yields may be less than half this in areas of growth stress such as high aluminum and/or acidic soils.

Differential tolerance to aluminum among wheat varieties was first shown by Neenan (1960). Foy and coworkers (1965a; 1965b; 1967) have repeatetly demonstrated striking differences among both wheat and barley varieties.

Most of the effective genetic sources originated from Brazil (Rajaram *et al*, 1981) and are late maturing and unduly tall. Incorporation of tolerance by backcrossing and field selection on extremely acid soils (pH 4.0-4.6) has been very effective in Zambia producing varieties, notably 'Whydah' (formerly designated PF7748) and PF7260, which may yield about 1.8 tonnes per hectare on these soils compared to 0.4 tonnes per hectare for varieties lacking tolerance (Little, pers. comm., 1985).[6] CIMMYT has taken a major role in sending aluminum tolerant wheat screening nurseries to regions with soil acidity problems, and the same good sources as in Zambia were independently identified on soils of pH 4.6 in Kenya in 1981 (Briggs, Kenya/Canada CIDA Wheat Project, 1982 Annual Report), where

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[6] *Zambia/Canada CIDA Wheat Project P.O. Box 7 Chilanga, Lusaka. Zambia.*

non-tolerant wheats were killed by the soil acidity. The known tolerance to acidic soils of the Kenyan variety, Romany, and its derivatives has also been confirmed in field tests and greenhouse pot tests in Kenya (Nyachiro and Briggs, 1981-1983, unpublished).

Against this background, it is possible to breed varieties that are tolerant to high aluminum and/or acid soils, which may eventually yield more grain per unity of available arable land. In order to achieve this several preriquisites are needed. Establishment of the distribution of aluminum tolerance genes among Kenyan licenced varieties is a first preriquisite. Some of the licenced Kenyan varieties have a reputation of doing better than others in areas of acidic soils, but the genetic backgrounds of these varieties have not yet been fully studied. A clear knwoledge of the number of genes confering aluminum tolerance and their mode of inheritance in Kenyan varieties and other tolerant cultivars is needed for planning an effective breeding program for this trait. Once this has been established it will be necessary to establish a collection of aluminum and/or acid tolerance germplasm for future use, containing maximum genetic diversity for the trait.

Numerous reports in the literature indicate that aluminum tolerance is a genetic trait controlled by single dominant genes (Aniol, 1983; 1984) and Kerridge and Kronstad, 1968). Lafever and Campbell (1978) and Campbell and Lafever (1981) on the other hand have suggested that aluminum tolerance in wheat is dominant and additive in its inheritance. Further studies on inheritance of aluminum tolerance from a wider range of sources are needed. This will provide a better understanding of this phenomenon and its practical utilisation in breeding.

If breeders are going to make practical use of differential aluminum tolerance in breeding programs, it is essential that rapid and inexpensive screening procedures be used as sophisticated field and greenhouse experiments may be too costly and slow for the screening of large numbers of entries. Aniol (1983; 1984), Campbell and Lafever,(1981), Lafever and Campbell (1978) and Rajaram (1981) have described some of the rapid screening procedures. However, correlative studies of results from these methods with plant performance under Kenyan field conditions still need to be conducted.

While developing wheat varieties tolerant to aluminum toxicity it should be noted that other desirable traits like disease resistance (stem and stripe rust, septoria, heliminthosporium and leaf rust) need to be incorporated.

Some of the tolerant varieties / cultivars indicate some fair to good disease resistance. (Nyachiro, 1985. pers. comm. -field observations at Mbala-Zambia). In earlier observations (Briggs and Nyachiro, 1981-1983,pers. comm.) it was noted that while most of the pre-screened aluminum tolerant materials of CIMMYT origin were very susceptible to disease especially rusts under Kenyan conditions ,but few lines were noted to have fair to good resistance. To date no studies have been done to establish whether there is any genetic relationship between aluminum tolerance and rust susceptibilty under Kenyan conditions.

Summary

Improving wheat production in areas of high aluminum and/ or acid soils in Kenya can be achieved by use of lime , varieties which are more tolerant or a combination of both. Before those expected yield increases can be realized several basic studies should be completed. Factors determining the selection of a particular liming program should include: (1) lime requirement of the crop to be grown (2) texture and organic matter of the soil as well as the pH (3) time and frequency of liming (4) nature and cost of liming material and (5) depth of tillage. In using the varietal option good tolerance to aluminum plus other desirable agronomic characteristics will be the key factor. Co-operation of Kenya with breeding programs in other countries which have aluminum toxicity problem (especially Zambia) will be of benefit,for the development of accelerated shuttle breeding programs.

In view of the large acreage of Kenyan soils suitable for wheat, but that has a soil acidity problem, it is to be hoped that an increased capability for interdisciplinary management/ breeding research for acid soil production can be developed in the near future. Kenya badly needs the extra wheat production that could come from agronomic

REFERENCES

Aniol, A. 1983. "Aluminum uptake by roots of two winter varieties of different tolerance to aluminum." *Phsiol. Pflanzen* 178:11-20.

Aniol, A. 1984. "Introduction of aluminum tolerance into aluminum sensitive wheat cultivars." *Z. Pflanzenzuchtg* 93:331-339.

Ayres, A.S., H.H. Hagihara and G. Stanford . 1965. "Significance of extractable aluminum in Hawiian sugar cane soils." *Soil Sci. Soc. Ame. Proc.* 29:387-392.

Briggs, K.G. 1984. "Wheat production and development in Kenya." *Agriculture and Forestry Bulletin* 7:27-32.

Campbell, L.G. and H.N. Lafever. 1981. "Heritability of aluminum tolerance in wheat." *Cereal Res. Comm.* 9:281-287.

Cate, R.B. 1965. "Sugestoes para adubacao na base de analise de solo: Primera aproximacao duarte coelho, Recife, Brasil. (An English Abstract)

Coleman, N.T. and G.W. Thomas. 1967. "The basic chemistry of soil acidity." In R.W. Pearson and F. Adams (ed) Soil acidity and liming. pp. 1-41. American Society of Agronomy, Madison, Wisconsin.

Dunford, G.C. 1983. "Agriculture abroad." *Agriculture Canada* 38:28-33.

FAO/UNESCO. 1974. "Soil map of the world." 1:5,000,000 scale, FAO/UNESCO, Rome.

Foy, C.D., W.H. Armiger, L.W. Briggle and D.A. Reid. 1965a. "Aluminum tolerance of wheat and barley varieties." *Agron. J.* 57:413-417.

Foy, C.D., G.R. Burns, J.C. Brown, and A.L. Fleming. 1965b. "Differential aluminum tolerance of two wheat varieties associated with plant induced pH changes around their roots." *Soil Sci. Soc. Amer. Proc.* 29:64-67.

Foy, C.D., A.L. Fleming, G.R. Burns and W.H. Armiger. 1967 "Characterization of differential aluminum tolerance among varieties of wheat and barley." *Soil Sci. Soc. Amer. Proc.* 31:513-521.

Hoyt, P.B. 1977. "Effects of organic matter content on exchangeable aluminum and pH-dependent acidity of very acid soils." *Can. J. Soil Sci.* 57:221-222.

Hoyt, P.B., M. Nyborg and D.C. Penny. 1982. "Farming acid soils in Alberta and northeastern British Columbia." *Agriculture Canada* 1521/E:3-14.

Kamprath, E.J. 1970. "Exchangeable aluminum as a criterion for liming leached mineral soils." *Soil Sci. Soc. Amer. Proc.* 34:252-254.

Kerridge, P.C. and W.E. Kronstad. 1968. "Evidence of resistance to aluminum toxicity in wheat." *Agron. J.* 60:710-711.

Lafever, H.N. and L.G. Campbell. 1978. "Inheritance of aluminum tolerance in wheat." ***Can.***

improvements on these currently marginal soils.

J. Genet. 20:355-364.

Neenan, M. 1960. "The effect of soil acidity on the growth of the differential reaction of varieties thereto." *Plant and Soil* 12:324-338.

Nuwamanya, J.K. 1984. "The effect of lime levels on the growth of beans and maize and nodulation of beans in three tropical acid soils." *Comm. in Soil Sci. Plant Anal.* 15:1017-1027.

Rajaram, S.J., C.E. Lopez, C.E. Villegas and N.E. Borlaugh. 1981."Breeding for resistance to aluminum toxicity in wheat." *CIMMYT Publication* ,Mexico.

Ssali, H. and J.K. Nuwamanya. 1981. "Buffer pH methods for estimation of lime requirement of tropical acid soils." *Comm. in Soil Sci. Plant Anal.* 12:643-659.

Ssali, H. and J.K. Nuwamanya. 1982. "Soil acidity components of tropical acid soils: their roles in determining lime requirement values and the effect of lime upon them." *Comm. in Soil Sci. Plant Anal.* 13 :203-214.

Tisdale, S.L., W.L. Nelson and J.D. Beaton. 1985. "Soil fertility and fertilizers." *McMillan Publishing Co.,New York.*

Discussion

(A. MOSHA):

Mosha and Munisi obtained wheat yields of 1.5 - 2.0 t/ha on soils with pH 4 to 5. Any comments?

Ans from M. W. OGGEMA Assuming no error in yield or pH estimation, there are two explanations:

a. the variety is tolerant to soil acidity, or

b. high phosphorus fertilizati gave additional nutrient to the crop.

Synopsis of Session 2

Biological constraints

Ghairman: RAKOTONDRAMANANA, Fifamanor, B. P. 198, Antsirabe, Madagascar

Rapporteur: J. C. P. NAMWILA, Mount Makulu Research Station, Private Bag, Chilanga, Zambia

The presentations focused on weeds, plant diseases and insects.

1 Weeds:

i Herbicides are more effective when they are used in combination with other cultural practices;

ii Repeated (continued) use of any one herbicide should be discouraged.

2 Diseases:

i Fungal causes: Wheat rusts are recognized as the major problem and most of the effort in disease work focuses on this area. The Scientific Phytopathological Laboratory in Ethiopia appears as a possible solution to identify rust races. Other fungal diseases of concern include blights caused by Septoria or Helminthosporium, and rottings provoked by Sclerotium.

ii Virus diseases: The barley yellow dwarf caused by a virus and transmitted by aphids was reported from Ethiopia. Further distribution in the region could not be firmly ascertained.

3 Insects:

Work on antibiotic resistance of wheat to the green bug (*Schizaphis graminum*) was reported. It appears that yield can be protected by growing some of the commercial varieties which show a certain degree of resistance against this aphid.

From the discussions that ensued the various presentations, it was noted that more attention should be given to pests and diseases regarded currently as of minor importance. They should not be left until they are a serious menace to the crop.

Progress on weed management in wheat production in Ethiopia

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INTRODUCTION

Wheat is one of the major cereal crop in Ethiopia. It is grown widely under rainfed condition in large scale on state farms and farmers fields. It ranks 5^{th} in area of crop production (2). The total area of production of wheat in the country in 1971, 1974, and 1980 were 1092,000 ha, 816,000 ha and 516,000 ha, respectively (2). The National average yield ranges from 7 to 9 q/ha (4). The low average national yield obtained could be partially attributed to poor methods of weed control resulting in high weed competition.

In wheat production, weeds bring about heavier crop losses than diseases and insect pests. This could be due to poor cultural practices, ie. improper time of ploughing and sowing, low seeding rate coupled with other poor methods of weed control which cause a very pronounced and serious weed infestation in wheat fields.

In wheat production more time, energy and expense are allocated for weed control than on other cultural practices. Use of chemical and other advanced technologies of weed control methods are limited only to state farms and agricultural research stations where the scale of operation, quality of work and the available resources seem to command their application. Whereas, at small farmers level, lack of knowledge in the use of herbicides coupled with insufficient supply of improved agricultural inputs for weed control have contributed much to the serious weed problem. Consequently, subsistence farmers usually apply mannual hand picking of weeds, or leave the field unweeded due to shortage of family labour or expense to hier labour at peak season of weed infestation (1).

MAJOR WEED SPECIES

Based on survey of the major wheat growing areas and farmers response at peak season of weed infestation, some of the most wide spread and troublesome weed species are listed in Table 1.

Table 1. The most troublesome weed species in Wheat(5,6).

Broad-leaf Weed spp.	Grass weed spp.
Amaranthus sp.	*Avena abyssinica*
Convolvulus arvensis	*A. Fatua*
Commelina sp	*A. sterelis*
Calusea abyssinica	*A. Strigosa*
Datura stramonium	*Bromus pectinatus*
Galinsoga parviflora	*Dinebra retroflexa*
Galium spurium	*Lolium temulentum*
Guizotia scabra	*Phalaris paradoxa*
Medicago polymorpha	*Snowdenia polystachya*
Polygonum nepalense	
Scorpirus muricatus	

In state farms where monocropping of wheat and herbicides against broad-leaf weeds were repeatedly applied for a number of years, graminous weeds have become a serious problem (6). Also, higher infestation of grass weeds was observed in sand loam than in heavy clay soil (1). Hence, to minimize grass weed problem use of herbicides rotation or mixture and crop rotation seem to be advisable. Moreover, due consideration should be given in the use of clean crop seed to prevent the spread of wild oat and other grass weeds in wheat fields.

PRESENT WEED CONTROL METHODS

Small Scale Farming

Oxen poughing and hoeing by hand are the common methods of land preparation. Wheat is broadcasted by hand and covered by oxen ploughing or hoeing at the soil depth of 5 to 15 cm which usually gives favourable condition for germination of annual weeds and persistence of perennial weed species.

During the peak season of weed infestation hand picking of the weed plant is the common method of weed control which small farmers apply using family labour. The length of rainy periods also has great influence on the control of weeds by mannual means on time (3). Handweeding is effective and applicable only in small farms and/or where there is enough family labour to apply it at critical period of weed competition with the crop. Otherwise, most of the farms remain unweeded or weeding is done late after weeds inflicted serious damage to the crop(3). In some areas farmers plant wheat late (August)in the cropping season by ploughing their field after all the weeds have germinated thereby killing them by desication rather than planting early (mid July) at the recommended date and applying hand-weeding. Hence, indirectly crop loss is incurred due to shortage of rainfall late in the cropping season for complete growth and development of the crop. The lower seeding rate used by the farmers increases weed competition and thus contributes to the problem of weeds in the wheat fields. Farmers rotate wheat with pulse crops to improve the soil fertility. This will indirectly help to control grasses and other weeds which usually grow in association with the crop.

Although the use of herbicides is potentially one of the most labour saving innovation if it is properly used, post emergence herbicides (2,4-D, MCPA, 24DP) are usually applied by the farmers who are close to the research stations and state farms where they can easily get the know how of application and develop interest in their use by looking at herbicide demonstration plots (3).

Table 2. Some of the common herbicides used in large scale state Farms (6).

1) Herbicides	2) Rate prod. 1/ha	Time of appl.	3) Weeds Controlled
2,4-D amine (720gm/1)	1	Post em.	B.W
2-4, Dp (620gm/1)	3.5	Post em.	B.W.
2,4D + CMPP	2.5+1	Post em.	B.W+Gallium spp
Bromoxynil	3	Post em.	B.W
Britox 52.2%	2.5	Post em.	B.W
Diclofop-methyl(360gm/1)	3	Post.em	B.W + wild oat & A.G.
Carbyl	1.8	Post em.	Wild oat
Terbutryne 500FW	4	Pre-em.	B.W. & A.G.

1) Herbicides: Britox 52.2% (Bromoxynil + loxynil + mecoprop ester)

2) Time of application: a) Post em. (5 to 6 leaf stage of the crop and at young seedling stage of the weed)

3) Weeds Controlled: Broad leaf weeds (B.W) and Annual Grasses (A.G)

Large Scale Farming:

Convential tillage ie. mould board and 1-2 disc ploughings and harrowing are applied before wheat is broadcasted and covered by disc ploughing. Cultivation after planting is not a common practice (5). Due to increase in the acreages of crop production areas and cost for fuel and spare parts of tractors, the concept of reduced tillage has been started to be applied in some of the state farms recently. In minimum tillage programme, Glyphosate 500FW at the rate of 3 to 4 l/ha product is applied 7 days before planting the crop. Then, wheat is sown by broadcasting and the seeds are covered using disc harrow (5). However, more research on minimum tillage seem to be necessary to apply it efficiently and widely in large acreage of production areas.

In state farms herbicides are used widely because they are one of the most important labour and time saving technologies for weed control. For a number of years phenoxy group of herbicides (24-D, MCPA, 24-DP, etc) have been repeatedly applied (5). This has brought about a shift in the composition of the weed species from susceptible broad leaf weeds to resistant graminous weeds such as Avena spp, Setaria spp, Phalaris spp, Bromus spp and Snowdenia spp. Broad-leaved weed spp (Guizotia scabra, Galium spurium Oxalis spp etc.) were also observed to be tolerant to 2, 4-D and MCPA. Hence, recently the use of herbicides rotation and mixtures have been started to be practiced (Table 2). Although Terbutryne 500FW has been the only Pre-em. herbicide used against some of the annual grass weeds; its toxicity on the crop has restricted its application on large aceages. Hence, screening of promising herbicides against grass weeds seem to be important. Illoxan (Diclofop-methyl) is the post em. herbicide widely applied against wild oat (5).

Hand pulling or roughing is applied as a final teatment to remove those weeds which escape the main treatments (tillage and herbicides) (6).

WEED CONTROL RESEARCH ACTIVITIES

Yield losses due to weeds are much higher than generally recognized. In addition to reduction in grain yield a large amount of expense and time are incurred for mannual and chemical weed control. Hence, due consideration has been given to research in cultural and chemical control of weeds in wheat.

Weed-Crop competition Study

Growers often assume erroneously that removing weed competition any time during the growing season solves weed problem. However, substantial evidence indicates that time of removal is as important as removal itself (7). Unquesionably, the longer weeds compete after crop emergence, the greater their effect may be (7). Hence, in this study the time and frequency of handweeding neccessary to optimize grain yield with lower cost for weed control was determined (3).

Results

Handweeding was found to be more effective in controlling broad - leaved weeds than grasses which are similar in morphology and size to the crop (3).

The best time of weed removal by mannual hand pulling was found to be at early tillering (Et) (25 to 30 days after emergence) stage of the crop. Significant increase in grain yield over single handweeding at Et was not obtained by handweeding twice or three times at different growth stage of the crop. Handweeding at post heading is not advisable since it resulted lower grain yield than the unweeded check. Moreover, in areas where there is low weed infestation handweeding once at Et is economically profitable. Crop loss due to weed competition was found to be about 47% (3).

Chemical Weed Control

Some of the herbicides tested against broad-leaved weeds were 240 amine, MCPA, 24DP, Medoprop, Bromoxynil, ioxynil, Dicamba, cynazine and their mixtures. Most of these herbicides satisfactorily controlled the major broad-leaved weeds(Table 1). However, recently some weed species such as Guizotia scabra, Oxalis spp and Galium spurium were found to be more tolerant to phenoxy group of herbicides (24D, MCPA) than to hydroxy benzonitriles (ioxynil, bromoxynil), Dicamba and mecoprop mixtures (5,6).

Although pre-em. herbicides such as Terbutryne 500FW, Flouridefen, pendimethalin and Dichlofop-methyl showed better selectivity to the crop none of these herbicides satisfactorily controlled the major grass weed species (Setaria spp, Phalaris spp, Snowdenia spp, Bromus spp and Lolium spp), (6). Hence, screening of promising herbicides against grass weeds which are at present a menace to large scale state farms seem to be worth considering(5).

CONCLUSION

- Using clean crop seed should be encouraged to minimize the spread of weeds especially Avena spp and Lolium spp.
- Use of proper cultural practices such as time of land preparation, sowing, seeding rate and optimum time and frequency of weeding should be emphasized.
- Use of herbicides rotation and mixtures and crop rotation seem to be advisable to minimize the problem of tolerant broad-leaved and grass weeds.
- Due consideration should be given to research in screening of herbicides and other cultural control methods of grass weeds which are at present a threat to large scale wheat production
- Weed control research should be strengthened by increasing the number of trained man power in weed science and improving research facilities (Laboratory, means of transportation etc.).

REFERENCES

1. Birhanu Kinfe, 1980. Distribution and Control methods of weeds in Tef. Master's thesis, Addis Abeba University, College of Agriculture. Addis Abeba, Ethiopia.

2. Centeral Statistics Office (1971-80). Ethiopian Statistical Abstract.

3. Debre-Zeit Agricultural Research Center. 1984. Crop protection department progress report 1977-82. Addis Ababa, Ethiopia.

4. Institute of Agricultural Research. 1980. Wheat production guidline. IAR, Addis Ababa. Ethiopia.

5. Personal communication with farm manger in ministry of state farm.

6. Rezene Fesehaie. 1985. Review of weed science research activities in wheat and barley. Paper presented in the first Ethiopian crop protection symposium.

7. Aimdahl, R.L. 1980. Weed-Crop Competition. A review. International Plant Protection Center. Oregon State University, Corvallis, Oregon.

DISCUSSION

(N. A. MASHIRINGWANI):

What is the reason for the decline of wehar surface from one million ha to 600,000 ha?

Mostly is due to the shifting to tef which is a staple crop in Ethiopia. It has to do also with the drought that affected the country in the last few years.

Progress on weed control in the Hanang wheat complex, Tanzania

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ABSTRACT

A number of chemicals for grass weed control in wheat especially lovegrass (*Setaria verticillata*) were tested to determine whether they could be economically and effectively used for the control of *Setaria verticillata* and other annual grasses in wheat. Between the years 1983 - 1985 the following chemicals were tested.
1. Diclofop-methyl + bromoxynil 2. Isoproturon + 2,4-D 3. Methabenzthiazuron 4. Pendimethalin 5. Trifluralin 6. Isoproturon + Mecoprop. Results indicated that pendimethalin, trifuluralin and a mixture of diclofop-methyl + bromoxynil controlled lovegrass and resulted into significantly higher yields than a mixture of isoproturon and 2,4-D amine, methabenzthiazuron and the control (1984 progress report).

Economics of herbicide use were also evaluated by comparing the value of yield increase due to the use of a herbicide over that of the control and the cost of herbicide. Results indicated that it pays to apply effective herbicides to control lovegrass and other grasses in wheat.

INTRODUCTION:

The problem of annual grass weeds particularly lovegrass *Setaria verticillata* has been noted in northern Tanzania for a long time. At Hanang wheat complex where a total hecterage of more than 22,205 is under wheat cultivation, serious yield loses has been experienced due to lovegrass. In West Kilimanjaro, lovegrass has been described as a weed causing serious yield loses (1984 Progress report). The chemical weed control experiments conducted are aimed at the following objectives.

1. To determine the efficacy of herbicides used for the control of grass weeds in wheat such as lovegrass (*S. verticillata*).
2. To determine the economics of herbicide used for weed control.
3. To evaluate yield reduction due to lovegrass.

MATERIAL AND METHODS:

The experiment was located on an upland block which has a history of heavy lovegrass infestation. The wheat variety T.Mbuni was seeded using a double disc press drill at a rate of 100kg/ha.

The trial was laid out in a strip plot technique with each strip measuring 50m x 4m. The following herbicides (both pre and post emergence) were tested. 1. Pendimethalin 2. Trifluralin 3. Methabenzthiazuron 4. Diclofop-methyl + bromoxynil 5. Isoproturon + mecoprop 6. Isoproturon + 2,4-D.

The pre-emergence herbicides were applied immediately after seeding, whereas the post-emergence herbicides were applied when the wheat crop was at 3-4 leaf stage and lovegrass was at 2-3 leaf stage of growth. Spraying was done using a hand operated backpack sprayer, calibrated to deliver 150 l/ha at an output pressure of 2.11 kg/cm^2. Visual ratings of crop tolerance, and weed control were carried out at crop emergence for the pre-emergence treatments. For the post emergence treatments rating was done two weeks after application of the chemicals and also at boot stage. The assessment was rated on a 0-9 scale, where 0 indicates either no control of weeds or no Injury to the crop; and 9 means complete weed control (when applied to weeds), when applied to the crop indicates complete crop kill respectively (burrill et al 1976).

Harvesting was done by means of a Hege plot combine. Four samples, each from an area of $12m^2$ were harvested from each strip; cleaned, weighed and subjected to statistical analysis.

RESULTS AND DISCUSSION:

In 1984 results obtained indicated that there was no significant yield difference between trifluralin, pendimethalin and a mixture of diclofopmethyl and bromoxinil, however all three chemicals resulted in significantly higher ($p=0.05$) yields than a mixture of isoproturon and 2,4-D amine, methabenzthiazuron and the control (Table 1.). The poor performance of isoproturon in 1984 could be attributed to the dry conditions that prevailed before and after the chemical was applied as isoproturon is a urea derivative which is readly absorbed by the weed via the root system under moist soil conditions.

TABLE 1: 1984

Table 1: Rates of herbicide application, weed control, tolerance and grain yield at Basotu, 1984.

TREATMENT	Rate (kg ai/ha)	Weed Control %	Wheat tolerance (0-9)	Grain yield (kg/ha)
1. Control	-	-	0.0	240
2. Diclofop-methyly + bromoxynil	0.735+0.331	50	0.0	1040
3. Isoproturon + 2,4-D	1.5 + 0.56	0	0.0	290
4. Methabenzthia-zuron	2.8	0	1.0	210
5. Pendimethalin	1.5	85	0.0	1180
6. Trifluralin	0.8	90	0.0	1260
MEAN				703

In 1985, results obtained indicated that, pendimethalin, and a mixture of diclofop-methyl + bromoxynil resulted in higher yields than trifluralin, isoproturon + mecoprop, and isoproturon + 2,4-D. However all the five treatments, significantly outyielded the control p=(0.05) (Table 2.).

TABLE 2: 1985

Rates of herbicide application, weed control, tolerance and grain yield at Basotu, 1985.

TREATMENT	Rate (kg ai/ha)	Weed Control (%)	Wheat Tolerance (0-9)	Grain Yield (kg/ha)
1. Control	-	-	0	758.3
2. Diclofop-methyl + bromoxynil	0.735+0.331	90	0	1606
3. Isoproturon + 2,4-D	1.5 + 0.56	70	1	1169
4. Pendimethalin	1.5	90	0	1603
5. Trifluralin	0.8	85	0	1346
6. Isoproturon + mecoprop	1.2 + 2.0	85	1	1268
M E A N				1292

Grain yield reduction due to lovegrass competition could be estimated from the difference between the mean yields of the most effective chemical weed control treatment and the control plot mean yields. From the 1984 data grain yield reduction due to lovegrass competition was 81%. In some cases. where lovegrass infestation is very heavy and conditions are favourable for rapid development of the weed, complete crop kill (i.e. zero yield) may occur.

The economics of herbicide use could be evaluated by comparing the value of yield increase due to the use of a herbicide over that of the control and the cost of the herbicide.

Table 3 below compare the increase in yield due to trifluralin, pendimethalin and a mixture of diclofop-methyl and bromoxynil over that of the control in 1984. In computing monetary returns, the following factors were taken into consideration.

(1) The price of wheat per kilogram - 4/=

(2) The price of trifluralin (TREFLAN) per litre - 45/=

(3) The price of pendimethalin (STOMP) per litre - 156/=

(4) The price of diclofop-methyl + bromoxynil (ILLOXAN B) per litre - 168/=.

(5) d= difference in net returns between herbicide and control.

TABLE 3: Economic of herbicide use 1984

TREATMENT	YIELD kg/ha	YIELD INCREASE OVER CONTROL (kg)	VALUE OF YIELD INCR- (TSHS)	COST OF HERBICIDE PER HA (TSHS)	NET RETURNS (TSHS)	D (TSHS)	RELATIVE NET INCREASE (%)
1. Control	240	-	-	-	960	-	100
2. Trifluralin	1260	1020	4080	90	3990	+3030	415
3. Pendimethalin	1180	940	3060	468	3292	+2332	345
4. Diclofopmethyl + bromoxnil	1040	800	3200	504	2696	+1736	281

The use of herbicides resulted in 4 times relative net yield increase over the control (Table 3.) Therefore it is obvious that it pays to apply effective herbicides to control lovegrass and other grass weeds in wheat.

In the northern highlands of Tanzania, results of grass weed chemical control studies over the years (1980 - 1982 progress reports) have shown that Arelon (Isoproturon), Illoxan (Diclofop-methyl) and Dosanex (metoxuron) controlled lovegrass effectively. These chemicals are currently recommended for grass weed control in wheat in Tanzania.

TABLE 4: Recommended herbicides for grass weed control in wheat.

CHEMICAL	RATE OF APPLICATION (kg a.i./ha)	STAGE OF WEED GROWTH
ARELON (Isoproturon)	• 1.5	(i) When the grass is at 2-3 leaf stage (ii) When the soil is moist
ILLOXAN (Diclofopmethyl)	0.71	Same as above
DONSANEX (Metoxuron)	4.0	Same as above

The economic considerations for the use of these chemicals indicate that they can be economically used in wheat. However, their use should be limited to selective areas with the severe grass infestation for the operation to be economical, because of the current high costs of the herbicides. It is also recommended that good control can be effected if and when the applications are done correctly and timely. This is very critical when the infestation is wide spread and spraying capability is limiting.

CONCLUSION:

Results obtained todate indicate that pendimethalin and trifluralin at the rates of 1.5 and 0.8 kg a.i/ha applied as preemergence herbicides controls lovegrass effectively and resulted in higher yields. This agrees with similar work conducted in Kenya by Stobbe 1983 that pendimethalin effectively controls lovegrass (*Setaria verticillata*). A mixture of diclofop-methyl + bromoxynil when applied as post emergence herbicide at a rate of 0.735 + 0.331 kg ai/ha controled lovegrass effectively and some of the broadleaved weeds such as *Chenopodium* spp, *Amaranthus* spp and *Argemone* mexicana. These results agree with earlier finding of experiments conducted at Basotu (1982) that diclofop-methyl + bromoxynil controlled lovegrass effectively.(P.E.I.94)*and resulted in significantly higher yields (P=0.05).

This herbicide has an added advantage that the mixture is effective on both broadleaf and grass weeds and will therefore be very useful in large scale wheat production.

REFERENCES:

1. Zimdahl R.L. - weed crop competition (1980).
2. Harlan E.R. - weed control, cultural and chemical Ohio Agric. Education Service Agdex 641-1978.
3. L.C. Burril, J.Cardenas, E. Locateli - Field mannual for weed control research - International plant protection centre,Covallin Oregon (1976).
4. Stobbe E. Regional wheat workshop for Eastern Central and Southern Africa. (1983).
5. Crop protection Research report (1980,81,82,83,84)

*Percent effectiveness index.

DISCUSSION

(J. E. BRANDLE):

Was the trifluralin incorporated after application, and if so, what implement was used?

Ans. It was incorporated with a spike tooth harrow.

(W. C. JAMES):

Is the crop loss estimate of 80% reported in your paper, a representative figure for losses due to weeds in the Hanang Wheat complex of Tanzania?

Ans. Yes. Some years there are total losses due to weeds.

(E. BARAK):

To be effective, Stomp must be applied prior to irrigation or rainfall. What is your experience?

Ans. Both at Hanang and Arusha, Stomp controls lovegrass without immediate follow up of rain.

Wheat stem rust race identification in Ethiopia

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ABSTRACT

Stem rust is one of the important wheat diseases in Ethiopia. There were severe epidemics of this disease in different wheat growing regions in 1975 and 1976. In 1977, 1980, 1981 and 1983 there were local epidemics in different areas. Until 1974, races 9, 11, 14, 15, 17, 19, 21, 24, 32, 34, 40, 42, 53, 75, 83, 88, 115, 117, 122, 123, 126, 151, 295 and 296 were identified by different researchers. Regular studies of wheat stem rust physiologic race composition have been undertaken by the Scientific Phytopathological Laboratory (SPL), Ambo, Ethiopia, since 1974. During this period, the following 41 races were identified: 3, 9, 11, 14, 15, 16, 17, 21, 24, 25, 34, 40, 41, 42, 52, 53, 75, 83, 86, 88, 89, 102, 111, 115, 117, 122, 123, 131, 138, 143, 179, 184, 189, 194, 208, 229, 230, 243, 262, 270 and 294. Races 15, 40, 53 and 117 have been prevalent since 1974, the other races were of low frequencies.

INTRODUCTION

Wheat (*Triticum spp.*) is one of the main cereal crops in Ethiopia. It ranks fifth in hectarage and production after teff, barley, maize and sorghum (6). The wheat growing area in Ethiopia comprises about 529-550,000 hectares of land with the average yield of 8.8 q/ha (3, 4).

In Ethiopia this crop is subjected to frequent damage by a number of fungal diseases, one of which is stem rust. This disease generally causes heavy damage at altitudes below 2300 m above sea level (4, 9).

Effective control of wheat stem rust by resistant varieties requires continued monitoring of the variation in the pathogen population for virulence. These have been done annually in Ethiopia for several years, particularly after the establishment of the SPL in 1974.

The Period Prior To 1974

Studies on wheat stem rust physiologic race composition in Ethiopia started in the late 1930's (8). Further investigations were undertaken from the late 1950's to early 1970's (1, 2, 5, 6). However, the studies carried out up to 1974 were not regular, i.e. race surveys were not done annually. During this early period, samples of rust infected wheat or barley were sent to institutions outside the country (mainly to Cairo - Egypt and Minnesota - USA) for race identification.

Early stem rust studies were conducted by Sibilia in 1939 (8) and races 14, 17, 19, 24, 42, 75 and 88 were identified. In 1963, race 53 was also identified. During 1964, races 9, 14, 17, 21 and 24 were isolated, where as in 1965 the following fifteen races were determined at Giza: 122, 295, 17, 11, 296, 9, 14, 117, 53, 19, 21, 42, 123, 24 and 83 in order of prevalence (1). In 1969, races 9, 11, 14, 15, 17, 19, 53, 115, 117 and 123 were identified. In 1970, races 9, 11, 14, 17, 21, 24, 34, 53 and 117 were identified from Tigrai, Shewa, Arsi and Sidamo collections. Race 53 occupied the first rank accounting for 31.7% of the total isolates, race 24 came second, race 34 third, followed by races 17, 117, 11, 14, 9 and 21 (1, 2, 6). In 1973, Dereje Ashagari (5) reported races 15, 32, 34, 40, 126 and 151 from rust collections at Alemaya, Ethiopia. It is noteworthy that races 11, 14, 15, 17, 21, 24, 34, 42 and 117 appear to be common to Ethiopia and Kenya (6).

The Period From 1974 To 1984

Regular studies of wheat stem rust physiologic races have been undertaken by the SPL since 1974 (7). In this study two basic survey approaches are used. The first involves the use of mobile units with plant pathologists, travelling to major production areas. The second is based on a "special purpose" nursery, the Rust Spore Trap Nursery (RSTN) planted at many strategic locations. Results of annual physiological race surveys since 1974 are summarized below:

1974 - During this period, races 24, 20, 42, 53, 88 and 194 were identified.

1975 - The disease was scattered in the important production areas. Favourable environmental conditions led to moderate epidemics in Arsi, Bale, Hararge, Shewa, Sidamo and Wollega regions. Severity was about 50% on susceptible varieties cultivated by peasants, but loss was considered light. Races 24, 40, 52, 53, 88 and 117 were identified, with 40, 53 and 117 as predominant.

1976 - Severe epidemics were observed in the main wheat growing areas. There was a noteworthy heavy development of stem rust in off-season, especially on wheat cultivated under irrigation. Races 3, 9, 15, 34, 40, 42, 53, 88, 115, 117, 179, 189 and 208 were identified, with the prevalence of 15, 40, 42 and 53. The highly virulent race 189 was found in the collection from Alemaya.

1977 - Moderate local epidemics occured in Arsi, Shewa, Gonder and Gojam Administrative Regions. At Ambo and Debre Zeit the disease severity reached to 80%

on susceptible wheat varieties. Among 12 races identified, races 122, 123 and 262 were new records for Ethiopia. Races 53 and 117 were predominant. It should be noted that race 42 was more widespread than in 1975 and 1976.

1978 - 1979 Stem rust epidemics were practically absent in all regions of the country. However, there were light infections in many areas. In 1978, seventeen and in 1979 ten races were identified. As in the previous years races 53 and 117 were prevalent, races 24 and 40 were widely distributed.

1980 - Stem rust epidemics were encountered in some parts of Shewa region (Holetta, Debre Zeit, Ambo, Debre Sina). Races 53, 117, 138, 189, 243, 262 and 270 were identified, with 53 and 117 as predominant.

1981 - Moderate epidemics were observed in some parts of Arsi, Shewa and Sidamo regions. Races,namely 16, 41, 53, 75, 230 and 294 were isolated.

1982 - Stem rust epidemics were practically absent in almost all wheat growing regions. Only three races, i.e. 40, 53 and 117 were identified.

1983 - Local epidemics were observed in some areas of Shewa region. Sixteen races were identified, with the prevalence of 15, 53, 86 and 117. Races 86 and 89 were identified for the first time from a number of isolates. These two new races were found in 38.5% of the total isolates (9).

1984 - Rust diseases were not recorded in all the growing areas except Ambo, Debre Zeit and Burie. Wheat in different nurseries and production fields was virtually free from rust. Races 15, 53, 83, 86 and 89 were identified. The most prevalent races were 86 and 83 found in 55% and 17% of the total isolates, respectively.

Thus, a total of 41 stem rust races were identified from 1974 to 1984 (table I). Distribution of the important races is presented in Fig.I. Since 1974, races 15, 40, 53 and 117 were isolated frequently. Some races, namely 24, 34, 42, 88, 122, 189 and 262 were observed for about 4-6 years, while the others were found in trace amounts. There was no serious shift in the stem rust race composition from 1974 to 1984. However, there was an increase of the races 86 and 89 in the pathogen population since their appearance in 1983.

None of the Sr-genes were found to be resistant to all stem isolates. The genes Sr5, Sr22, Sr26, Sr27, Sr29, Sr30, Sr Tt-1, Sr Tt-2 and Sr Gt were lightly attacked by a few isolates. Genes from these series may be useful for developing resistant varieties.

Table I. Races of *Puccinia graminis tritici* identified in Ethiopia from 1974 to 1984

Year of identification	Type of races identified
1974	24, 40[a], 42, 53, 88, 194
1975	24, 40, 52, 53, 88, 117
1976	3, 9, 15, 34, 40, 42, 53, 88, 115, 117, 179, 189, 208
1977	24, 34, 40, 42, 53, 88, 117, 122, 123, 189, 262
1978	9, 14, 15, 17, 24, 25, 34, 40, 42, 53, 115, 117, 123, 184, 194, 208, 270
1979	15, 24, 40, 53, 102, 111, 117, 122, 229, 294
1980	53, 117, 138, 189, 243, 262, 270
1981	16, 41, 53, 75, 230, 294
1982	40, 53, 117
1983	9, 11, 15, 17, 21, 34, 40, 53, 83, 86, 89, 117, 122, 131, 143, 179
1984	15, 53, 83, 86, 89

[a] Prevalent races, numbers are underlined.

Fig.I. Distribution of important stem rust races in Ethiopia during 1974-1984.

Note: * prevalent races

** 11, 15*, 34, 40, 53*, 88, 117*, 131, 179.

References

1. Abdel-Hak, T. 1966. Report on identification of physiologic races of wheat rust in the Near East Countries and reaction of wheat and barley varieties to different races. Cairo. 14 pp.

2. Abdel-Hak, T., and A.Kamel. 1971. Identification of physiologic races of wheat rusts in the Near Eastern countries and reaction of wheat varieties to rust isolates. Information Bulletin, Cereal Improvement and Production Near East Project, FAO, 8: 17-21.

3. Central Statistics Office. 1979. Ethiopian statistical Abstract.

4. Dagnachew Yirgu. 1967. Plant diseases of economic importance in Ethiopia. HSIU, College of Agric. Expt. Stat. Bull, No 50, 30 pp.

5. Dereje Ashagari. 1973. Races of Puccinia graminis f. sp. tritici found at Alemaya, Ethiopia, in 1972. Plant Sciences Annual Research Report 3: 135-142.

6. Institute of Agricultural Research (IAR). 1970, 1971, 1972, 1982. Progress Reports for the period March 1968 to March 1969, April 1969 to March 1970, April 1970 to March 1971 and 14th National Crop Improvement Conference. Addis Ababa, Ethiopia.

7. Scientific Phytopathological Laboratory (SPL). 1977-1984. Annual Progress Reports. Ambo, Ethiopia.

8. Sibilia, C. 1939. Le razze fisiologiche di "Puccinia graminis tritici Erikss. et Henn." Nell' Africa Orientale Italiano. Bull. Staz. Pat. Veg. Roma. Anno XIX, Rome, Italy. Cf.Abdel-Hak, et.al. 1972. Present status of wheat stem rust in the Near East Region. In Regional Wheat Workshop, Beirut, Lebanon.

9. Temam Hussien. 1984. Distrubution and prevalence of physiologic races of Puccinia graminis tritici in some parts of Ethiopia and reaction of wheat cultivars to these races. MSc. thesis, Addis Ababa University.

Discussion

(A. L. DOTO):

What is the rate of breakdown of stem rust resistance in Ethiopia, and what strategies are you using to cope with the problem?

Ans. We know some varieties have been out of production because of resistance breakdown, but we do not have estimated the rate.

(A. MOSHA):

From the geographic distribution of races in Ethiopia, it appears as if some races are location specific. Can you suggest reasons for this distribution?

Ans. Race distribution follows that of the host. This is probably the reason in Ethiopia also.

(C. MANN):

In which manner are your efforts linked to those of other breeders to incorporate resistance?

Ans. We receive different material from breeders and test them against different rust races.

(E. E. WHINGWIRI):

How is the incidence of stem rust races in Ethiopia influenced by other countries?

Ans. Rust spores are windborne and may move across national borders. We do not have specific information on your question, and that is why we all must cooperate in order to have effective control.

The influence of plant architecture on levels of infection by Helminthosporium sativum in wheat

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Chilanga, Zambia

INTRODUCTION

Helminthosporium sativum, the pathogen causing spot blotch, is a serious disease problem of wheat in the tropics. As wheat production expands in the tropical areas of the world, a concerted breeding effort must be undertaken to alleviate this major production constraint (CIMMYT, 1981). Advances in breeding for resistance to this pathogen are slow, mainly because resistance is difficult to detect and incorporate into breeding lines. As in the case with resistance to *Septoria nodorum* (Fried and Bronniman, 1982), true genetic resistance to *Helminthosporium sativum* may be modified by certain disease escape mechanisms such as tallness. The purpose of this paper is to determine the extent of this escape mechanism in *Helminthosporium sativum* resistance.

MATERIALS AND METHODS

A single location experiment was conducted during January to May 1985. Twenty-three varieties were selected from yield trials, all except two contained at least one Brazilian parent exhibiting some resistance to *Helminthosporium sativum*. Varieties selected showed wide variation in height, peduncle length and length of the last internode.

The experiment was located at MT. MAKULU RESEARCH STATION, CHILANGA, ZAMBIA. The varieties were arranged in a randomized complete block design with 3 replications. Each plot contained 4 rows spaced 20 cm apart and a 60cm gap was left between each plot to minimize the influence of tall varieties on short ones. The seeding rate was approximately 64 seeds per metre. All plots were seeded on January 11, 1985.

The centre two rows of each plot was evaluated for flag leaf and ear infection levels 4 weeks after heading. A 0-9 scale was used for both leaf and ear ratings. Plant height, peduncle length (flag leaf ligule to base of the head) and length of the last internode (flag leaf ligule to 2nd leaf ligule) were measured five weeks after heading. Regressions and correlations between these factors and the sum of leaf and ear infection were calculated.

RESULTS

The regression between plant height and the sum of leaf and ear infection was significant (Table 1). The correleation between these factors was negative (Table 2). The regression between peduncle length and the sum of leaf and ear infection was significant and the correlation was negative.

TABLE 1. Analysis of variance table for regressions between plant height, peduncle length, length of the first internode and total infection level.

CHARACTER	SOURCE	DF	MS	F
PLANT HEIGHT	REGRESSION	1	40.24	7.81**
	RESIDUAL	21	5.15	
PEDUNCLE LENGTH	REGRESSION	1	48.80	10.29**
	RESIDUAL	21	4.75	
LAST INTERNODE	REGRESSION	1	37.55	7.11**
	RESIDUAL	21	5.28	

* indicates significance at the 0.05 level of probability

** indicates significance at the 0.01 level of probability

TABLE 2. Correlations between plant height, peduncle length, length of the first internode and total infection level.

CHARACTER	TOTAL INFECTION
PLANT HEIGHT	-0.52**
PEDUNCLE LENGTH	-0.57**
LAST INTERNODE	-0.50*

* indicates significance at the 0.05 level of probability

** indicates significance at the 0.01 level of probability

The regression between length of the last internode and the sum of flag leaf and ear infection was significant, the correlation was negative. Plant height varied from 61 cm to 110 cm, peduncle length varied from 9 cm to 20 cm and the length of the last internode varied from 18 cm to 31 cm.

DISSCUSSION/CONCLUSION

The negative correlation between plant height and the sum of flag leaf and ear infection indicates that taller plants tend to have lower disease scores. The relationship between the length of the last internode and the sum of leaf and ear infection is negative, as is the correlation with peduncle length. This would indicate that the greater the distance between the lower leaves and the flag leaf and ear, the lower the disease severity on the flag leaf or ear.

Inspection of the graphical representations of the data (Fig 1) indicates that short resistant varieties do exist. However, given the relationship between tallness and lower disease severity the trend in selection would be towards tall plants. A means of creating a uniform epidemic over a range of plant heights would be required in order to create uniform selection pressure. A greater understanding of the genetic nature of *Helminthosporium sativum* resistance would assist greatly in separating the enviromental effects from true genetic resistance and allow the formulation of an adequate breeding strategy.

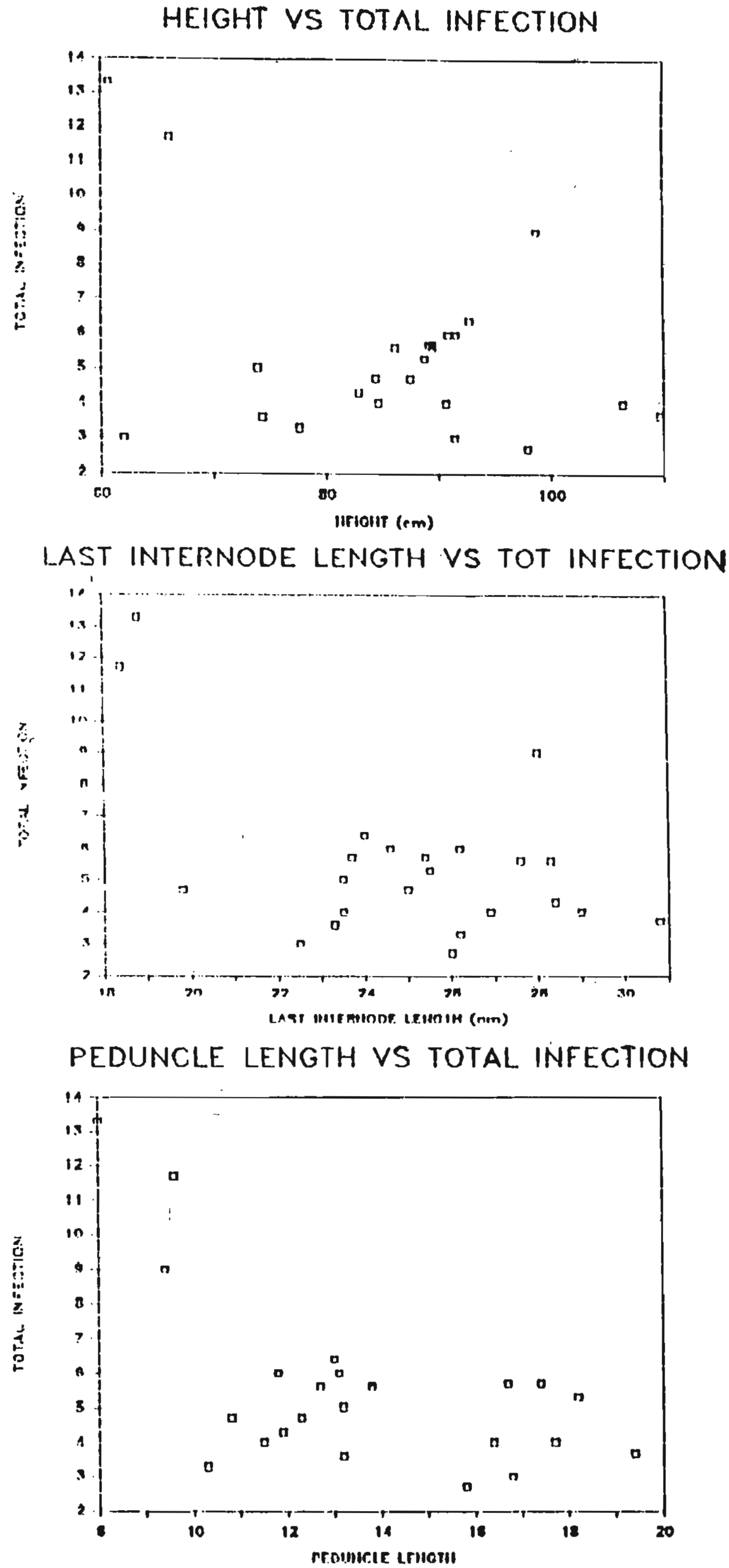

Fig 1. Graphical representation of components of height versus total infection.

At this point the bulk of the sucessful varieties in the Zambian National Wheat Triáls are tall (>90cm) and quite prone to lodging. As a consequence, lodging has set a yield ceiling on rainfed wheat production. Progress towards shorter varieties, with sufficiently high resistance under Zambian conditions has been slow. However, the use of Brazilian germplasm showing high levels of *Helminthosporium sativum* resistance in combination with adapted lines of good agronomic character should yield shorter resistant material. Field observations indicate that the genetic resistance is often weak and that these physical factors may be required to obtain suitable resistance levels under Zambian conditions. In cases where neither genetic resistance nor physical factors are present, as in the two lines without Brazilian parentage, (see Fig 1) infection levels are extremely high.

In conclusion, the presence of significant negative correlations between the components of plant height and *Helminthosporium sativum* infection levels indicate that disease escape plays a significant role in the evaluation of germplasm for resistance. It is apparent that further work on the genetics of resistance and a practical means of obtaining uniform epidemics are required in order to establish effective screening for both pure lines and segregating material.

REFERENCES

CIMMYT, 1981, International Maize and Wheat Improvement Centre. CIMMYT Rep. Wheat Improvement 1981, ElBatan, Mexico.

Fried, P.M. and Bronniman, A. 1982. Septoria nodorum Berk on wheat: Effect of inoculation time and peduncle length on yield reduction and disease development. Z. Pflanzenzucht 89:312-28

D I S C U S S I O N

(GETINET BEGEYEHU):

Is there a relationship between infection and crop maturity?

Ans. Yes; it is seen as late plants tend to escape disease.

(A. L. DOTO):

The plant characters that you associate with resistance appear to be negatively correlated with grain yield. Based on your results, what would be your advice to a wheat breeder?

Ans. My belief is that breeding should concentrate on genetic resistance rather than physical escapes. It is necessary to study mechanisms of resistance to *H. sativum* and their inheritance, because there is a tendency of losing resistance in shorter plants.

(G. L. RICHARDSON):

Dis you determine reasons why taller plants are less subject to attack that shorter plants?

Ans. The inoculum spreads by rain splash. Therefore, the longer the distance between lower leaves and head, the less the chances of infection.

C O M M E N T

(C. E. MANN):

Coefficient of determination for each character alone is about 0.25 and thus it should be interesting to calculate a multiple correlation among all of them. If factors are not additive, there is space to introduce genetic factors in determining resistance.

Tolerance of some wheat cultivars to septoria blotches

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Septoria blotches of wheat caused by *Septoria tritici* Rob. ex Desm. and *S. nodorum* (Berk) Berk are the second, next to the rusts, most important wheat diseases in Ethiopia (1,3). The yield loss due to these diseases could reach as high as 55 to 82 percent when a susceptible cultivar was planted early in the season (2,5,6). The replacement of the tall late maturing cultivars by short, early maturing ones together with the use of high fertilizer level had been reported to increase the severity of the diseases (8). Breeding for true resistance to Septoria blotches being complicated by the occurrence of physiologic races of the pathogen (4), breeding or selecting cultivars that are tolerant to the disease has been considered as one way of curtailing the problem (9,10).

Wheat cultivars that are currently on production in Ethiopia are not resistant to Septoria blotches. But most of the bread wheat cultivars were selected at Holetta Research Station under heavy Septoria blotches incidence. This study was undertaken to determine if some of these cultivars exhibit tolerance to the disease and to examine methods for measuring tolerance.

The test was made for three seasons begining in 1982/83 at Holetta Research Station. Seven bread wheat cultivars namely; K6106-9, Kvz x Kal-Bb, 7C-An x INIA-B.Man, ET13A2, Veery 11, Bobwhite 52, Romany back cross and Laketch as susceptible check were obtained from the National Wheat

Improvment Program. These were planted in paired plots, sprayed and unsprayed in three replications. Sprayed and unsprayed plots were separated by 5 rows tall oat cultivar to avoid spray drift. Three rows of susceptible wheat cultivar was planted on the side of unsprayed plots to initiate high disease pressure. Benomyle (Benlate) 0.03% and Fentinacetate + Maneb (Brestan 60) 0.1% were used alternately at 7 days interval starting at the on-set of the diseases. Several scorings on 0 to 9 scale (0 = no disease and 9 = the disease reached the head) for disease progress and a 0 to 5 rating Of 100 flag leaves per plot for disease severity has been done. 1000 seed weight was taken for yield analysis since seed weight is the main yield component affected by the disease and is a useful measure of tolerance (10). Reduction in 1000 seed weight for one interval difference in the 0 to 9 and 0 to 5 scorings between sprayed and unsprayed plots was determined for each cultivar as follows:-

$$\frac{\text{Difference in 1000 seed wt between sprayed \& unsprayed}}{\text{Difference in 0 to 9 or 0 to 5 scoring between sprayed \& unsprayed}}$$

Seed weight ratio (7) was also determined for each cultivar as:

$$\frac{\text{1000 seed wt of unsprayed}}{\text{1000 seed wt of sprayed}}$$

The results of the disease scores and 1000 seed weight are shown in Table 1. Cultivars were compared under sprayed and unsprayed treatments. Most cultivars showed significant difference from each other in Septoria blotches as measured by both 0 to 9 and 0 to 5 scorings when sprayed. When not sprayed however most cultivars, excluding the susceptible check, were not significantly different from each other. This indicates that some cultivars responded differently to the fungicide spray treatments. As indicated by the result of the percentage loss in 1000 seed weight there would be very little increase in yield by spraying cultivars such as K6106-9 and 7C An x INIA - B. Man. On the otherhand, spraying Veery-11 and Laketch which showed about 14 to 30% loss could have a positive economic impact. Cultivars K6106-9 and 7C An x INIA - B.Man were not significantly different from Veery-11 in the 0 to 9 scores when not sprayed. But the large difference in the seed weight loss may indicate that the two cultivars were more tolerant than the Veery-11.

Low values of reduction in 1000 seed wt for one interval difference in disease scores and high values of seed wt ratio were obtained for cultivars K6106-9 and 7C An x INIA - B. Man (Table 2). This again indicates that these two cultivars were relatively tolerant than the rest. The reduction for one interval difference in 0 to 9 score for the cultivar Bobwhite 52 was the same as the susceptible Laketch but its seed weight ratio was the third largest along with Romany BC.

The three parameters used to assess the relative tolerance of the cultivars were good measure of tolerance. There was high positive correlation between the reduction values measured by 0 to 9 and 0 to 5 scorings ($r = 0.74$, $p = 0.05$). The correlation between the reduction values for one interval difference in these scores and 1000 seed weight ration was high and negative ($r = -0.67$, $p = 0.05$). Any one or a combination of these can satisfactorily be used as measures of tolerance of wheat cultivars to Septoria blotches.

Table 1. Septoria blotches scores and 1000 seed weight of 8 bread wheat cultivars under sprayed and unsprayed treatments. Average of 3 seasons

Cultivars	0 - 9 Scores		0 - 5 F.L. Scores		1000 seed wt (g)		
	S	US	S	US	S	US	% Losse
K6106-9	3.1	4.2	1.2	1.9	35.3	34.6	2.0
Kvz X Kal - Bb	2.4	4.2	0.6	1.6	40.3	36.1	10.4
7C - An X INIA - B.Man	2.9	4.2	0.8	1.7	35.3	34.1	3.4
ET13A2 .	2.9	4.6	1.2	2.0	41.6	38.7	7.C
Veery 11	3.1	4.8	1.1	2.7	40.6	35.1	13.5
Bobwhite 52	3.5	3.9	1.4	2.0	36.1	33.8	6.4
Romany BC	2.7	3.8	0.8	1.7	41.9	39.2	6.4
Laketch (suscept. check)	4.4	6.1	2.2	4.4	33.0	23.2	29.7
LSD (0.05)	0.85	0.97	0.44	0.46	1.9	2.6	

F. L. = Flang leaf, S = Sprayed, US = Unsprayed

Table 2. Reduction in 1000 seed weight (g) for one interval difference in disease scores and 1000 seed wt ratio for the 8 bread wheat cultivars. Avg. of 3 seasons.

Cultivars	1000 Seed wt. reduction for one interval difference in: 0 - 9 Score	0 - 5 Score	1000 Seed wt. ratio
K6106-9	0.6	1.0	0.98
Kvz X Kal - Bb	2.3	4.2	0.90
7C-An X INIA - B.Man	0.9	1.3	0.97
ET13A2	1.7	3.6	0.93
Veery 11	3.2	3.4	0.86
Bobwhite 52	5.8	3.8	0.94
Romany BC	2.5	3.0	0.94
Laketch (Suscept.check)	5.8	4.5	0.7C

R E F E R E N C E S

1. Dagnatchew Yirgu 1967. Plant Diseases of economic importance in Ethiopia. H.S.I.U. College of Agric. Experiment Station Bull 50 P. 12

2. Eshetu Bekele 1983 Wheat Diseases in Ethiopia proceeding of the Regional Wheat Workshop for Eastern, Central and Southern Africa. Arusha, Tanzania June 13-17, 1983 PP. 92-94

3. Eshetu Bekele, 1985. Review of Research on Diseases of Barley, Teff, and Wheat (unpublished). Paper presented at the 1st crop protection symposium Feb. 4-7 Addis Ababa, Ethiopia

4. Eyal, Z. Z. Amiri, and I. Wahl 1973. Physiologic Specialization of Septoria tritici. Phytopathology 63: 1087-1091

5. Hingurani, H. 1971. Terminal Report Institute of Agric. Research Addis Ababa, Ethiopia.

6. Institute of Agricultural Research (IAR) 1970 Holetta Genet Research Station. Progress Report for the Period April 1969 to March 1970 Addis Ababa P. 1962

7. Politowski, K., and J. A. Browning 1978. Toleranc and Resistance to Plant Diseases: An epidemiological study. Phytopathology 68: 1177-1185

8. Saari E.E., and R. D. Wilcoxson, 1974 Plant Disease Situation of high-yielding dwarf wheats in Asia and Africa. Annu. RRev. Phytopathol. 12: 49-68

9. Ziv., O., and Z. Eyal, 1976 Evaluation of tolerance to Septorial Leaf blotch in Spring Wheat. Phytopathology 66: 485-488

10. Ziv. O., J.M. Sacks and Z.Eyal. 1981 Inheritance of tolerance to Septoria leaf blotch of Wheat Phytopathology 71: 119-123

D I S C U S S I O N

(K. G. BRIGGS):

Are you using the association of reduced seed shrivelling under intense infection to select for tolerance in segregating populations by bulk seed screening?

Ans. This method was not in use.

(L. M. M. MURIITHI):

Given the complexity of the Septoria group, how did you do the scoring? Also, how did you differentiate true Septoria lesions from other similar symptoms?

Ans. At Holetta there are *Septoria tritici*, *S. nodorum* and *S. avenae*, but we did not score separately. In the scoring we included only those lesions which are clearly caused by a Septoria organism. When in doubt we collect pycnidia for further laboratory confirmation.

C O M M E N T

(HAILU GEBRE-MARIAM):

Some of the varieties which were reportedly tolerant to speckled blotch are now being grown and they are taller than the susceptible varieties such as Lakesch.

Isolation and evaluation of host specialization of an isolate of Sclerotium rolfsii

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Sclerotium rolfsii sacc., causal agent of Southern blight, is a soil-borne plant pathogen which infects a wide host range. The pathogen causes economically important diseases in warm, moist climates and acidic soils throughout the world(2). In Kenya, there is little information on this important plant pathogen particularly on cereal crops. The pathogen has been reported to infect coffee, ground nuts, potatoes etc.(4.5). The incidence of this pathogen has been low although the disease may increase in importance on cereal crops.

Field collections of S. rolfsii represents hererogeneous isolates (8,9). The isolates form characteristic small spherical tan to dark brown sclerotia which survive for a long time in the soil. The survived sclerotia or mycelia in the soil can initiate infection of susceptble hosts(6). The symptoms of this disease have been described previously (1,7).

The purpose of this preliminary study was to evaluate effects of S. rolfsii obtained from a barley variety(Bima) on various crops with particular reference to cereals.

MATERIALS AND METHODS.

Isolation: Diseased barley plants were collected from **Mahari Farm, Endebess, Kitale.**

Several 1cm pieces of the crown were cut and sterilized for 1 min. in 2% sodium hypochlorite solution (NaOcl), rinsed in sterile water and plated on PDA. The cultures were incubated at normal room temperature.

<u>Identification:</u> Between 2-3 days of incubation, typical mycelial growth emanating from lesions were observed through a dissecting microscope. The heavy mycelial growth was followed by formation of white sclerotia which gradually changed colour to tan, later dark-brown within 10 days.

Single sclerotia cultures were developed on PDA from randomly selected sclerotia. These cultures were re-plated on PDA (four per petri-dish). Lack of formation of a barrage indicated that the isolates were similar and, therefore, the isolate was treated as a single isolate. A single sclerotia isolate was used in subsequent tests.

<u>Innoculation:</u> Seeds of wheat varieties (K. Fahari, K. Popo and K. Kulungu), barley (Bima and Proctor), Oat (Sure grain) and Maize (H625) were pre-germinated on sterile petri-dishes. In addition, soybean (Bunia and Hill), ground nuts (2 varieties) and dry bean (Rose coco) were used as check host crops. Twenty germinated seeds with only redicle developed, were placed on culture on PDA in a petri-dish for 36-48hr before transfering them onto 6" plastic pots containing sterile soil. Another set of 20 seeds was placed directly on the soil previously innoculated on the surface with micerated agar media containing the culture.

The experiment was replicated four times and each replicate included two control pots. In one of the control pots, the germinated seeds were placed directly on PDA without the pathogen whereas in the other control seeds were placed on sterile soil. Both were covered with a layer of sterile soil.

Counting: The number of seedlings which dumped-off either pre-emergence or post-emergence was determined through counting. The average height of plants which survived was measured at heading stage.

RESULTS AND DISCUSSION:

Greenhouse and Laboratory observation confirmed that the fungal isolate from the barley variety Bima was *Sclerotium rolfsii* Sacc. causal of Southern blight. The typical mycelial growth on PDA agar media emanating from the germinated sclerotia or white mycelia on host tissue and the size, shape and colour of sclerotia confirmed the identity of the pathogen. The young colonies were white and some of the hyphae had clamp connections at some strands (teleomorphs) and small spherical tan to dark-brown sclerotia. The hypae tip cells were multinucleate. These observations are in agreement with the previous reports (1,8).

Germinated seeds directly placed on the culture and then covered with sterile soil dumped-off. Heavy white mycelia and numerous sclerotia developed around the wilted seedlings.

However, one plant survived to heading to heading but did not fill. The germinated seeds placed on theculture and the seeds placed on innoculated sterile soil behaved similarly and, therefore, the results of the two treatments were pooled (Table 1). There was a marked difference between seedlings in the treated pots and the controls for all crops tested. Some of the seedlings dumped-off (pre- and post-emergence), some of the survirors wilted, others had yellow lower leaves and a few survived to maturity. Most of the wilted plants had several sclerotia around the crown.

Samples taken from the plants appearing healthy yielded the pathogen. The observation suggested that some degree of resistance may exist in crops tested and this possibility calls for further evaluation for resistance in greenhouse under controlled environments. A significant genetic variability in other crops has been suggested(3). Further more, variability within pathogen's isolate has also been indicated(8).

The host crop plants tested confirmed that the pathogen has no host specialization. However, some of the host crops appeared more susceptible to the isolate than the others (Table 1). Among the cereal crops tested, wheat and barley were more affected. The legumes tested as check hosts (not included in Table 1) indicated that groundnuts (Peanuts) soybeans were more susceptible. Although the rate of growth of infected and control plants differed in height, the differences were not considerable (Table 1).

Table 1 Effect of *Sclerotium roflsii* on Wheat, Barley, Oats and Maize Seedling Emergence and Development

			WHEAT				BARLEY				OATS		MAIZE	
	K. Fahari		K. Kulungu		K. Popo		Proctor		Bima		Sure grain		H 652	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b
Emerged Seedlings(%)	95	100	100	75	65	85	100	100	90	80	70	100	100	100
Survived Seedlings(%)	58	85	40	55	35	65	35	95	56	100	50	100	90	100
Height(cm)	47.6	50	22.2	38.2	30.7	34.2	36.7	38.2	24.	25.9	25	41	nm	nm

a = Inoculated; b,= Control; nm = not measured.

This may suggest that the greenhouse environment was not conducive enough for total expression of the organism's pathogenicity. Probably the soil pH, which was not adjusted at the start of the experiment may have affected the performance of the pathogen reducing its impact on the development of the various crop plants tested.

These preliminary findings indicated that if this pathogen increased in Kenya, it may cause a significant economic loss particularly to susceptible host crops grown in warm-humid areas with acidic and sandy soils. The current disease surveys have revealed both scattered individual plants and small patches in several wheat fields. The observations dictate an intensive investigation on spread, incidence, severity as well as determination of economic loss particularly in the wheat and barley production.

ACKNOWLEDGEMENTS.

The authors wish to extend their sincere thanks to the Ministry of Agriculture and Livestock Development through the Director N.P.B.S., Njoro for the major support, K.S.C. Ltd. for collecting the diseased plants, Mr. L. Mumela, Egerton College, for providing certified legumes' seed and staff members of Pathology Section N.P.B.S. Njoro for their dedication during the tenure of the experiment. All the above made this work possible.

LITERATUE CITED:

1. Agrios.N.G. 1978. Plant Pathology. 2nd Edition AP NY 703pp.

2. Aycock,R. 1966. Stem rot and other disease caused by Sclerotium roflsii. North Carolina Agr.Exp.Sta.Tech. Bull. 174:202pp.

3. Dukes,P.D., R.L. Ferry, Alfred Jones, U.S.D.A. 1983. Evaluation peppers, cowpeas, sweet potatoes and tomatoes for resistance to southern blight incited by sclerotium rolfsii sacc. Abstr. Phytopathol. 73(5):155.

4. Nattrass,R.M. 1961. Host lists of Kenya fungi and bacteria E.A.A. & F.R.O.

6. Punja,Z.K. and Grogan,R.G. 1981. Production of perfect (basidial) state of Sclerotium rolfsii. in culture and its potential significance. Abstr. Can. Plant Pathol. 3:118.

7. Punja,Z.K. Grogan,R.G. and Adama,G.C.Jr. 1982. influence of nutrition, environment, and an isolate on basidiocarp formation, development and structure in Athelia(Sclerotium)rolfsii. Mycologia 74:917-926.

8. Punja,Z.K. and Grogan,R.G. 1983a. Basidiocarp induction, nuclear condition, variability, and heterokaryan incompatibilty in Athelia(Sclerotium) rolfsii. Phytopathol. 73:1273-1278.

9. Punja,Z.K. and Grogan,R.G. 1983b. Hyphal Interactions and antagonism among field isolates and single-basidio-spore and strains of Athelia(Sclerotium) rolfsii Phytopathol. 73:1279-1284.

(C. E. MANN):

Inspite of the relatively low importance of this disease, there is need to work on it because wheat may move towards warm and humid environments. From my experience I cannot confirm that soil pH is an influencing factor. There is one preliminary report that indicates genetic variability in reaction to this disease. Since rice - wheat rotations are being followed in the Region, this research should be encouraged.

Barley Yellow Dwarf in central Ethiopia

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ABSTRACT

In 1984, low incidences of barley yellow dwarf (BYD) in wheat and barley crops have been recorded in Arsi and Bale administrative regions in Central Ethiopia. Positive ELISA reactions with antibodies to PAV and MAV isolates of BYDV were obtained for wheat and barley samples from Bekoji and Herero, while the samples from Goffer presumably contained only PAV-related virus. None of the samples from any of the locations surveyed displayed positive ELISA values with antibodies to RPV isolate. These results strongly suggest the presence of some BYDV isolates in major wheat growing areas of Ethiopia.

Barley yellow dwarf (BYD) is probably the most widely spread and economically important virus disease of small grain cereals. It was recorded throughout Europe, both Americas, Australia, New Zealand, and Africa. BYDV has its host range restricted to monocotyledonous plants, including most cereal crops and more than 100 species of wild grasses serving as natural reservoirs of the virus (Fargette et al., 1982; Wiece, 1977).

BYDV is transmitted by aphids persistently. More than 20 aphid species are known as efficient virus vectors, and some new species are still being reported to be involved in BYD spreading (Jedlinsky, 1981). Isolates of the virus are differentiated by their vector specificity, serology, and ultrastructural effects caused in plant tissues (Burnett, 1983).

BYD symptoms were more than once observed in Ethiopia (Stewart and Dagnatchew, 1967; Torres, 1983), but no laboratory identification has been conducted so far. Some data also suggested the presence of the disease in the country. Thus, highly BYD-resistant types in the world barley collection were found only from Ethiopia (Qualset, 1975). Surprisingly, the sources of resistance were non-randomly distributed in the country, with the increase of resistance frequency in sample collections from higher altitudes (Qualset, 1975). Aphid species known as principal BYD vectors, e.g. *Diuraphis noxia*, *Rhopalosiphum maidis*, *R. padi*, *Sitobion avenae*, and *Schizaphis graminum*, are distributed in Ethiopia (Crowe and Kemal, 1983).

This study was aimed to confirm BYDV presence in major cereal growing areas of Ethiopia. The survey was conducted at Debre Zeit, Debre Birhan, Sheno (Shewa), Asasa, Bekoji, Meraro, Kulumsa, Goffer and Dixis (Arsi), and Herero (Bale). At the time of observation (September) wheat crops inspected in experimental plots, farmers fields, and state farms, were at the heading stage. ELISA tests for dried leaf samples were done in accordance with the previously described method (Lister and Rochow, 1979). Each sample was tested in duplicate against antibody to PAV, MAV, and RPV isolates of BYVD. It should be noted that antibodies to PAV isolate normally react with PAV-like virus only, while MAV antibodies, besides specific reaction with homologous MAV antigen, also displayed non-specific (and more weak) reaction with PAV-like isolates.

Upon surveyes, BYD-like symptoms (stunting, rosetting, leaf yellowing and reddening) have been found at low incidences in most of the locations. The presence of BYDV antigen was confirmed in wheat and barley samples collected from Bekoji, Herero, and Goffer, at altitudes ranging from 2500 to 2800 meters above sea level (Table I). Thus, the results suggest PAV and MAV-like isolates in the samples from wheat and barley varietal trials at Bekoji and Herero, while wheat samples of the variety Bulk from Goffer state farm presumably contained only PAV-related virus. None of the samples tested showed positive reaction with antibody to RPV isolate (data not shown).

Low virus incidences in cereals in 1984 crop season might be particularly attributed to the lack of aphid vectors due to unusually dry conditions. In accordance with our observations and communications from experimental stations and state farms, aphids were much less abundant in most of the locations in comparison with previous years.

Ethiopia is considered to be one of the centers of origin and accumulation of cultivated wheat and barley, where the crops are grown under the vast range of ecological conditions. The crops land races are still used throughout the country; in some areas, however, an intensive cultivation of cereals, employing monocultures and genetically monogenous varieties has been increased in recent years. In this respect, the further study of BYDV isolates distribution in Ethiopia is of particulat interest.

Table I. ELISA values for wheat and barley samples collected from Central Ethiopia (Jan 9, 1985)

No	Sample kind nd origin	Antibody	
		P A V	M A V
1.	Bekoji, wheat	0.208	0.594
2.	Bekoji, barley	0.151	0.461
3.	Goffer, wheat	0.103	0.144
4.	Herero, wheat	0.185	0.607
5.	Asasa, wheat	0.045	0.137
6.	Dixis, wheat	0.036	0.152
7.	Huruta, wheat	0.039	0.137
	PAV standard [a/]	1.300	1.710
	MAV standard [a/]	0.093	1.931
	RPV standard [a/]	0.033	0.127
	Healthy control oats	0.034	0.147

[a/] = fresh, recently infected tissue.

References

Burnett, P.A. Preface in Barley Yellow Dwarf, Proceedings of the Workshop. CIMMYT 1984, pp. 6-13.

Crowe, T.J., and Kemal, A. 1983. A check list of aphids recorded from Ethiopia. IAR Entomological Bulletin No 3, Addis Ababa.

Fargette, D., Lister, R.M., and Hood, E.L. 1982. Grasses as a reservoir of barley yellow dwarf virus in Indiana. Plant Disease 66: 1041-1045.

Jedlinsky, H. 1981. Rice root aphid, R h o p a l o s i p h u m a b d o m i n a l i s, a vector of barley yellow dwarf virus in Illinois, and the disease complex. Plant Disease 65: 975-978.

Lister, R.M., and Rochow, W.F. 1979. Detection of barley yellow dwarf virus by enzyme-linked immunosorbent assay. Phytopathology 69: 649-654.

Qualset, C.O. 1975. Sampling germplasm in a center of diversity: an example of disease resistance in Ethiopian barley. In: Crop Genetic Resources for Today and Tomorrow, O.H.Fraenkel and J.W.Hawkes, Eds. Cambridge Unisersity Press, pp. 81-98.

Stewart, R.B., and Dagnatchew Yirgou. 1967. Index of Plant Diseases in Ethiopia. Addis Ababa University, College of Agriculture, p. 35.

Torres, E. Situation report for Eastern, Central and Southern Africa in Barley Yellow Dwarf, Proceedings of the Workshop, CIMMYT 1983, p. 197.

Wiece, M.V. 1977. Compendium of Wheat Diseases. The American Phytopathological Society, pp. 64-65.

Discussion

(J. M. ORONDO):

BYDV has been reported from Ethiopia. I would like to hear from other countries.

i (RAKOTONDRAMANANA): The disease is difficult to identify precisely without the adequate equipment, so that even if it is present, the problem may not be identified as BYD.

ii (M. W. OGGEMA): Although there were no firm reports of BYDV in Kenya, the Station Virologist has observed it recently on several varieties.

(N. A. MASHIRINGWANI):

BYDV has been reported on barley but not on wheat in Zimbabwe. Are there host specific strains?

Ans. There are no host specific strains. It is likely that BYDV symptoms on barley are more evident than those on wheat in your country. In that case, closer observations or even laboratory methods would be needed for diagnosis.

Comment

(C. E. MANN):

The above discussion indicates the need to train ourselves to identify symptoms of BYDV and thus be able to make field diagnosis. There are basis features that make one suspect of BYDV.

Bacterial stripe and black chaff of wheat in Ethiopia

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ABSTRACT

Bacterial stripe and black chaff were recorded on wheat varieties and monogenic lines grown in SPL collection at Ambo, Ethiopia. The pathogen was identified as *Xanthomonas campestris* pv. *translucens*, based on the studies of its biological properties.

Wheat is often affected by a number of bacterial diseases distributed in many cereal growing regions of the world, e.g. bacterial leaf blight(pathogen *Pseudomonas syringae*), basal glume rot (*P. atrofaciens*), spike blight (*Corynebacterium tritici*), pink seed (*Erwinia rhapontici*), and bacterial stripe and black chaff (*Xanthomonas translucens*). Some these diseases are economically important and widely distributed (Peresypkin, 1974; Wiese, 1977; Zillinsky, 1983).

In Ethiopia, the symptoms of black chaff disease were recorded in Shewa province earlier (Stewart and Dagnatchew, 1967). However, bacterial diseases of wheat have not been properly studied, and the pathogen isolation has not been conducted so far. In this study, we report the presence of bacterial stripe and black chaff caused by *Xanthomonas campestris* pv. *translucens*, on wheat varieties and monogenic lines grown in SPL collection at Ambo, Central Shewa.

Primary field symptoms, namely thin water-soaked stripes or elongated spots of different length, were observed in July 1985, at the jointing stage of the crops. Later these stripes became widened, with the appearance of light to dark brown necroses. Besides necrotic stripes, the disease was accompanied with the appearance of greyish-yellow or greyish-green irregular spots. The exudate droplets of different size were produced at the early stage of the disease. These cloudy yellow or grey droplets usually were clearly observed early in the morning, in humid conditions, being then dried and forming shiny films on leaf blades. Dark stripes and water-soaked streaks were also formed on the glumes and lemmas, with no exudate produced.

The incidence of bacterial stripe depended on variety or line of the host, ranging from 5 to 100% (Table I).

Table I. Affection of wheat varieties and monogenic lines by the bacterial stripe at Ambo, Ethiopia.

Varieties and lines	Per cent of bacterial affection*
Sr Tt_1	100
Sr T_2	100
Sr Gt (var.Gamut)	100
Lr B	21
Lr T	100
Cno-Chris x On/Nar 59-On SE 54...	15
Lr 4	22
Lr 10	15
Lr 11	15
CAR 853-Cocoraque 75 x Veery "S"	11
Lr 12	10
Conley	5

* Average from 3 replications, 500 plants each.

Thirty two bacterial isolates from total of 42 isolated and tested, have been shown to possess pathogenicity and caused the symptoms described above. The pathogenicity was determined either by pouring bacterial suspension (10^8 cells/ml) on wheat leaf surface with subsequent leaf injury with sterile needle, or by stem injection. A majority of isolates which produced yellow pigment on solid medium, caused bacterial stripe on leaves. These data are in good agreement with the results obtained previously (Wiese, 1977; Zellinsky, 1983).

All the yellow pigment-producing isolates tested appeared to be Gram-negative, with respiratory metabolism of glucose and other carbohydrates, never fermentative, and oxidase-negative (Table 2). Bacteria produced large amount of slime on nutrient media. The cells were visualised as single straight rods under light microscope after staining. They moved directly when examined in suspension.

Table 2. Biochemical properties of bacterial strains isolated from striped wheat samples at Ambo, Ethiopia

T e s t s		Number of strains displayed positive results	Number of strains displayed negative result	Total number of strains tested
Glucose utilization				
in aerobic conditions		14	-	14
in anaerobic conditions		-	14	14
Production of yellow pigment		24	-	24
Protopectinase		-	24	24
Oxidase		-	24	24
Catalase		24	-	24
Starch hydrolysis		24	-	-
Utilisation of:	mannose	18	6	24
	arabinose	20	4	24
	galactose	24	-	24
	sorbitol	9 slowly	8	17
	dilcitol	1	10	11

Taken together, these data allow one to suggest *Xanthomonas campestris* pv. *translucens* as a causal agent for the disease.

Besides yellow pigment-forming isolates, some wheat samples contained a distinct bacterium forming grey colonies on solid medium. The grey colony-forming isolates produced chlorotic lesions later transformed into light-brown irregular spreading spots. The further identification of this group of isolates is in progress.

REFERENCES

Dye, D.W. 1980, *Xanthomonas* In: Laboratory Guide for identification tion of Plant Pathogenic Bacteria, Bacteriology Committee of American Phytopathological Society, Minnesota, pp. 45-49.

Dye, D.W., and Lelliott, R.A. 1974. *Xanthomonas* Dowson, 1939. In: Buchanan and Gibbons (editors). Bergey's manual of determinative bacteriology, 8th ed., The Williams and Wilkins Co., Baltimore.

Peresypkin, V.F. 1974 Agricultural Phytopathology, Moskva, "Koloss", pp.66-69.

Stewart, R.B., and Dagnatcew Yirgou. 1967. Index of plant diseases in Ethiopia. Experiment Station bulletin 30, pp. 28-45.

Wiese, M.V. 1977. Compendium of wheat diseases. The American phytopathological Society, pp. 7-10.

Zillinsky, F.J. 1983. Common Diseases of Small Grain Cereals. A Guide to identification, Mexico, pp.101-107.

Screening of wheat cultivars for antibiotic resistance against the greenbug (Schizaphis graminum Rondani; Aphididae: Homoptera) in Kenya

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ABSTRACT.

Fifty wheat cultivars were examined for resistance against Schizaphis graminum Rondani in preliminary tests. Though no significant differences were observed in the capacity for increase (r_c) of the greenbugs on these cvs, four cvs with lowest and two with highest r_c values were selected and retested. Kenya Kulungu, K.Kiboko and K.Leopard are promising antibiotic cvs. K.Kifaru and K.Paka are susceptible to greenbug attack. Tolerant cultivars Africa Mayo, R306 and Kenya Fahari also possess antibiotic mode of resistance. The use of the r_c and the net reproductive rate(R_o) for determining the antibiotic mechanism of resistance is preferred to use of the (R_o) alone.

INTRODUCTION

The greenbug is a serious pest of seedling wheat and other small cereals (Starks and Burton, 1977a; Starks and Merkle, 1977) and in outbreaks years severely decreases crop yield if chemical control is not applied (Starks et al., 1975; Wilson et al., 1978). This aphid occurs in many parts of the world (Hill, 1975). In Kenya several outbreaks have been reported on young wheat (Wanjama, 1979). Where such outbreaks have occurred and chemical insecticides not applied total crop loss has been experienced in many cases.

The damage to seedling wheat is caused through direct feeding of the greenbugs and by toxic saliva injected into the plant tissue during feeding (Starks and Burton, 1977a). Elsewhere varieties of wheat (Joppa et al., 1980) sorghum (Morgan et al, 1980) Oats and rye (Starks and Burton 1977b) resistant to the greenbug have been used to reduce losses. No wheat varieties developed in Kenya have so far been screened for resistance against any insect pest. This work aims at identifying wheat cultivars that may posses antibiotic resistance mechanism. If identified, such cultivar(s) will be a source of resistance for developing future wheat varieties that will reduce losses incurred through the feeding of the greenbug. If commercial varieties are identified to be resistant, farmers will be encouraged to grow them to reduce losses due to the greenbug.

MATERIALS AND METHODS

Greenbugs were corrected from the field in Njoro in 1982 and placed in the greenhouse. Later a single female was removed from the greenbug population and placed on a potted wheat seedling and caged to raise a new clone. The cage consisted of a wire frame with a covering of a sleeve of nylon mesh. When a good colony of the new clone was established on the seedling the potted seedling bearing the clone was transfered into a bigger cage made of plexi glass with a big ventilation on top covered with nylon mesh. One side of this cage had no glass and was fitted with a long sleeve of nylon to nicely seal the edges of the open side. The other end of the sleeve was open.

This enabled one to place or remove easily material from the cage and then tie the sleeve to prevent greenbugs from going in or out. Several potted plants were placed in this cage and replaced frequently.

In 1982, fifty wheat cultivars were planted in plastic pots whose open ends were square 8.25 x 8.25cm and 9.5cm deep. Each cultivar was planted in four replicates. At growth stage 12 (Zadoks et al.1974; Tottman and Makepeace, 1979) the seedlings in each pot were thinned to leave only one. The remaining seedling was infested with two fecund greenbug females which were left overnight to reproduce. These were removed after 24 hours leaving the young nymphs. This ensured that all the greenbugs raised for this experiment had a maximum age difference of 24 hours only. The nymphs were reduced to one per plant on the fourth day and the remaining nymphs allowed to mature and reproduce. Records were taken on when individual greenbugs started bearing young. After every two or three days the nymphs were counted, killed and mothers left to continue reproducing. This was repeated till no more nymphs were produced. The records obtained were used to construct life tables for greenbugs on each cultivar. In 1983, six cultivars, namely Africa Mayo, R306, Kenya Fahari, Kenya Kima, Kenya Kiboko and Kenya Kifaru, selected on the basis of their tolerance, rather than antibiotic performance, from other work(unpublished) were tested for antibiotic resistance using the procedure described for the 50 cultivars. Ten replications rather than four were used. In 1985 six cultivars were selected based on the antibiosis experiment of 1982 with 50 cultivars. Four represented the most and two the least antibiotic cultivars.

Groups(Cohorts) of four greenbugs were used instead of single greenbugs. /‾Both apterae (wingless) and alate(winged) greenbugs were tested_/. However, each of the four greenbugs making a cohort was on separate plant. The cohorts were replicated six times. The same procedure used for the 1982 was used for the cohorts. Life tables were again constructed and following statistics computed:

R_o = the net reproductive rate = the number of times a population will multiply per generation.

T_c = cohort generation time = the pivotal age when 50% of the offspring are produced.

r_c = capacity for increase of a population per unit of time.

$$r_c = \frac{\log_e R_o}{T_c}$$

Laughlin(1965) has shown that the capacity for increase (r_c) is a useful statistic for estimating the rate of population growth of an organism and that r_c is a similar statistic to the intrinsic rate of increase (r_m) described by Birch(1948). The r_m however, relates to a population with a stable age distribution (Laughlin, 1965) and r_c is therefore the more appropriate statistic to use here.

The new data, the R_o, T_c and r_c for each experiment were subjected to analysis of variance.

A typical lifetable is given below for illustration and ease of reference.

TABLE 1.

Life Table for cohort No.2 of alate greenbug mothers on variety Kenya Paka in 1985.

Pivotal age* (days)	Proportion surviving	Fecundity rate (nymph/female)	
x	lx	Mx	lxmx
3.0	1.0	-	-
6.5	1.0	1.0	1.0
7.5	1.0	4.0	4.0
9.5	1.0	8.25	8.25
11.5	0.75	4.33	3.25
13.5	0.75	13.67	10.25
16.5	0.75	15.67	11.75
19.0	0.75	9.33	7.00
21.0	0.75	4.67	3.50
23.5	0.75	1.33	1.00
26.0	0.75	1.00	0.75
28.0	0.50	2.50	1.25
30.5	0.25	-	-

$R_o = \Sigma 1_x M_x = 52.$ $T_c = 14.79$ $r_c = \dfrac{\log_e 52}{14.79} = 0.2672$

* Pivotal age is the age half way between two consecutive sampling days.

RESULTS.

The r_c values for the 50 cultivars tested in 1982 are presented in Table 2. There were no significant differences between the r_c values for the 50 cultivars.

TABLE 2. Capacity for increase (r_c) for greenbugs on cultivars tested in 1982.

Cv.	r_c	Cv.	r_c	Cv.	r_c
K. Kima*	0.176	Hunter	0.203	K. Zabadi	0.218
K. Kiboko	0.177	K. Nyati	0.204	7186-1	0.218
K. Leopard	0.178	7002-13	0.204	Fanfare	0.219
K. Kulungu	0.184	R306	0.204	R235	0.219
7155-36	0.187	Africa Mayo	0.206	7208-1	0.220
R 351	0.188	GB 5764	0.206	7006-6	0.221
K. Fahari	0.189	7000-1	0.208	6952-1	0.221
K. Popo	0.191	Bounty	0.211	R306	0.221
R301	0.191	K. Swara	0.211	K. Nyoka	0.221
K. Mamba	0.191	K. Bongo	0.211	Page	0.222
K. Kongoni	0.192	7207-19	0.212	7107-21	0.228
K. Nyumbu	0.197	Trophy	0.214	R253	0.228
6940-1	0.197	K. Kuro	0.215	K. Paa	0.229
K. Ngiri	0.198	K. Tembo	0.215	K. Kudu	0.230
7207-1	0.199	R325	0.216	K. Paka	0.230
K. Nyangumi	0.200	Largo	0.217	K. Kifaru	0.232
K. Nungu	0.201	K. Kanga	0.217		

* K.- in all cases stand for Kenya.

The tolerant and susceptible cultivars tested in 1983 for antibiotic resistance showed differences for this mechanism of resistance. Kenya Kifaru and Kenya Kiboko were non tolerant cultivars. However, K. Kiboko had the highest antibiotic resistance, having a very low R_o and r_c. The R_o on A.Mayo was also significantly different from that of K. Kifaru, while the r_c on K. Kiboko, A. Mayo, R306 and K. Fahari were all significantly different from K. Kifaru. The result are summarised in Table 3.

TABLE 3. The net reproductive rate (R_o), cohort generation time (T_c) and the capacity for increase (r_c) for apterae mothers on six cultivars in 1983.

Cultivar	R_o	T_c	r_c
Kenya Kiboko	26.67 a	14.64 a	0.2247 a
Africa Mayo	29.33 a	15.04 a	0.2251 a
R306	32.83 ab	14.78 a	0.2362 a
Kenya Fahari	34.67 ab	16.08 a	0.2203 a
7002-13	40.17 ab	15.08 a	0.2442 ab
Kenya Kifaru	49.58 b	14.07 a	0.2777 b

1. Means followed by the same letter in the same column are not significantly different (S.N.K.). ($P< 0.05$)
2. Cultivars are arranged in order of increasing R_o.

TABLE 4. The net reproductive rate (R_o), cohort generation time (T_c) and the capacity for increase (r_c) for apterae and alate greenbugs in 1985.

Cultivar	R_o		T_c		r_c per day	
	Apterae mothers	Alate mothers	Apterae mothers	Alate mothers	Apterae mothers	Alate mothers
Kenya Kulungu	27.42 a	36.01 ab	14.97 a	12.80 a	0.2192 a	0.2736 b
Kenya Kiboko	33.92 ab	40.63 ab	14.73 a	14.92 c	0.2306 a	0.2420 a
Leopard	38.67 abc	34.78 ab	14.08 a	13.02 ab	0.2578 a	0.2643 ab
Kenya Kima	42.33 bc	27.78 a	14.92 a	11.44 a	0.2511 a	0.2804 b
Kenya Paka	43.50 bc	49.19 b	15.63 a	13.96 bc	0.2419 a	0.2755 b
Kenya Kifaru	48.33 c	48.86 b	15.85 a	13.25 b	0.2462 a	0.2930 b

1. Means followed by the same letter in the same column are not significantly different.(S.N.K.) ($P < 0.05$)
2. Cultivars are arranged in order of increasing R_o of apterae mothers.
3. Kenya Paka and Kenya Kifaru were used as the susceptible cvs.

The results of the tests of 1985 where apterae and alate mothers were used on six cultivars are summarised in Table 4. Kenya Kifaru and Kenya Paka were used as the susceptible cultivars. The R_o and r_c on these two varieties for both apterae and alate mothers were very high. Only the r_c values for apterae mothers that did not show significant differences. Kenya Kulungu and Kenya Kiboko had significantly lower R_o for apterae mothers than K. Kifaru. The R_o values for alatae were also lower in the latter two varieties than the K. Paka and K. Kifaru.

DISCUSSION

There were no significant differences between the means of r_c on the 50 cultivars tested in 1982. Resistance of a host plant to an insect pest may be high or low (Horber, 1980). If the level of resistance of a cultivar is low it is likely that statistical analysis may not reveal significant differences between cultivars with low level of resistance and the susceptible ones. However, if such low level of resistance exists in a cultivar then such a cultivar would be expected to rank higher than the susceptible ones whenever tested for resistance. In deed, a cultivar that does not show high level of resistance can still be useful in pest management because even low level resistance can be managed effectively against a pest. (Adkisson and Dyck 1980). Therefore the wheat cultivars on which the greenbug increases less rapidly may reduce losses in crop yield due to this pest. In 1983, of the six cultivars tested, Kenya Kifaru showed the least resistance.

It had the highest R_o, shortest T_c and highest r_c. The R_o values for greenbugs on Kenya Kiboko and Africa Mayo and the r_c values on Kenya Kiboko, Africa Mayo, R306 and Kenya Fahari were significantly different from the respective values on Kenya Kifaru. A cultivar in which more than one mechanism of resistance against a given pest operates would be at an advantage in the event of an outbreak of the respective pest. Therefore Africa Mayo, R306, and Kenya Fahari would survive better than K. Kifaru when attacked by greenbugs because the former are more tolerant and antibiotic against the greenbug than the latter.

The R_o values for both apterae and alate in 1985 tests are very close while the T_c and r_c values for alatae tend to be lower and higher respectively than those for apterae. The alatae are the migrant morph and therefore the colonizers of a new crop. An advantageous survival strategy for such a morph (alate) on landing on a new crop would be to produce as many progeny as possible in a short time. This results in an increased production of females/female/day (r_c). The apterae mature and reproduce on the same plant and the risks of their survival are therefore different from those of the alatae. The R_o for apterae on K. Kulungu, K. Kiboko and for alatae on K. Kima were significantly different from the respective values on K. Kifaru. Although the r_c values for apterae showed no significant difference for all the cultivars tested, the alatae on K. Kifaru had the highest r_c. K. Paka and K. Kima also had high r_c for alate and high R_o. Of the six varieties therefore K. Kifaru, K. Paka and K. Kima show least antibiotic resistance against greenbug while K. Kulungu, K. Kiboko and K. Leopard are promising resistant (antibiotic) cultivars.

However, since K. Kiboko has elsewhere been shown to have low tolerance,(unpublished), its use as an antibiotic cultivar may be restricted to a source of resistance in the development of resistant varieties.

The use of both r_c and R_o has provided more information about the performance of the greenbug on different wheat cultivars than when R_o is used alone. The pest may have low fecundity on one cultivar but have a high rate of increase on the same cultivar if its generation time (T_c) is short. Similarly if the pest is producing many offsprings on another cultivar but over a long period of time, then the rate increase of the pest on that cultivar will be low. A cultivar on which the greenbug produced many offsprings in a short time may be considered a susceptible one.

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References

Adkisson,P.L. and V.A.Dyck. 1980. Resistant varieties in pest management systems. pp.233-251 in Maxwell,F.G. and Jennings, P.R.(Eds) Breeding plants resistant to Insects. John Wiley, New York.

Birch,L.C. 1948. Intrinsic rate of natural increase of an insect population. J.Anim.Ecol.17:15-26.

Hill,D. 1975. Agricultural insect pests of the tropics and their control. Cambridge. London.

Horber,E. 1980. Types and classification of resistance, pp.15-21 in Maxwell,F.G. and Jennings,P.R.(Eds) Breeding Plants resistant to insects. John Willey, New York.

Joppa,L.R.; R.G. Timian and N.D. Williams. 1980. Inheritance of reistance to greenbug toxicity in an amphiploid of Triticum turgidum/ T.tauschii. Crop Sci. 20; 243-244.

Laughlin,R.1965. Capacity for increase: A useful statistic. J.Anim.Ecol.34:77-91.

Morgan,J.; G.Wilde and D.Johnson.1980. Greenbug resistance in commercial sorghum hybrids in the seedling stage. J.Econ.Entomol.73: 510-514.

Starks,K.J. and R.L.Burton. 1977a. Greenbugs: determining biotypes, culturing, and screening for plant resistance. With notes on rearing parasitoids. Agric.Res.Service, USDA Technical Bull. No.1556.(12pp).

Starks,K.J. and R.L.Burton. 1977b. Greenbugs: a comparison of mobility on resistant and susceptible varieties of four small grains. Environ.Entomol. 6;331-332.

Starks,K.J. and O.G.Merkle, 1977. Low level resistance in Wheat to greenbug. J.Econ.Entomol.70;305-306.

Starks,J.K.; E.A. Wood and R.L. Burton, 1975. Preventing greenbug outbreaks. USDA Leaflet No.309 (8pp).

Tottman, D.R. and R.J. Makepeace. 1979. An explanation of the decimal code for the growth stages of cereals, with illustrations. Ann.Appl.Biol.93;221-234.

Wanjama, J.K. 1979. Review of wheat aphid as a pest of cereals in Rift Valley Province. Kenya Ent.Newsletter No.9;3.

Wilson, R.L.; K.J.Starks, H.Pass and E.A. Wood. 1978. Resistance in four Oat lines to two biotypes of the greenbug. J.Econ. Entomol. 71;886-887.

Zadoks, J.C, T.T. Chang and C.F.Konzak. 1974. A decimal code for growth stages of cereals. Weed Research 14;415-421.

COMMENT

(E. TORRES):

The paper brings out a very important point, not only for entomologists but for pathologists and breeders as well. That is that low level resistance may be managed effectively to protect yields. Whenever it is difficult to breed for stable, high levels of disease resisttance, we should learn to manipulate minor genes and accept some amount of disease, just as entomologists accept a few insects.

Synopsis of Session 3

Wheat utilization

Chairman : S. KAMAU
Rapporteur: A. MREMA

Salient points of this Special Session are indicated below.

1 The quality of wheat is judged through the quality of the final products. Wheat is classified into "hard" and "soft". These categories reflect the gluten content. Hard wheats with high gluten content are used for bread baking and soft wheats with relatively lesser amounts of gluten are used for cookies (biscuits) and cakes.

2 Wheat flour can be blended with other flours to bake bread. The following composite flours have produced good quality loaves when wheat flour entered as 80 percent of the blend and the non-wheat flour as the remaining 20 percent:

Wheat:Maize, Wheat: Barley, Wheat:Triticale, and Wheat:Sorghum.

3 On acceptability and use of triticale:

i Millers are reluctant to buy triticale because of its low flour extraction index;

ii Bakers are not satisfied with triticale because its baking quality is not as good as that of wheat;

iii Improved triticale lines with improved flour extraction and baking quality are being developed at CIMMYT Mexico. These lines should be distributed through International Nurseries in a very immmediate future;

iv The use of triticale as food should be encouraged.

Composite flours: potential for utilization

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Introduction

Wheat is the major ingredient of most breads, rolls, chapaties, crackers, cookies, tortillas, cakes, pastas, and so forth. The quality of wheat is usually judged according to its suitability for a particular end-use; wheat that is suitable for one type of product may be quite unsuitable for another. Thus, wheat quality is largely relative and is considered in relation to a particular class or type of food product.

Although variety, *per se*, is an important factor influencing wheat quality, wheat is seldom marketed on the basis of individual varieties. Wheat is commonly segregated as it comes to the market according to class, each class consisting of a group of varieties having similar characteristics. Each class of wheat generally is used for similar purposes. Hard and soft wheats are two of the most important classes of grain that are used for the preparation of wheat products. Probably the most characteristic product from hard wheat is leavened bread; soft wheats are used to produce cakes and cookies.

Different instruments can be used to classify wheats according to their physical and chemical properties, but hard and soft wheats can be distinguished visually. The flour made from these two broad classes of wheat is used to prepare different products according to the physical properties of the flour. Several instruments are used to test such physical properties of flour as water absorption, elasticity, and gluten strength. The mixing characteristics of a flour are usually related to measures of gluten quality. These characteristics can be reasonably well defined by using recording dough mixers, as well as such instruments and tests as the mixograph, farinograph, amylograph, Chopin alveograph, and the Hagberg falling number test.

Knowing the dough characteristics, we can determine the appropriate uses for specific wheat varieties; in addition, we can determine their potential for use in the preparation of composite flours.

Composite Flours

To help cope with increasing levels of bread consumption, especially in countries where rising domestic wheat consumption is met by importing the grain, studies have been conducted to explore the potential usefulness of composite flours. The objective in using composite flours is to use raw materials other than wheat in the production of such wheat products as bread, biscuits, and pasta, as well as in the household preparation of family meals. Composite flours may also find application in breakfast cereals and in snacks.

The primary crops grown in the developing countries are: 1) the cereals (rice, oats, corn, sorghum, and millet), 2) roots and tubers (cassava and yams), and 3) the oil-bearing seeds (groundnuts, cottonseed, coconuts, soybeans, and pulses). All these crops may be suitable for use in composite flours. The quality of the baked goods and pasta products prepared from such mixtures should be, if possible, comparable to those made from 100% wheat. If so, composite flour technology can be used to extend expensive imported wheat.

In industrialized countries, studies have been conducted by the baking industry to determine the feasibility of using wheat flour mixed with the flour of different oil-seed crops, but primarily soybean flour for protein fortification. Besides the fact that most soybean production occurs in the industrialized countries, they also have the facilities needed for appropriate defatting of soybeans (or other oil-seed crops) in order to produce a protein-enriched flour mixture. Hence, this option does not appear viable for developing countries. Rather, in the developing world such mixtures as wheat-maize, wheat-barley, wheat-triticale, and wheat-sorghum hold more potential.

The addition of a non-wheat flour to wheat flour almost invariably results in a decline in baking performance. In other words, the mixture will behave like a bread flour having less favorable baking characteristics. Great differences have been observed in the baking characteristics of composite flours, and these differences are a function of: 1) the quality of the wheat flour component, 2) the proportion and type of the non-wheat component, and 3) the manner in which the non-wheat component was processed.

Wheat-maize flour blends--Some countries that consume wheat in the form of bread, tortillas or chapaties, especially those that produce maize domestically and import wheat, are interested in the preparation of these products using mixtures of wheat and maize flours. The CIMMYT Wheat Quality Laboratory has tested several wheat-maize flour mixtures for making bread and other products. Five whole-kernel maize flour samples were utilized, two of which were opaque-2, hard endosperm. After milling the samples in a Cecoco Mill, three levels of maize flour were mixed with wheat flour: 10, 20 and 30%. The 10% maize flour and 90% wheat flour mixture was the superior mixture in all cases. As the percentage of maize flour increased, water absorption decreased, the stability of the dough decreased, and the loaf volume was reduced (Tables 1 and 2).

Biscuits were prepared using mixtures of wheat and whole kernel maize flour at the levels of 25, 50 and 75% maize flour. At the 50% maize flour level, quality was acceptable compared with 100% wheat flour, but at the 75% level, even though the taste of the product was very good, the volume of the biscuit was significantly reduced.

Cookies prepared using 50 and 100% maize flour had good quality, and the organoleptic characteristics were very good. Chapaties were prepared using mixtures of 25, 50, 75 and 100% maize flour, mixed with whole wheat flour. The quality was acceptable up to the 50% level of maize flour, but at 75% the quality characteristics were adversely affected.

Greater attention should be given to research in this field, especially in those countries where increased maize production can help overcome food deficits and where improvements in nutritional quality can be achieved by using opaque-2, high-protein quality maize.

Wheat-barley flour blends--Barley grain contains very low levels of gluten, making it undesirable for baking yeast breads. However, when mixed with wheat flour in the right proportions, barley can be used in commercial bread making. This may prove particularly useful to those countries that produce insufficient wheat for their domestic needs, yet have adequate levels of barley production.

In the CIMMYT Laboratory, five different barleys were tested in 10, 20 and 30% mixtures of barley flour with wheat flour (var. Pavon 76). The barleys and wheats were milled in a Barbender Sinor Mill. It was observed that, during the baking process, a slight increase in mixing time occurred as the level of barley flour in the mixture increased.

Dough extensibility decreased as the level of barley flour increased. However, the handling characteristics of all the barley mixtures were acceptable. Satisfactory loaf volume, crumb texture and crumb color was obtained utilizing barley mixtures of up to 20%; higher concentrations of barley flour resulted in bread with unacceptable characteristics.

In addition to the tests conducted with wheat-barley flour mixtures, the effects on the quality of wheat flour when mixed with barley meal was examined. The same wheat and barleys were used; the wheat flour was blended with the five barley meals at concentrations of 10 and 20%. Wheat meal was also mixed with wheat flour in the same proportions as the barley meal, thus allowing for a comparison of differential effects in baking. The following observations were made:

1) differences in mixing time were not observed between the control (wheat flour alone) and the various blends;

2) there was a marked decline in loaf volume, crumb color, and crumb texture when the 10% barley meal blend was used;

3) the bread produced with the 10 and 20% wheat meal mixture were of inferior quality compared to the control, but they were significantly better than any of the breads produced from the 10% barley meal blend;

4) when the 20% barley meal blend was used, the breads obtained had low volume with very compact and dark crumb.

It can be concluded that while bread quality was adversely affected by the presence of barley meal in the blend, barley meal blended with a strong wheat flour at the 10% level results in bread of acceptable quality.

Wheat-triticale flour blends--Wheat and triticale flour mixtures have been tested in the CIMMYT Laboratory at 25, 50, and 75% levels of triticale flour mixed with wheats of weak, medium-strong and strong gluten. Comparisons were made with loaves of bread made from 100% wheat.

The quality of bread prepared with wheat-triticale mixtures was satisfactory and, in some cases, the loaf volume of the mixture was higher than the loaf volume produced using the 100% wheat flour. The mixture of the strong gluten wheat and triticale consistently produced good quality breads.

Wheat-sorghum flour blends--The use of composite wheat-sorghum flours for bread making has received considerable research attention. In the CIMMYT Laboratory, experiments with 10, 15, and 20% levels of sorghum flour or sorghum meal were conducted. It was observed that the loaf volume did not decrease significantly compared to the bread produced from 100% wheat flour, even when 20% sorghum meal was added to the blend. No decreases in mixing time and water absorption were observed, and the handling characteristics of the dough were acceptable, as were the crumb color and texture.

Conclusion

In general, we can say that products of acceptable quality can be obtained by blending up to 20% of non-wheat flour with 80% of wheat flour for the production of bread and for the preparation of other products.

Table 2. Bread produced using different levels of wheat-maize 1/ flour mixtures.

Maize Whole Kernel Flour (%)	Wheat Flour (%)	Water 2/ Abs. (%)	Mixing 2/ Time (Min.)	C r u m b Color*	Texture	Average Loaf Vol. (cc)
10	90	67.5	1.45	CR	G	750
20	80	67.0	1.35	CR	F	670
30	70	66.5	1.25	CR	P	555

1/ H.I. White Floury Maize (Pool-8)

2/ Sufficient water absorption and mixing time were provided to ensure proper dough development

* Color: CR = Cream

D I S C U S S I O N

(BIRHANU KINFE):

From your presentation, triticale seems to be as good as any wheat for bread making. Why is it that small scale farmers in developing countries do not grow it?

Ans. Farmers need to know about this crop, and of its uses. I can assure you that once they are aware of the facts, they will accept it easily.

Main industrial uses of wheat in Burundi, and current state of research on industrial quality of experimental varieties of wheat and triticale

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I. INTRODUCTION

The main industrial uses of wheat to be dealt with in this paper are the preparation of porridge, consumed mainly by rural populations and bread, consumed largely by the urban population with a higher buying power. Only the preparation of porridge, which represents the most common way of wheat consumption in Burundi, will be approached in detail. Given the present state of research on industrial quality of experimental germplasm at the "Institut des Sciences Agronomiques de Burundi (ISABU)", this paper is restricted to the main industrial qualities of wheat and triticale produced in Burundi.

II. MAIN INDUSTRIAL USES OF WHEAT IN BURUNDI

i. Preparation of porridge - Most of the wheat produced in Burundi is consumed locally as porridge. The preparation of this porridge is similar to that of maize and cassava porridge. The grain is threshed and winnowed and roasted in a clay cooking pot at low heat. This preparation is critical because it renders the grain easy to grind and imparts a pleasant aroma that appears in the porridge. Roasted grain is crushed between two pieces of stone into a fine wholemeal (whole wheat flour). The water for making dough is brought to a boil in a pan or clay cooking pot. Making the dough consists of mixing thoroughly water and flour and it is done by stirring continuously the mixture with the broad flat blade of a wooden paddle.

A well prepared dough is very hot, gives out a pleasant odour, releases water vapour and is slightly thicker than that of the bread dough. Such a porridge has a highly nutritional value because its prepared from whole wheat flour keeping all grain components. This porridge is eaten hot with milk, meat, fish or cooked green vegetables.

ii. Bread making - Bread is regarded in Burundi as a luxury food accessible only to the better-off urban sections. It is made following the classic process of making the dough, fermenting and baking. There are two types of bakeries, according to the level of technology used and the quality and quantities of the finished product: industrial bakeries and small scale bakeries. Industrial bakeries are often in big cities where there is access to adequate infrastructure and to an abundant clientele. These bakeries operate modern equipments and produce large quantities of high quality bread. Small scale bakeries are often at the shopping centres scattered throughout the country, and along the main roads where bread is purchased by travellers and itinerant workers. These bakeries function under primitive conditions and all operations are done manually. This kind of work is extremely tiring and time consuming. Bread is of inferior quality. There are also schools that make bread mainly for children's breakfast.

In 1982, the first modern Mill in Burundi was built about 50 km from Bujumbura. Before then, flour was imported. Often, this imported flour was not fit for baking because its quality was damaged during transportation and storage (flour is a perishable commodity). With the establishment of the Mill, flour is produced locally and the risks of damage are eliminated. This Mill has a capacity of 10,000 tons per year. Nearly all wheat produced in Burundi is consumed by the producers as porridge, and therefore wheat processed by the Mill is imported; thus, flour quality depends upon the quality of imported wheat. In the interest of supplying local bakers with flour of good quality, the Mill uses additives such as ascorbic acid and enzymes when needed. In general, flour produced by this Mill has a satisfactory quality.

III. CURRENT STATE OF RESEARCH ON INDUSTRIAL QUALITY OF EXPERIMENTAL VARIETIES OF WHEAT AND TRITICALE AT ISABU

The improvement of wheat and triticale at ISABU is centered at the Kisozi agricultural research station located at 2175 m altitude. All the experimental material is imported from CIMMYT. The improvement technics used is variety selection.

Since 1982, the program of wheat-triticale has a laboratory to assess milling and baking quality. The purpose of this laboratory is to determine industrial quality of plant materials selected, with a view to distribute those varieties of wheat and triticale that combine desirable agronomic characteristics and good industrial qualities. The main instruments used in this laboratories are:

A Chopin Alveograph, a Brabender farinograph, a Zeleny Shaker with accessories, a falling number 1600, a Chopin-Dubois laboratory grinder, a Brabender mill and a KT120 grinder to prepare wholewheat flour.

The laboratory begin operations in 1983. Since then, it has devoted to assess industrial quality of experimental materials; specifically, of six varieties of wheat and five of triticale that has been put in multi-location variety trials during 1983. Another goal of the laboratory was to evaluate the effect of location, variety and fertilizer on industrial quality. The results follow :

1. Wheat and triticale perform completely different from quality point-of-view. Wheats possess strong gluten (W greater than 250; Zeleny index grater than 40) and can be classified among hard wheats and enzymatic activity is deficient (falling number < 400 secs). Triticale possess very weak gluten (W < 100) and intense enzymatic activity (falling number < 100 secs). From these results it follows none of the two cereals will result in a high quality bread. Therefore, research efforts are needed to improve gluten contents of triticale and enzymatic activities of wheat.

2. Application of fertilizers affect gluten content and does not affect the enzymatic activities.

3. Locations affect quality and quantities of gluten and enzymatic activities. There was interaction varieties X Location.

Synopsis of Session 4

Small scale wheat cultivation

Chairman : HAILU GEBRE-MARIAM
Rapporteur: W. WAGOIRE-WAMALA

It was evident from the presentations, that small scale farmers contribute substantially to wheat output in the Region.

Some of the problems that small scale farmers confront in wheat production have immediate solutions. Others require further research. The following is a partial listing of the different categories of problems.

i Economic factors limit their access to farm machinery; a negative result is that farmers tend to be late in their operations. One suggested remedy is to grow early maturing varieties.

ii Poor plant stand is a common feature in small scale wheat fields. Thera are many contributing factors, such as seedbed preparation, method and time of sowing, and quality of seed used. Suggested partial remedy: teach farmers how to select good seed and how to store this seed to maintain viability.

iii Problem soils are a common constraint in the region. Soil acidity appears to be the most generalized difficulty within this category. Suggested solution: continue efforts to develop acid soil tolerant wheat varieties (liming is discouraged due to economic considerations).

iv Untimely weeding is also a common fault in small scale wheat cultivation. Whenever compatible with other activities, weeding must be appreciated by the farmer as a high priority. It is important to convey the message that a late weeding may reduce yields.

v Harvesting and threshing if done by hand is slow and laborious, and may endanger the crop when a rainy season is close. There is an urgent need for simple, inexpensive threshers for use by small scale wheat growers.

Potential research priorities for the small scale wheat farmer

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Much of the wheat grown in Eastern, Central and Southern Africa is produced on relatively large scale farms, either under dryland or irrigated conditions. In fact, the success with which the wheat crop has been mechanized, in terms of land preparation, planting and harvesting, has led to the predominant development of large production units to take advantage of economies of scale. Nevertheless, in Malawi, Burundi, Zaire, Rwanda, Madagascar, Ethiopia, Kenya and Tanzania, at least a part of the national wheat crop is grown on small scale farms, and, in certain areas, by subsistence farmers. The latter group demonstrates that, despite the common association of wheat in this region with large, capital intensive, arable development, clearly it is possible to produce the crop using simple hand tools and a high labour input.

While it may be argued that the wheat produced by small farmers is negligible in relation to the regions' total wheat production, for the small scale farmers concerned this wheat may play an essential role as a dependable staple food crop and a source of income. In the highlands of South-West Tanzania, for example, subsistence farmers grow an estimated 8,000 ha of wheat and hull-less barley on plots of 1/2 ha or less in area; under the cool, ambient temperatures at elevations of up to 2,400m in this area, maize can take up to 10 months to mature and incurs the risk of killing frosts. In other agro-ecological zones, where potential maize production may also be marginal and limited, wheat, triticale or barley may provide the small farmer with a basic food supply and/or a marketable cash crop. Another instance of small scale wheat production is found in Malawi, where small farmers are able to fully utilize their environment by producing wheat as a relay intercrop with maize, utilizing residual moisture without affecting maize yields; in the process, they increase the total productivity of their land in addition to net income.

In this presentation, we will examine several agronomic factors pertinent to the small wheat farmers' circumstances, discuss problems or limitations that may be associated with their practices and suggest appropriate research to aid in resolving the problems. Keep in mind that many agronomic practices, problems and research objectives are site-specific; as a result, much of the discussion in this afternoon's session will deal with particular and perhaps localized problems. We must attempt, therefore, to concentrate on the broader agronomic principles involved, and shall do so under the following categories: land preparation, stand establishment, plant nutrition, water utilization, weed control, and harvesting methods.

It is worth stressing at the outset that we are not advocating that agronomists should conduct research into all these agronomic factors in their specific zone or region. Rather, it is essential that initially the agronomists conduct diagnostic surveys and exploratory trials under representative small farm conditions in their area; this should enable them to identify priority research subjects - those which are most seriously limiting the yield and economic returns of the small farmer - and to conduct the priority research meaningfully.

I. Land Preparation.

Small wheat farms of up to 10 ha in size are not economically capable of supporting the machinery required for fully mechanized production of wheat. Unless the farmers have access to collective or custom-hire equipment, either privately owned or government subsidized, their only alternative is to produce the crop with a combination of animal and human power. Even when they have access to rental equipment, the small farmers can experience a serious problem of timeliness of operations; the contractors may be few in number and operational bottlenecks may develop. Also, the fact that the small plots of wheat may be separated by large distances makes for inefficient and expensive machinery usage. Thus, contractors normally give a lower priority to small farmers and may charge them a higher fee per hectare for operations, thereby reducing the net return from the crop.

If land preparation is not carried out in a timely fashion, the small wheat farmer may be detrimentally affected in several ways. As previously mentioned, he may be growing a wheat crop in an area that is ecologically marginal; delays in land preparation may result in a later than optimum seeding date, rendering the crop susceptible to drought, frost, pest or disease pressure during grain filling. Limited availability of equipment may also result in the farmer working the soil when it is too wet or too dry, resulting in poor seedbed preparation. Similarly, cultivation may not be possible at a particular critical time for moisture conservation or optimum weed control.

Three different avenues of research may prove to be of assistance to small wheat farmers hindered in proper land preparation.

First, the development of earlier maturing cultivars may offer the small farmer greater flexibility and some protection when forced to seed late. Table 1 contains data from Bangladesh, from which we are able to compare the yields of 4 wheat lines varying markedly in maturity. The yield of later maturing lines was reduced drastically due to a decrease in seed set and an increase in grain shrivelling, caused by high temperatures in the latter part of the season. Thus, earlier maturing cultivars may allow small farmers to escape the problems of late season drought or frost. In East and Central Africa, where much of the wheat production takes place at high altitudes, it is advisable to remember that the time to maturity of any cultivar will be delayed about 15 days for every 300 m increase in altitude; maturity ratings developed at a research station at a lower altitude will not be applicable to the small farmer at higher altitudes.

Another appropriate form of research may be to examine various methods of reduced tillage. Chisel rather than mouldboard plowing may reduce the farmers' production costs and have other beneficial effects on soil moisture conservation and in minimizing soil erosion. Several factors must be examined before recommending any form of reduced primary tillage. The incidence of diseases, such as tan spot, Septoria leaf and glume blotch, and of many weed species may be increased by reduced burial of crop stubble. Also, soils high in clay content are often adversely affected by reduced tillage. Table 2 contains an example of just such a tillage by soil type interaction: the silty clay loam soil is poorly drained and responds positively to tillage, while the well-drained silt loam responds positively to the maintenance of mulch cover. Appropriate research trials are required to generate specific tillage recommendations tailored to site, soil type and cropping sequence.

Reduced tillage may also be accomplished by using the final disc-harrowing for incorporating broadcast seed and fertilizer. In fact, some small farmers may have already adopted this method of seed incorporation to reduce production costs. Research may be required to determine if recommended seeding rates should be increased to compensate for the failure of some deeply buried seed to emerge. Under certain conditions, disc incorporation of seed has been demonstrated to be superior to drilling. In the highland region near CIMMYT's headquarters in Mexico, small farmers' wheat is often planted into dry soil and is dependent on the start of the rains to stimulate germination and emergence. If significant dry periods occur immediately after the initial light rains, however, newly emerged seedlings can be killed or stunted. In fields where seed was broadcast and disc incorporated, many viable seeds remained beneath the shallow zone of wetting caused by the early rains; subsequent, heavy rains stimulate these seeds to germinate and emerge. In several years of on-farm experimentation in this region, broadcast and disc incorporated wheat seed resulted in yields equal to or significantly higher than drilling, depending on the weather pattern.

This brings us to the consideration of animal power as an alternative means of land preparation. The concept of an animal-drawn implement is not new, but, through years of experience and development, various design and functional weaknesses have been improved. Engineers at ICRISAT, in Hyderabad, India, have developed a multipurpose wheeled tool carrier which permits farmers to carry out their basic operations of tillage, seeding, fertilization and weeding in a timely and precise manner. It is capable of virtually all operations that can be done with a tractor and offers time-saving advantages to the farmer. A traditional wooden plow in India with a maximum working width of 15 cm requires 67 km of travel by the farmer and his bullock to cover 1 ha. By comparison, a 75 cm blade harrow attached to and stabilized by the tool carrier frame developed by ICRISAT requires only 13 km of travel - 20% that of the traditional plow.

Farm surveys carried out by ILCA show that animal power usage on small farms in Ethiopia averages more than 1000 hours/farm/year, most of which is accounted for by land tillage with a traditional plough pulled by a pair of oxen. Since only 30% of the farmers own a pair of oxen, the majority are forced to hire oxen for field cultivation. By developing a suitable yoke and harness, and modifying the local plough, a team of researchers at ILCA have shown that cultivation can be done using a single ox. In fact, the work output of oxen used singly was found to be 40% higher than that using the double-ox plough. A high level of interest has been generated amongst small farmers: through the use of the single-ox plough, significant increases in their efficiency and profitability can be achieved.

II. Stand Establishment.

Small farmers may also encounter a problem in establishing a good stand of plants in their wheat crop. Stands with less than optimum plant densities may result in a yield reduction directly, if tillering does not compensate, or indirectly, if a high weed population develops and competes with the crop for nutrients, light and moisture.

Factors contributing to poor stand establishment include: the use of poor quality seed, poor seedbed preparation, incorporation of seed at an improper depth (either too deep or too shallow), low seed rates, crusting of the soil surface before seedling emergence, a high incidence of soil insects and/or seedling diseases, and too much or too little moisture.

Most small farmers will retain some of their grain for planting the following season's crop, since the farm supply infrastructure in their area may be poorly developed and certified seed too expensive or unavailable. Residual grain may exhibit reduced germination and vigour as a result of improper storage under poor conditions, with the seed exposed to the harmful effects of high humidity, high temperature and/or insect pests, such as weevils. Definitely, research on seed storage and handling must be a priority when severe reductions in germination are frequently encountered; sieving to remove shrivelled grain before planting or treating seed grain with insecticide or fungicide at a specific point in the storage cycle may improve seed quality dramatically.

It is important to determine the optimum seeding rate for commonly used wheat cultivars, for, in several countries in the region, wheat seedlings are exposed to rainy season temperatures higher than optimum and exhibit reduced tillering.

As discussed previously, seedbed preparation and the method of seeding may be affected by the decision of the farmer to opt for reduced tillage practices. Ideally, the seedbed for wheat will consist of moderately fractured particles and clods, has some protective plant residue on the surface and is free from weed growth. Wheat seeded at a depth of 4 cm into moist soil, subsequently packed around the seed, assures the most rapid and uniform germination. If it is necessary to reduce the number of tillage operations and/or to broadcast and disc incorporate seed, a higher seed rate may be required.

The crusting problem frequently encountered in loam soils may be reduced by maintaining a higher level of crop residue on the surface and in the top layer of soil; this can usually be accomplished by reducing the number of tillage operations, or by using implements such as the chisel plough which minimizes trash incorporation.

Soil insects such as white grubs and termites can cause serious damage to a wheat crop by destroying the root system, and are currently controlled by the use of highly toxic chemicals with residual activity such as aldrin and dieldrin. Small farmers may benefit from research to determine alternate chemicals, equally effective in controlling insect pests but less toxic to humans. Also, research on required rates of chemicals and optimum timing for insect control may yield beneficial information.

III. Plant Nutrition.

Low productivity of the wheat crop can result from poor nutrient status in the soil or from an improper balance of nutrients. Small farmers may be hampered by a lack of appropriate recommendations as to the rate, type placement and timing of fertilizer applications. In many countries, micronutrient deficiencies can exert significant effects on the wheat crop: copper deficiency has been reported in parts of Kenya and Southern Tanzania, manganese deficiency in Northern Tanzania and boron deficiency in some of the soils of Madagascar and Zambia. Toxic levels of aluminum and/or manganese occur in many acid soil areas of the region, and are particularly prevalent in Zambia, Burundi, Madagascar and Kenya.

Phosphorous availability is a critical problem on acid soils as the nutrient is chemically bound in a form that is unavailable to the wheat plant. If phosphorous is applied by broadcasting, a large amount must be added before any plant response occurs. The efficiency of phosphorous utilization can be substantially increased and the fertilizer requirement reduced by banding the phosphate with or close to the seed. Needless to say, for small farmers this presents certain technical difficulties. However, on small farms in Chile, farmers using animal traction approximate such a banding: they prepare their seedbed with shallow furrows and ridges, broadcast seed and fertilizer and then have their oxen drag a wooden beam across the field, filling the furrows in with the ridges. This produces a high concentration of seed and phosphorous fertilizer in the filled-in furrows, and fairly uniform, vigorous stands result.

Research on the utility of liming to correct soil pH and reduce aluminum levels may be another high priority area of research for areas with acid soil problems. Optimum rates and timing of lime applications (ie. annually or less frequently) must be determined, as well as the methods and depths of incorporation possible within the constraints of small scale production practices. Soil amendment by liming should be studied in conjunction with the research on phosphorous utilization; lime and phosphorous interact positively on the wheat crop, due to increased P solubility, and the optimum practice for the small farmer may consist of a particular rate, method and depth of incorporation for each input.

Given the costs and potential difficulties associated with soil liming by small farmers, identifying genotypes which are tolerant of acid soil conditions could be very beneficial for those affected regions. In recent years, the ability to tolerate acid soils has been incorporated into high yielding varieties of wheat. Utilizing this tolerance can substantially increase wheat yields in acid soils. In Mbala, Zambia, for example, where the soils are very acid, grain yields varied greatly, largely depending on the amount of aluminum tolerance each variety had (Table 3). In particular, the superior performance of lines developed under the acid soil conditions of Passo Fundo, Brazil, is evident. Also, in dry years such as 1981, triticale lines outperform the breadwheats on average, perhaps due to an ability to tolerate higher aluminum concentrations in the soil solution.

Nitrogen is one of the most commonly used fertilizer nutrients, and ranges in use from an average of 2 kg/ha in Argentina to 180 kg/ha in some European countries. It is the most universally deficient fertilizer nutrient, and soils which are highly fertile will, more than likely, need fertilizer nitrogen after many years of cropping. Agronomists should realize, however, that nitrogen fertilizer does not necessarily result in higher yields unless combined with other essential practices. For instance, there can be a critical interaction between fertility and weed control practices (Table 4). The data show that little yield response occurs with the separate application of nitrogen or herbicides; however, a large increase was obtained when both practices were combined. Since capital resources are usually scarce for the small farmer, it is extremely important that the most economical use of inputs be precisely identified.

In determining optimum fertility levels, the researcher must be aware of important interactions amongst nutrients. Although N is usually the most important fertilizer, the proper combination of nutrients can give substantially higher yields than any one nutrient. The importance of using nutrients in the proper balance can be illustrated with data from Pakistan (Table 5). By applying only phosphorous, the farmer actually lost money. With nitrogen, a 350% return on investment resulted, but the highest return was obtained with a combination of N, P and K. A fertilizer recommendation with the proper ratio of nutrients will gain much faster acceptance by farmers, because it will bring more return on the investment.

Research to assure that micronutrients are not limiting wheat yields should be conducted when deficiencies are suspected, requiring close contact with the farmer and an understanding of his circumstances. The detection of micronutrient deficiencies is often more difficult than for macronutrients, but can usually be accomplished by observing characteristic symptoms. However, correction is usually readily accomplished and can be easily adopted by small scale farmers. In Southern Tanzania, for example, copper is deficient in many of the highland soils, but the farmers apply a copper oxychloride based tomato fungicide, Blitox, to the wheat foliage, thereby correcting the deficiency. Research may be required to determine the optimum rates and method of micronutrient application (ie. seed dressing and/or foliar spray), and whether formulations for foliar application are compatible and can be tank mixed with herbicides. During the exploratory stage of experimentation, researchers should be aware of the potential antagonistic relationship between certain elements, such as iron deficiency induced by an excess of molybdenum, copper or manganese. Also, soil pH affects micronutrient availability markedly; liming can induce micronutrient deficiencies by increasing pH.

IV. Water Utilization.

Satisfactory wheat yields can be, and have been, produced with as little as 500 mm of annual rainfall. However, where annual rainfall is largely ineffective due to poor distribution and/or high intensity and low frequency of rains, management practices have to be designed to conserve more of the rainfall for wheat growth. The actual situation in many countries is such that the limited rainfall received is often poorly used; that is to say, the crop evapotranspiration demands often exceed the available water, resulting in moisture stress.

The moisture stress problem can be worsened by several factors. With poor weed control either on fallow land or in a growing crop, the amount of water available for the wheat crop will be greatly reduced. Soils with low fertility status or with toxic levels of microelements, such as aluminum, will have poor water uptake and water use efficiency, due to shallow rooting and a general lack of plant vigour. Structural problems in clay soils and poor drainage in depressional areas result in wastage of rainfall by runoff and reduced vigour in crop plants due to waterlogging

Areas with insufficient rainfall for the reliable production of a wheat crop in any one rainy season can benefit greatly from a properly managed fallow system. Regardless of the number of rainy seasons per year, a fallow system reduces the farmer's risk by augmenting rainfall during the cropping season with stored water from the previous rainy season. In general, a minimum of 100mm of plant available water is required to support the vegetative growth necessary for grain yield; additional water contributes to grain filling. In Washington state of the U.S.A.; wheat farmers are able to produce wheat yields in excess of 2 t/ha with less than 250 mm of precipitation annually by conserving 150 to 200 mm in the soil horizon from the fallow season. Appropriate management techniques must be developed for specific areas, but in general will include practices designed to: (1) control weeds, as previously mentioned; (2) maintain a rough soil surface so that infiltration is maximized and runoff minimized; and (3) avoid excess tillage that loosens or exposes moist soils to rapid drying. Timing of tillage may also be critical; in low rainfall areas of Kenya and Tanzania, immediate post-harvest tillage has been found to promote the maximum infiltration and retention of rainfall from the "short" or inter-season rains, especially on soils low in clay content.

An additional benefit to proper fertilizer practices is that available moisture is utilized more efficiently. Because of this, fertilizer has often been called the next best thing to rain. In fact, the highest yield increases from fertilizers, percentage-wise, frequently occur in dry years or areas. Thus, the commonly held belief that there is no response to fertilizer in cases of low available moisture, may not always be true. For example, in Argentina, in two different rainfall zones, one can see a large increase in water use efficiency by using fertilizer N and P (Table 6).

Research in ICRISAT has revealed that, by adopting different agronomic practices, more efficient use of rainfall can be achieved on the heavy montmorillinitic soils or Vertisols, one of the most abundant soil orders found in the semi-arid tropical zone. Relative to the other abundant soil order, Alfisols, the Vertisols undergo pronounced shrinkage and cracking during drying but are extremely sticky and difficult to work when wet. Traditionally, small farmers did not plant crops on Vertisols until towards the end of the rains, avoiding some of the management difficulties. However, research at ICRISAT indicates that a Vertisol cropped throughout the rainy season using the bed and furrow system experiences much less runoff (Table 7) than either a fallowed Vertisol or a cropped Alfisol. The increase in retained rainfall of 165 mm or 24% of incident rainfall allows crop production with much less risk of moisture stress. The raised bed and furrow system also helps eliminate the problem of waterlogging which can occur in depressions in flat-cultivated fields.

Timely weed control can also aid in the efficient use of water. This is well illustrated by data obtained on small wheat farms in Mexico during an unusually dry year (Table 8). With an early application of herbicide (bromoxynil), a 100% increase in yield was obtained, compared to a 30% increase when the herbicide application was delayed until 30 days post-emergence (2,4-D). The extra increase was largely due to more water being available to the wheat plants, as weed competition was removed earlier.

Appropriate rotations or intercrop patterns can also be developed to maximize the use of incident rainfall. In Northern Zambia and Malawi, for instance, early planting of wheat results in near total crop destruction due to the high disease pressure in the early part of the rainy season. As previously mentioned, small farmers in Malawi are able to circumvent the ecological limitation to wheat production and actually boost total crop production by growing wheat as a relay intercrop in maize, planting the wheat between the maize rows after tasselling has occurred. Attempting to monocrop the same land with wheat necessitates the expenditure of a large amount of energy to keep the fallow land weed-free until a later planting date; in addition, the bare soil is much more susceptible to runoff and erosion problems than if it were cropped. In such an ecological zone, wheat may be a more profitable crop for small farmers than for mechanized large farmers; the relay intercrop practice would be extremely difficult using conventional implements.

For the small farmer, wheat may be an important component of the rotation or may have value as a catch crop if maize fails due to delayed or irregular precipitation patterns. While maize may possess higher yield potential than wheat on average in many specific areas, there may be an attendant greater risk of crop failure in maize. Also, it may be important to consider the degree to which each crop in a potential rotation depletes soil moisture (and nutrient) levels and the implications this may have for the succeeding crops.

V. Weed Control

Wheat yields throughout Africa are often seriously reduced by competition from high weed populations, especially the grassy weed species. In particular environments (ie. the highlands of Rwanda), weed control has been reported as being the most expensive input for wheat production on small farms.

Poor weed control by small farmers can be attributed to the unavailability of appropriate herbicides to control the weed species present, and the lack of understanding of application rates, methods and proper timing. Weed control is not limited only to herbicides, and can be achieved with proper pre-seeding tillage and hand weeding. However, it is worth remembering that the process of hand weeding is often carried out too late, reducing the crop's yield potential either through competition or by physical damage.

Appropriate research for small wheat farmers should compare the relative economic values of timely weed control by chemical means and by hand-weeding. If hand weeding is to be practiced, proper recommendations need to be developed for the optimum timing. Small farmers will also benefit from knowledge of effective herbicides that are affordable, produce a net benefit and are easily obtained through the local infrastructure.

Lack of appropriate application devices is often a serious constraint for the small farmer. The preferred method may be to use efficient back-pack sprayers that are easy to use and maintain; many countries, realizing the importance of weed control, have made such sprayers available, sometimes at subsidized prices, through their farm supplies distribution system. For areas distant from a clean water supply and to which it is difficult to transport large volumes of water, an inexpensive ultra-low volume sprayer might prove to be useful; the utility of the first ULV sprayers was largely dependent on the availability of batteries but there are newer designs which are driven by pump compression. Research may be required to determine which herbicide formulations are appropriate for use with ULV applicators, but much of this information is currently available and can be adapted to local conditions.

Small farmers may also lack an understanding of herbicide dilution and the importance of application timings. Thus, a more intensive educational effort will be required from the extension services if small farmers are to realize the potential benefit from their weed control package.

Non-chemical methods can also be used to effectively lower weed populations and increase wheat yields, including the use of rotations, higher crop seeding rates and precisely timed tillage to destroy the first flush of weed growth. This type of research requires a thorough knowledge of the cropping system and the farmer's practices. Data from Mexico (Table 9) illustrate that in this specific study of wild oat infestation in irrigated wheat, the cultural practice of inducing weed germination with a pre-seeding irrigation reduced the ultimate weed population and increased yield equally as well as chemical control. The use of a higher seeding rate significantly reduced the weed population but failed to increase yields in this trial.

VI. Harvesting Methods

Where wheat on small farms is harvested by contractors using combine harvesting machinery, the farmers are completely dependent on the good-will of the contractors for whom it is inefficient to harvest small plots of wheat. As was the case with land preparation, the small farmer is thus presented with a problem of timeliness; late harvesting compounds crop losses due to shattering, bird and insect damage and quality loss due to exposure to weathering. In addition, the use of large harvesters for small parcels of wheat can contaminate the farmer's seed with admixtures of other varieties and/or weed seeds, reducing the grade and income from the crop. Wild oats, in particular, can be spread readily from one field to another in the combine harvester.

If the only alternative to combine harvesting is to harvest and thresh the crop by hand, this will act as a major impediment to small farm wheat production in areas where wheat must compete with maize and other crops. Estimates of labour requirements per hectare were made in Zimbabwe for various crops grown by small farmers in settlement areas; the harvest and removal of small grains incurred a labour expenditure several times greater than that for maize. Threshing requirements tipped the labour scales further in favour of maize.

Obviously, alternative harvesting and threshing methods would be of great benefit on smaller plantings of wheat. For intermediate sized wheat farms of from 2 to 10 hectares, research could be conducted into the suitability of small gasoline-powered implements such as the Suzue binder used in rice harvesting. Such small equipment may help to overcome the cost inefficiency of using combine harvesters on small fields of wheat in remote and often steeply sloping fields; the availability of small harvesting equipment could be encouraged through various forms of government intervention and assistance.

Small, motorized stationary threshers are available in several countries, and in conjuction with a binder could help alleviate the large labour requirement on small wheat farms. Additionally, agricultural engineers at IRRI in the Philippines have developed a thresher powered by bicycle pedals for small rice farmers; conceivably, this system could be modified sufficiently for threshing wheat. Even if threshing equipment had to be custom-hired by the small farmer, there should be a lower cost relative to a combine and a reduced risk of seed contamination using these smaller, more readily cleaned threshing units.

For the smallest, subsistence level farmers, growing ½ hectare or less of wheat, labour requirements are not likely to be as great a disincentive to the production of the crop as they may be in larger scale production. Thus, hand labour will continue to be the best option on these subsistence wheat plots.

Conclusion

Wheat can be economically produced on small farms covering a wide range of environments, but research is required to identify improved and appropriate agronomic practices to correct the most limiting factor or factors. Ultimately the results of such research can be used to build a package of recommendations which, when adopted, will provide high yields and optimum economic returns to the farmers.

If we look at Bangladesh, a country where wheat is grown primarily by small farmers using animal traction and hand harvest, we can find several factors which contributed to the dramatic increase in wheat production since 1975. Currently, in Bangladesh, 600,000 hectares of wheat are produced with the national yield averaging more than 2 t/ha. The essential factors which contributed to this success are: (1) adapted high yielding varieties; (2) agronomic research which identified appropriate recommendations for the farmers; (3) efficient seed production and distribution; and (4) fair prices for inputs and a ready market for the harvested crop.

Obviously, not all of these factors can be resolved by agronomic research, as some are more related to government policy. However, to assist small farmers, it is essential that we as researchers understand the farmer's circumstances and work towards solving his problems. The best way to do this is to work in cooperation with the farmers and to superimpose experimental treatments on representative farmers' fields.

Table 1. Effect of days to maturity on yield of bread wheat. (Bangladesh, 1979)

Genotype	Yield (kg/ha)	Days to Maturity
Inia 66	6037	107
Jupateco 73	4944	113
Phoebe "S"	3963	117
Era	2111	135

Table 2. Influence of tillage and soil type on grain yield of maize. (Ohio, U.S.A., 1976)

Soil type	Average grain yield - years 2-6 (kg/ha)		
	No-till	Mouldboard plow	Prob.
silt loam	7060	6370	0.001
silty clay loam	5720	6490	0.001

(from CRC Handbook of Agricultural Productivity, Volume I, pg. 256)

Table 3. Influence of variety and year on yield in acid soils.
(Mbala, Zambia, 1981 and 1982)

	Yield (kg/ha) 1981	1982
a) Bread Wheat		
Highest yielding line	1040	2401[a]
Average of all lines	557	911
b) Triticale		
Highest yielding line	2161[b]	1855
Average of all lines	1525	986

[a] PF 7748 from Brazil
[b] PFT 7727 from Brazil

Table 4. Effect of nitrogen fertilizer and weed control on wheat yield.
(Obregon, Mexico, 1984)

Kg N/ha	Herbicide	Yield (t/ha) 12 advanced Bread wheat lines	Yield (t/ha) 13 advanced Durum wheat lines
0	-	1.7	1.8
0	+	1.9	2.0
75	-	2.4	2.4
75	+	3.9	3.8

Table 5. The effect of N, P and K on yield and rate of return in wheat. (Pakistan, 1984)

Nutrient level (kg/ha)	Yield (kg/ha)	Variable cost (rupees/ha)	Net benefit (rupees/ha)	Rate of return (%)
0- 0- 0	1510	0	2416	
0-85- 0	1890	331	2373	-
85- 0- 0	3030	539	4309	350
85-85- 0	3750	810	5109	295
85-85-50	4210	887	5849	961

Table 6. Effect of N and P on water use efficiency. (Argentina, 1981)

Crop water use (mm)	Check		N+P [a]	
	Yield (kg/ha)	Water use (kg/mm)	Yield (kg/ha)	Water use (kg/mm)
300	2780	9.2	4290	14.3
220	2080	9.5	2950	13.4

[a] Average of several treatments with N and P

Table 7. Rainfall and runoff on a cropped Alfisol and Vertisol and a fallowed Vertisol. (Hyderabad, India, 1976)

Treatment	Runoff (mm)	% of total rainfall [a]
Cropped Alfisol	141	21
Cropped Vertisol	73	11
Fallow Vertisol	238	35

[a] Total rainfall = 679 mm (June-October)

(from ICRISAT Journal Article 30)

Table 8. Effect of weed control on yield under drought conditions. (Mexico, 1982)

Weed control treatment	Yield (kg/ha)
No weed control	600
Early control (at 10 days with Bromoxynil)	1200
Normal control (at 30 days with 2,4-D)	800

Table 9. Effect of three years of continuous cultural practices on weed control and wheat yield. (Mexico, 1981)

Cultural Practice	Observations in year 3	
	wild oats/m^2	yield (t/ha)
a) Seeding rate 100 kg/ha	69 *	3.9 n.s.
b) Seeding rate 200 kg/ha	49	3.8
c) Pre-seed irrigation	12 **	4.5 **
d) Seeded dry	105	3.2
e) Chemical control	30 **	4.1 **
f) No chemical control	88	3.6

Level of significance * = 0.05

** = 0.01

Obtaining representative yield samples from on farm trials

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Introduction

On-farm trials are conducted to verify the results of on-station research, but also to obtain new information on the response of crop plants to a somewhat different environment than that extant at the station or substation. Since many of the practices are usually performed with the farmer's equipment and labor and the trials are distant from the researcher's base of operation, management or control of the trials is not as precise as we would like. Daily, or even weekly, observations of the progress of the trials are often difficult or impractical. Along with the vagaries of weather, events often occur within the trials that are considered abnormal and thus the response of the crop plants is not alone due to the imposed treatments. When these factors influence only part of the plants in a trial, our usually desirable random selection of yield samples is no longer a suitable procedure for obtaining representative yield samples. Thus, we must turn to other methods of harvesting the trial.

In Lesotho, we have on-farm trials in three distinctly different prototype areas, one of which requires a full-day's travel to reach it from our base of operations. Last summer we had fifteen (15) trials in each prototype area, all of which were duplicated in a separate field, because of the lack of control, local weather hazards and biological factors.

We limited our on-farm trials to the testing of wheat, maize, sorghum, and beans - the major agronomic crops in Lesotho. We compared varieties, starter fertilizer rates, plant populations, topdress (or sidedress) nitrogen rates, timing of plowing, and methods of cutworm and stalkborer control. This season we are adding methods of seedbed preparation to the list.

Procedures

Our procedures are probably similar to FSR procedures in other areas. We ask our local Extension Agents to select cooperating farmers and we make the final selection of the fields, attempting to find fields that are relatively uniform in soil type and topography. We donate seed, fertilizer, and insecticides and apply them in the proper manner, using the farmers' equipment and some of his labor. The farmer plows the field, prepares the seedbed, and controls the weeds. We monitor the progress of the trials, take our yield samples and the farmer harvests the balance of the crop.

Trial Design

Our fields are small, usually 1/4 to 1/3 of a hectare. Since Lesotho is called the "Mountain Kingdom", nearly all of our fields are narrow strips of land between terraces, often only 15 to 20 meters wide and 75-150 meters in length. We test 3 or 4 treatments, with three to six replications.

There is almost always the local or commonly used treatment, plus 2 or 3 improved or comparative treatments. And the method of applying the treatment is always one that the farmer can easily use.

Main Problems or Constraints to Successful Research Techniques

By far the main problem we had last season was inadequate stands. Failure to achieve desired plant populations can be ascribed to the following:

1. Inadequate seedbed preparation
   a. Large, compact clods stopping the drive wheels of the planter (row crops)
2. Improper operation of the planter (row crops)
   a. A new planter, the Ariana, was used
3. Inadequate rainfall for successful germination and emergence
4. Uneven planting depth (broadcast crops)
5. Cutworm damage.
6. Plant loss during cultivating and hoeing

Another serious problem, which is probably common in other areas, is that of partial or complete destruction of the plants in a trial. In this category, we found that animal consumption (oxen, poultry, birds, rodents), hail, untimely frost, weed competition, and lack of normal rainfall unduly affected the response of the plants to the imposed treatments. Several of our trials were abandoned because of severe frost damage.

Our Sampling Procedures

Field crops research is done to obtain information which can be used to predict the expected plant response to certain imposed environments. The soil fertility, improved by the rate of fertilizer application, is a common and usually desirable type of environment to test. Plant population, especially under rain-fed conditions, and genetic potential of selected plant types or varieties are two other examples.

Because of the problems that developed during the progress of the trials, we abandoned our system of random selection of harvest samples. We inspected each plot in each trial for areas that were minimally affected by these abnormal conditions. We were especially careful to take our sample from areas having the desired plant population. In the case of wheat we take our square meter samples only from areas that are not adversely affected by abnormal conditions. In row crops we select our samples from areas in each plot where the desired plant spacing is found. We try to take the same type of sample from each treatment in a single replication, but may vary the size of the sample between replications. However, we are careful to stay away from the "border effect", if at all possible.

Evaluation

Since we are more interested in comparative yields than we are in absolute yields, we feel we have adopted a much more reliable method of sampling for yields. We make our plots approximately 3 meters wide and 25 to 50 meters long. The length allows us to select areas which we feel are typical of the expected response to the treatment. We have three experienced agronomists who agree on each area to be sampled. Thus, we do our best to avoid the possibility of a bias entering into our selection.

Another problem we have grappled with is the use of replications in trials using ox-drawn planters. For example, it is very time-consuming and difficult to stop the oxen at the same distance from the beginning point in a plot, change the seed to another variety, and repeat the process 2 or 3 times in each row. In place of such a procedure, we plant each variety from one end of the trial to the other. Then we divide the trial into "modified" or "manufactured" replications, which actually results in subsamples being obtained from a long, single plot. We realize that these are not "true" replications, but we treat them as such, and feel that our means and variances are accurate enough to draw valid conclusions.

We also have reduced our plot width to 3 rows (for row crops) and take our samples only from the center row of each plot. We sample entirely within each replication until we have taken all of the samples from that replication, before we proceed to the next replication. We do our best to eliminate errors by having at least two people to check all steps in the sampling procedure, which is the same technique we use in "planting" the trials.

Thus, we feel that we are obtaining data that is representative of the "normal" response of the plants to the imposed environment (treatment). We decided on our present procedure when we noticed that data from previous years often indicated, for example, that the "no fertilizer" treatment in one replication had a much higher yield than a plot receiving a substantial amount of fertilizer in the same replication. The other main factor that helped us to adopt the new procedure was the very "poor" stands which we obtained this past season. Naturally, we learned a lot from last year's trials, and we plan to eliminate as many as possible of the abnormal events that caused the loss of stand and of the entire trial. Next season we hope to be able to obtain even more representative yield samples.

Cropping systems in small scale wheat cultivation

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Introduction:

Lesotho is a small country about 30,350 km², completely surrounded by the Republic of South Africa. The entire country lies between 27° and 30° East and between 27° and 33° South of the Equator.

Elevation:

The country is divided into three ecological zones or regions, namely: the lowlands which are about 1500-2100 m above sea level, the foothills 2100-2600m, and the mountains from 2600-3400m (Figure 1).

Rainfall:

The annual rainfall in the northern lowlands is about 700 mm, while in the southern lowlands is about 500 mm. In the foothills average rainfall is about 700-900 mm, while in the mountains it can be as high as 1500 mm. (See Figure 2 for rainfall distribution throughout the country).

Temperature:

Temperatures range from 32°C in summer to -7°C in winter in the lowlands, while in the maloti mountains temperatures can drop even to -20°C.

As a result of the above conditions the growing season in the mountains is about 138 days, while that of the lowlands is about 250 days.

Occasional frost in the middle of summer is experienced in some years.

Wheat is the third major crop, following maize and sorghum, grown throughout the country, with winter wheat covering the lowlands and spring wheat grown in the foothills and in the mountain areas.

Table 1 shows the area planted to the three major cereal crops from 1978/9 - 1982/3.

Table 1. Planted areas of Major Cereals

1978/79 to 1982/83

All figures are in hectares

Crop	1978/79	1979/80	1980/81	1981/82	1982/83
Maize	122,338	118,460	136,520	136,668	126,824
Sorghum	54,105	64,537	63,734	58,673	56,947
Spring wheat	28,445	19,860	19,238	19.532	13,504
Winter wheat	9,532	10,790	4,301	7,469	18,504
All Wheat	37,997	30,650	23,539	27,001	31,846

Source: Bureau of Statistics, Maseru

Since most of the production is in the hands of individual small farmers in Lesotho, it is important, therefore, to consider small-farm practices.

Small farmers in the three ecological regions more or less follow the same pattern of cultivation. They traditionally use ox-drawn implements to prepare the seedbed. Some farmers broadcast the seed (usually their own saved) and then plough it under, while others plough their fields, broadcast the seed and then harrow to cover it. Usually no fertilizer is used. If it is used, as is sometimes the case in some lowland areas, it is applied by broadcasting it together with the seed. And a very small percentage of farmers use improved seed.

Under these conditions, it is difficult to achieve a good stand, as seeds will often be left uncovered on the surface.

Other Constraints on the Production of Wheat:

- The greatest limiting factor in wheat production in Lesotho is moisture, but in wet seasons good yields can still be realised, even on infertile lands.
- Lack of fertilizer usage, especially in the lowlands where soils are less fertile.
- inadequate supplies of fertilizers and improved seed at the time of planting.
- Lack of cash to purchase fertilizers or seed when they are available, and unwareness of the potential for fertilizer and improved seed due to the farmers belief in traditional practices.
- Lack of good cultivation practices, untimely and improper land preparation.
- Lack of good management, as well, results in low yields. Weeding wheat is not common in the country and not much pest control and bird scaring is done.

Harvesting of wheat is a major concern for the small farmer. Traditionally performed by hand-cutting with sickles, the practice is so time consuming and tiresome. This may result in the crop being left in the field and lost to rotting and germination in the head.

Threshing, too, is another major problem where there are no mechanical threshers.

Poor storage facilities.

All these factors have contributed to declining of wheat yields over a period of years and to making wheat production less popular among small farmers.

Research Efforts:

1. The Research Division of the Ministry of Agriculture is engaged in screening and evaluating improved varieties from the Republic of South Africa and other international institutions for better yield, adaptation, resistance and tolerance to diseases and insects.

2. Lesotho, with increased cooperation between the Maseru Research Station and the Small Grain Centre in Bethlehem, South Africa, is working towards stimulating wheat production by testing different varieties and selecting those varieties which seem suited to Lesotho conditions.

   More trials are conducted every year, and seed from varieties which prove adaptable is obtained, mainly from RSA, for seed multiplication.

   The varieties commonly grown and which appear adaptable and high-yielding are Scheepers '69, Wilge, SST 102, Flamink, and Betta. These are winter varieties and are grown mainly in the lowlands, while in the mountain areas and the foothills, varieties such as Flamink, Kenya Sokkies, Bolane and Gamka yield higher than most other varieties. However, research yield results proved higher than the farmers' usual low yields, as will be seen in Table 2.a and 2.b.

TABLE 2.a Wheat Yield in Lesotho - Nine Year Average

1973/74 to 1981/82*

Yield in Kilograms per Hectare

District	Winter Wheat	Spring Wheat
Butha-Buthe	392	557
Leribe	807 (h)	975
Berea	548	767
Maseru	797	1089
Mafeteng	535	402 (L)
Mohale's Hoek	712	654
Quthing	499 (L)	787
Qachas' Nek	NA	906
Mokhotlong	NA	1241 (h)
Thaba-Tseka	NA	769
	613	1028

(h) high
(L) Low
*Wheat Task Force, 1984 Report

TABLE 2.b Winter Wheat Results for 1982/83 and 1983/84 in Two Districts of Lesotho

Yields in Kilograms per Hectare

District	Variety	1982/83	1983/84
Maseru	Sch. '69	*	1036
	SST 102	*	964
	Wilge	*	821
	Betta	*	750
Mafeteng	Sch. '69	3068	1196
	Wilge	2770	750
	SST 102	2060	893
	Betta	2087	1018

* 1982/83 Yield data is unavailable.

3. Varieties from CIMMYT are being tested and workshops, such as this one, are helping our research efforts. We are looking for better adapted varieties that have been developed at high elevations and thus be suitable for Lesotho conditions.

4. Education of farmers through extension courses given by the Research Division and through trials conducted on their fields is helping the farmer to realise the effectiveness of proper tillage operations and of good management of the crop.

5. Trials on land preparation, as an important factor in any production program are also carried out. The reduction of seed competition, moisture conservation and good yields are the benefits that the farmer realizes if more energy is applied.

6. The Soils Section in the Research Division is at the moment very busy with soil analysis from different soil types to test for soil fertility, deficiency or toxicity. This helps in the proper fertilizer recommendations in these areas.

Conclusion

Although the majority of farmers still follow the traditional way of cultivation, more and more are moving away by planting improved varieties, applying fertilizers, improving their tillage operations and ploughing their fields soon after harvest to help conserve moisture.

The Ministry of Agriculture, working with local manufacturing companies are researching on appropriate, stationary threshers to enable farmers in remote areas, where combines are less accessible, be able to thresh their produce with ease, hence an incentive for them to increase their production.

Wheat production methods under peasant farming conditions

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Role and importance of peasant farmers is being increasingly realised in increasing food production in the third world countries because they constitute a large proportion of the farming community. In the continent of Africa before the countries became independent, mainly two scales of farming operations were in existence: large scale, fully mechanised commercial farms owned largely by the colonial farmers and in contrast, subsistance farms owned by the local people using hoe cultivation methods. Following independence, many countries made attempt to involve more people in agriculture, resulting in a considerable increase in the number of small holders. In the Rift Valley of Kenya, in 1968, 80% of the farm holdings were 20 - 400 hectares, whereas in 1982. 72% of the holdings were less than 20 ha (8). In Zambia, the number of small holders (<2 ha), is estimated to be approx. 600,000, and of large commercial farmers approx 400. In between, there are a few thousand emergent farmers (5 to 100 ha). The small farmers produce nearly 60% of the maize surplus, the rest being produced by the commercial farmers (4). In Zimbabwe, the position is reverse and bulk of the maize surplus is produced by the approx. 5000 large farmers, who control about one half of the land (4). In Nigeria, more than 90% of the farmers are still dependent on hoe as the predominant method of cultivation (1). Increasing productivity of these small holders is, therefore, the key to success in solving continent's food crisis.

Wheat is becoming an important food crop in Africa. The demand is rising and production is static. In Zambia, wheat is becoming a rare commodity, since the country is producing only approx. 8 - 10% of it's requirement. At present, it is all produced by the commercial farmers under irrigation. Intensive research on rainfed wheat is in progress with some promising results lately. If it succeeds, peasant farmers will be involved in wheat production in Zambia. In Kenya, according to Mulamula (8), in 1982, 64% of the small farmers in the main wheat producing district of Nakuru were growing wheat in <4 to 8 ha area.

However these small wheat producers are having problems in the absence of proper and efficient production resources mainly for sowing, harvesting and threshing of the crop. It was in this reference that this presentation was considered appropriate, which is based mainly on experience in India. In India, nearly half of the production of 45 million tons recorded in 1984-85, is produced by farmers growing less than 5 ha of wheat. Even large wheat farmers growing > 50 ha, produce the crop with minimum mechanisation using mainly oxen power source and surface irrigation methods.

METHODS OF PRODUCTION

Source of Power: Productivity of small farmers has been largely limited by, to what extent he can till, seed, weed, harvest, thresh and prepare the crop for himself and for the market. Importance of animal power mainly oxen, in peasant farming situations is unquestionable and is being more and more promoted in many countries of the African continent for various reasons. For one, it reduces dependency on mechanical (tractor) power derived from non-renewable energy sources, which is expensive and not available in many countries. Secondly, the use and maintenance of tractors for want of spares and trained operators in remote areas is difficult, disrupting crucial farming operations at times. Finally, peasant farmers for want of capital, cannot afford to purchase these and their use often, is not economical.

In this presentation, wheat production methods based on oxen power and simple, easy to operate and maintain threshing machines will be discussed. It would be appropriate to mention here that efficiency of oxen cultivation will depend upon type of oxen, implements available and their proper use. The oxen used in this part of the world are not good draught animals. For example, one pair of oxen is required to cultivate 4 - 5 hectares, whereas in India, the corresponding acreage is about 12 - 15 hectares. There are specific breeds of cattle mainly for draught purposes in India. Same thing can be said about use of oxen and types of implements available. In those countries, one man operates the oxen in the field but here, often two men are seen - one holding the implement and another pulling the oxen. Often engineers are seen busy designing yokes, drawbar, oxen cart etc. in this continent, starting in a way from scratch, when efficient designs of these are already available elsewhere. There is an urgent need therefore, to introduce and improvise appropriate oxen-cultivation technology in many countries in Africa, simultaneously with the promotion of oxen cultivation.

Seedbed Preparation. Nature of operations for seedbed preparation will vary depending upon soil type, cropping system, land topography etc. What is important, is, that the farmers should not cultivate land more often than is necessary. In rainfed cultivation, moisture conserving tillage practices are important and often use of mouldboard plough is not proper, unless fields are heavily infested with weeds or ploughing is done before or immediately after start of the rains. The concept of minimum tillage should be considered where-ever appropriate. In the Dryland Farming Research in Botswana, low-draught tine (chisel plough) tillage and minimum tillage techniques were found to be more appropriate(2). Minimum tillage consisted of a single-pass implement that breaks up the soil with a sub-soil tine and then sows the seed and places fertilizer. Only cultivation in rows is undertaken and soil between rows is not disturbed. Rain water penetrate into the plant rows only, since the inter-row soil is compact.

One most versatile and useful equipment for peasant farming is Animal Drawn Tool Carriers. Their advantage is that many tools for a range of operations, can be attached to the tool bar and eliminates the need to purchase different individually mounted implements. One such design is available in the name of Tropicultor manufactured by Muzon* in France. However, it's cost of around US $1,000.00 (about two years ago) is beyond the reach of many peasant farmers. Recently a new low-cost and simple version named Wheeled Tool Carrier+ has been developed jointly by ICRISAT, in India and the National Institute of Agriculture Engineering, in Britain and is now in commercial production in India. It's design is simple and should be possible to fabricate locally in many countries. The main tool bar is 40 mm x 40 mm, 1.5m wide and is built from steel sections readily available in India. Adaptation to alternate sections available in other countries is quite straightforward(7). It is fitted with two pneumatic tyres and draught requirement is matched to the power of two oxen. It is controlled by one man riding and is useful for all tillage operations, sowing, inter-row cultivation, and levelling. It can be easily converted into one tonne cart for transport. In evaluation trials, its performance was equal to that of Tropicultor

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(Table 1). Compared to these, a low power tractor had only 33% higher efficiency. On an average, the machine has workrates of 1ha/day for primary cultivation and 1.5 to 2.5 ha/day for secondary operations, Kemp (7) reported that with good management, one Tool Carrier and two pairs of oxen have sufficed for the production of two crops per season on 15 hectares of vertisol watersheds at ICRISAT.

Table 1. Machine hours required per hectare for different oerations during rainy season. (Source: ICRISAT Annual Report, 1981).

Machine	Ploughing + seedbed preparation	Sowing + fertilizer application	Inter-row cultivation	Total
Wheeled Tool Carrier	9.9	4.7	6.0	20.6
Tropicultor	10.7	4.0	5.4	20.1
Low Power Tractor	8.4	1.9	4.7	15.0

Summarising, the technology of Wheeled Tooled Carrier cultivation does appear promising in peasant farming and may have application in this part of the world and needs to be introduced. However, because of rather poor draught animals and other factors, certain modifications may be necessary to suit local conditions. It was primarily designed for the Broad Bed System of cultivation developed by ICRISAT (Beds 1.2m wide, furrows on either side and spaced at 1.5m pitch), but is equally applicable to flat bed system of cultivation.

Sowing and Fertilizer Application: Appropriate method will depend upon whether the crop is rainfed or irrigated. For irrigated crop, broadcasting seed and fertilizer followed by mixing in soil has given as good results as drilling. For rainfed crop, as a general principle, proper placement of seed and fertilizer at right depth in moist soil is essential for a good stand. Broadcasting seed may be suitable under certain rainfed conditions as being tried in Kenya (8) but is 'risky' and not advocated. It's success will depend upon timing, and nature of rains soon after broadcasting; a delay or heavy rain is likely to affect germination. Basal dose of fertilizer should, preferably be drilled for best results at or before seeding.

For the above considerations a proper seed-drill is very important. Several versions of these are available and are in use in India and other Asian countries: two or three row type, only seed-drill or seed cum fertilizer drill, manual or automatic type. In many situations, a multicrop two row seed cum fertilizer drill will be appropriate with adjustable row width for different crops. In the simplest versions, the seed and fertilizer is drilled manually. Three persons are required to operate: one to control the oxen and two dropping seed and fertilizer separately. Fertilizer placement is about 1" below and on side of the seed. The design is very simple. It is made by the village blacksmith using locally available material e.g. hard wood for main body, cast iron bars for furrow openers, wooden seed hoppers and bamboo or cast iron or polythene pipes for dropping seed etc. With a pair of oxen, it can sow about one ha in a day and costs approx Rs. 300 (US $ 25.00). Improved versions mainly built with cast iron and automatic type, where seed and fertilizer drops automatically using fluted rollers are available. One such seed drill has been developed by the I.A.R.I.* New Dehli, India. The Tool Carrier described above has a seeding attachment, which can be used for sowing wheat.

Harvesting, Threshing and Cleaning: These operations are posing serious problem in small scale wheat production in this continent because use of combine harvesters is expensive and not practical. Simple mechanisation of harvesting wheat appears to be impractical in peasant farming and therefore has not become popular even in the green revolution countries. In Asia, which produces most of the developing countries wheat, nearly 80% of the crop is hand harvested using a sickle or a scythe (5). After cutting, the shieves of wheat are tied in bundles and taken to the threshing area. On an average, about 12 - 15 men - women are needed to harvest one hectare of rainfed crop producing 1000 - 1200 kg of grains. Although hand harvesting is a labour intensive job but where plenty of manpower is available, it is practical and required skills need to be developed to improve efficiency.

Traditionally, wheat is threshed in a variety of ways such as beating with sticks, beating against a wall, trampling by humans or animals, etc. The most common method in India, used to be and still practiced in remote areas, is trampling by oxen to break the straw in very fine pieces (commonly known as bhusa), which is then piled in heaps and grain separated from 'bhusa' by hand winnowing. The winnower stands on a stool carrying the threshed material in a

* Indian Agriculture Research Institute.

small basket ,tosses the contents into wind and repeats the operation two-three times. Finally the grain is sieved, to remove dirt and other foreign material. This method is slow and time consuming, dependent upon a brisk wind which at times is not present, wasting time and manpower.

For the above reasons, simple mechanisation of threshing and cleaning operations spread rapidly in past 10-15 years following green revolution in India, Pakistan and other countries. Stationary multicrop threshers of varying size requiring 3 to 20 h.p. of electric or diesel power, have become a most favorite machine of small and big farmers alike. These threshers are suitable, by simple adjustments and changing sieves, for a range of crops - wheat, barley, paddy, sorghum, soyabean, millets, etc. Since wheat straw (bhusa) is fed to cattle in many of the Asian countries, these machines are designed to break the straw finely to make 'bhusa'. The output of a small 3.5 h.p. machine is approx. 300-400 kg of grain an hour and costs approx. IRs. 3000-4000 (US $250-350). These can be moved easily from one place to another and can be operated in the field, if required power source is available. The power source is detachable and can be employed for irrigation or any other purpose. Several makes and models are currently marketed in India. One such make is being imported into Zambia and was priced K4,250.00 last year with a 5 h.p. electric motor. It need not be emphasised that the stationary thresher is the most useful and necessary machine for small and medium scale wheat production and is an example of appropriate mechanisation. The design is simple, and it should be possible to make them locally in many countries of this continent.

SOME RELEVANT CONSIDERATIONS

Farmers will adopt an improved technology only when it is 'relevant' to his situation and offers a clear economic advantage. In such cases, they will move-in quickly. Risk tolerance capacity of small farmers is rather low or non-existant and should be kept in view while recommending expensive inputs. Some aspects of minimising risk and ensuring greater returns are considered below:

(a) Intercropping: Intercropping or mixed cropping has a definite place in peasant farming for obtaining greater returns from the same piece of land and to minimise risk of a total or partial crop failure. Small farmers have learned this through experience and had been traditionally practicing the system. One interesting example is a farmer evolved system of growing a mixture of paddy and maize in a certain district in Central part of India.

Reasons for this most unusual crop combination was erratic rainfall pattern - i certain years too much and in others, too little. The farmer thus ensured harvest of paddy or maize in all the years and of both in certain years.

Rainfed wheat is intercropped or grown mixed with chickpea or linseed (flax) by some farmers in certain parts of India. Depending upon weather conditions - rainfall, temperatures, frost (chickpea very sensitive) and diseas incidence (linseed very sensitive to Fusarium wilt), farmer is ensured of some harvest and hopefully greater harvest than that of the sole crops. Irrigated wheat is intercropped with sugarcane (in first year) in the Eastern part of India and by the Nakambala Sugar Estates in Zambia. Suitable wheat based intercropping system preferably with a legume crop, therefore, needs to be evolved for the peasant farmers.

(b) Spreading Use of Fertilizer: Fertilizer response follows the Law of Diminishing Returns, meaning maximum response at lower levels and gradually diminishing at higher levels, of application. For example, in 300 wheat irrigated trials on 11 varieties over a four year period in India, average response to nitrogen was 18.7, 12.3 and 6.0 kg of grain per kg of nitrogen at dose intervals of 0-40, 40-80 and 80-120 kg N/ha respectively (6). Fertilizer is an expensive input and 'spreading' it's use to cover more land area will be overall more beneficial in order to achieve greater production. At the same time, relatively lower levels of fertilizer application will minimise the likely risk of lack of response or reduced response due to factors beyond control. Moderate levels of fertilizer recommendations, therefore, appear to be more beneficial in a peasant farmer's situation particularly under rainfed conditions, where it's response is not always consistent.

(c) Spreading Use of Irrigation Water: The continent seems to be some years away in production of irrigated wheat by peasant farmers. However, there is an increasing realisation in many countries, of the need to expand irrigation for increasing and stabilising agriculture production. Few comments, therefore will not be out of place. Irrigation is a much more expensive input than fertilizer and therefore, should be used with maximum efficiency. Appropriate surface irrigation methods are needed to minimise capital investment, which is beyond the reach of the small farmers. Like fertilizer, irrigation response in wheat and in several other crops, follows the Law of Diminishing Returns. Extensive research carried out on dwarf wheats in India has established that when water is limited, more total production can be obtained by applying one, two or three irrigations at critical stages and thereby 'spreading' it's use to cover more area under irrigation. This is possible where land is not limiting as is often the case in this continent. To illustrate, suppose a farmer has adequate water to grow 5 ha of fully irrigated wheat applying about 500 mm of water and 120 kg N + 60 kg P + 30 kg K fertilizer per hectare. His expected total production will be 25 tons assuming 5t/ha yield. Instead, suppose he spreads his water and fertilizer to 10 ha (provided no other crop is or can be grown) and gets a yield of say 3.5t/ha, his total production will be 35 tons amounting to ten tons of increased production.

The concept of spreading scarce and expensive resources like fertilizer and irrigation in small farmer's situation is important, particularly in this continent, where extensive agriculture is practised. Situation will vary from farmer to farmer and different strategies will be needed in different farmer's situations. Technology is available elsewhere and through adaptive research, it needs to be varified and improvised to suit local conditions. Of course, economic aspects of such a technology by way of cost-benefit analysis will be necessary, to ensure that beside increase in production, the farmers are also benefitted financially.

CONCLUSIONS

Wheat is becoming an increasingly important food crop in Africa and it's production is beginning to spread to peasant farmers. Appropriate oxen-based technology for use by such farmers, therefore, is needed. Such technology is available in the wheat producing Asian countries and much can be learned, improvised and applied in this continent from their experience. Following steps are necessary:

1. Introduce 'right' methods of using oxen in the fields such that for many field operations, only one person is required for the control of both, oxen and the implements.

2. Introduction of simple two-row seed cum fertilizer drills, both manual and automatic type.

3. Introduction of the multipurpose low-cost Wheeled Tool Carrier developed jointly by ICRISAT and NIAE. This may prove the most useful equipment for oxen cultivation.

4. Introduction of small and medium size electric and diesel operated stationary multicrop threshers for threshing and cleaning operations. These have proved very successful in the green revolution countries.

5. On a long term basis, introduce appropriate breeds of drought cattle to increase efficiency of oxen cultivation methods.

Initially a limited number of the above implements and machines should be introduced, tested and suitably modified to suit local conditions. At the same time possibility of local fabrication should be explored.

Risk tolerance capacity of small farmers is rather low. Therefore, production practices should aim at minimising risk and ensuring greater economic returns. One such practice is intercropping and suitable wheat based intercropping system preferably with a legume crop, therefore, needs to be evolved. Application of fertilizer under rainfed conditions should be carefully monitored. In certain situations, 'spreading' the use of scarce and expensive inputs like fertilizer and irrigation to cover more area may have a greater production efficiency and should be considered.

ACKNOWLEDGEMENT

The sponsorship of Cimmyt to attend the Workshop is gratefully acknowledged, without that it would not have been possible.

REFERENCES

1. Anonymous. 1985. Animal draught systems. African Farming, May-June, 1985. 30-33

2. Anonymous. Report, National Institute of Agriculture Engineering U.K.

3. Annual Report, 1981. International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India.

4. Eicher, Carl K. 1982. Facing up to Africa's food crisis. Foreign Affairs, 61:151-174.

5. Hanson, H., Borlaug, N.E., and Anderson, R.G. 1982. Wheat in the Third World.

6. Indian Agricultural Research Institute. 1968. Five years of Research on Dwarf Wheats.

7. Kemp, D.C. 1980. Development of a new animal drawn tool carrier implement for dryland tillage. Report presented at CEEMAT Technical Meeting II, March, 1980.

8. Mulamula, H.H.A. 1983. Wheat in Kenya: Current Status. Proc. Regional Wheat Workshop, Arusha, Tanzania.pp. 26-31.

Wheat and triticale development with small scale research and production farmers:

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Wheat is grown in Madagascar under two different seasons : the rainy season and the irrigated season, the irrigated wheat in the rice field is grown during the coolest period of the year but the rainfed one is limited by high temperatures and disease incidence. Wheat is grown essentially by small scal farmers in both seasons. This communication will focus on the effort being made to find suitable varieties and appropriate technologies to increase production with small scale farmers.

1. Research on rainfed wheat :

The limiting factors for wheat growing during the rainy season are the high temperatures, the acid soils and the competition with other more profitable crops.

The effect of temperatures has been demonstrated by A.B. Ericksen (1984) with her works in the phytotron using soils from Madagascar. Two regimes of temperatures were used in the phytotron : one regime with a minimum night temperature of 8°C and another regime with a minimum night temperature of 16°C; both regimes have a maximum day temperature of 32°C.

Table 1. Yields of two wheat varieties after treatment with two regimes of temperatures (grams/pot)

	Volcanic soils		Ferrallitic soils	
Minimum night temperatures / Varieties	8°C	16°C	8°C	16°C
Romany	3,7	0,6	2,67	0,78
PF 71131	5,1	4,6	4,49	3,52

There is a tremendous increase of yield by lowering the minimum night temperatures from 16°C to 8°C both with the two types of soils and two varieties. Low temperature affects mainly the tillering of the wheat crop and therefore the number of heads but it affects as well the number of grains per head.

These works in the phytotron were trying to simulate the prevailing conditions in the wheat growing areas in Madagascar. Fig.1 shows the average minimum temperatures and the rainfall recorded in the Antsirabe region.

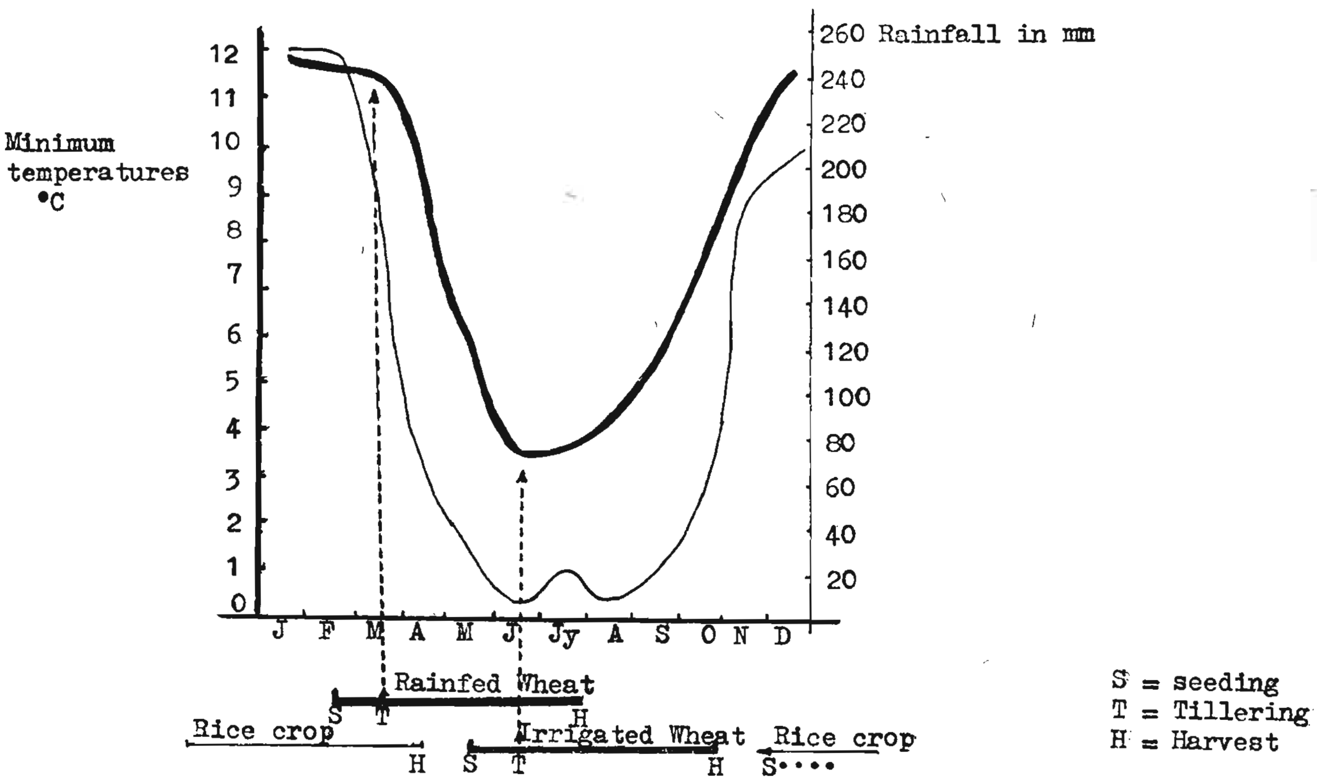

Fig.1 : MINIMUM TEMPERATURES AND RAINFALL (AVERAGE OF 7 YEARS)

After many years of experiments and observations, it was found that the best date of seeding is from mid-February to the beginning of March. In fact if seeding is done on mid-February, tillering will start mid March where the minimum temperatures drops very quickly (fig.1) Seeding in January resulted in low yield and more disease (Helminthosporium sativum and Septoria nodorum). Looking at the graph of fig.1, it seems that wheat is going to suffer from drought at the end of the growing season; this problem is alleviated by the fact that a very wet wind (Alize) blowing from the South Pole carries a lot of moisture to supplement the water deficit.

Acid soils :

There are two groups of soils in the area :

- the volcanic soils with high pH, good fertility in general and where good yields of wheat have been obtained. Raunet (1981) estimated these good volcanic soils to be roughly 18,750 ha in the Antsirabe region. At the moment, most of the rainfed wheat are grown on those areas. Small scale farmers get yields between 2 and 3 T/ha in those type of soils.

- the ferrallitic soils :

These are poor soils with low nutrient content, especially phosphorus, and Al+++ toxicity. Initial application of lime (2T/ha) and phosphorus (300Kg/ha of P_2O_5) are required to rise the pH and the fertility level. Each season, it is necessairy to apply 500Kg/ha of dolomite besides the recommended rate of NPK compound.

Competitions between crops

During the rainy season, wheat is a "half season crop" : this means that it is possible to grow a short cycle crop before seeding wheat during the same year; crops mainly used are beans and potatoes. Potatoes or beans are planted in October and harvested in January and then land preparation is done to sow wheat in February.

But actually, the use of maïze-beans-wheat in the same land is a common practice : maïze is planted at a wide spacing (from 0,80 to 1,00m) and beans are planted between rows, both crops being seeded on October. Beans are harvested on January and wheat is seeded between rows of maïze in February. Maize is harvested beginning of May; both grain and straw are removed and the land is left with a crop of wheat. Very good results have been obtained by small scale farmers so far. Somme more research are needed to solve problems related to row spacing for maize, rate of seeding for both beans and wheat.

This technique of association Maize-beans, Maize-wheat has solved the problem of land scarcity especially in the volcanic soils.

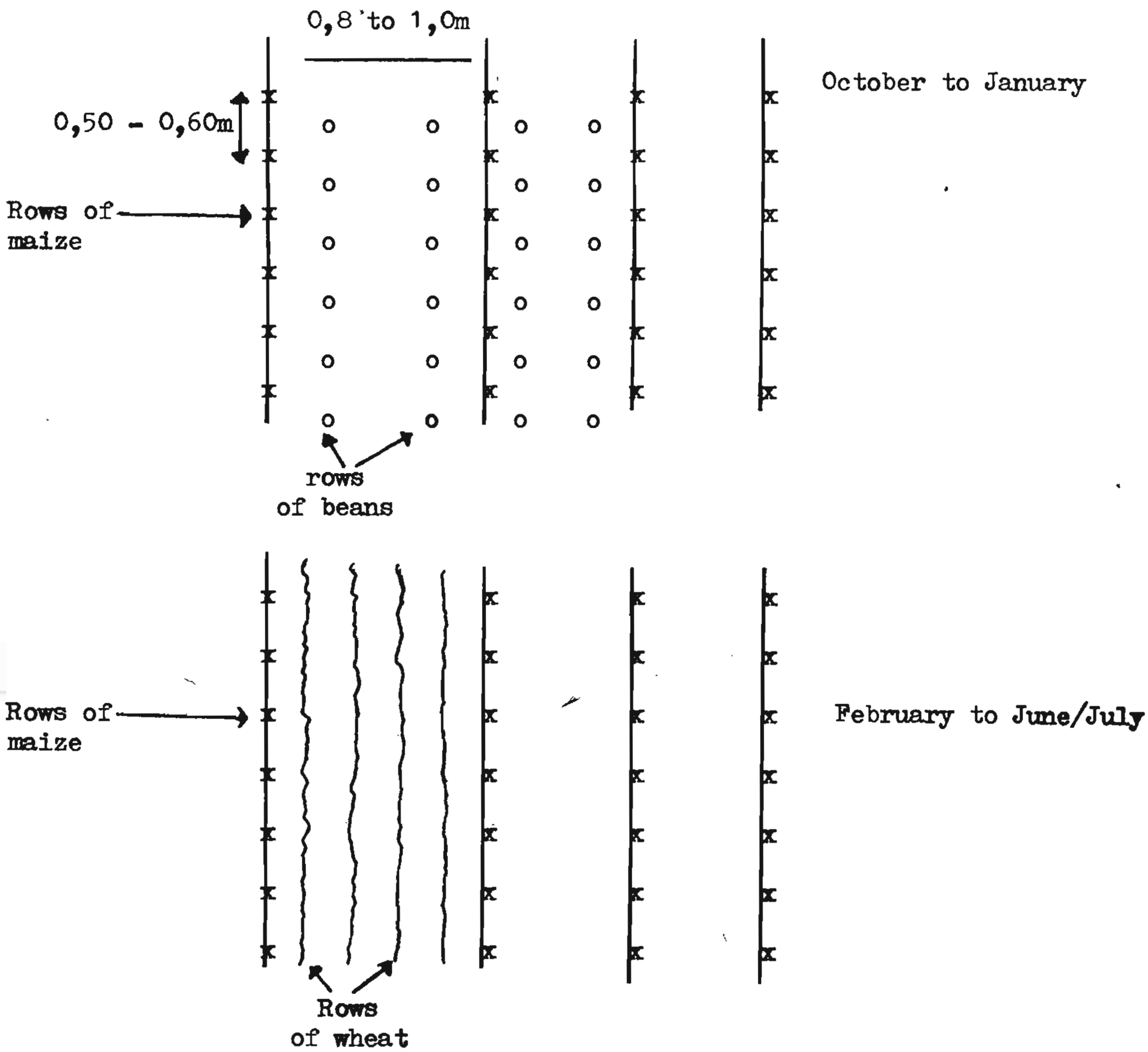

Fig.2 = Associations Maize-Beans, Maize-Wheat

Selections of varieties

Since 1983, the line PAT 7219//KAL/BB (CM 56795), a selection made locally from the F2 MASA Alluminium/Septoria know, as PAT, is the best wheat variety grown commercially during the rainy season. It is used as a check in all the rainfed experiments and replaces the old variety Romany; on average it has an yield increase of 30% over Romany, it matures earlier than Romany (120 days), its disease resistance is good and it is easy to thresh (threshing is one of the problem for small scale farmers). The height is 90cm and therefore, lodging occurs very occasionally.

Table 2 gives a sumary of the best lines under rainfed conditions on different types of soils and using PAT as a check.

Variety or crosses	Number of trials						index
	22	16	15	13	7	6	
CNT 7 Sel 1	2945						94
PF 7339/Aldan Sel.1		2870					95
PF 70354 Sel.1			3580				112
Romany				2470			78
PF 70354/3/KAL/BB/AID sel.1					2700		91
PF 70354/Aldan sel.3					3255		109
Moncho "S"						3090	92
CZHO/RON//AID						3150	94
PAT 7219//KAL/BB (check)	3120	3030	3190	3150	2970	3355	100

Table 2. Average yields of the best lines from different sites in the Antsirabe region (1982 to 1984)

It is clear from these results that the brazilian line PF 70354 is outyielding PAT. PF 70354 is 5 to 10 days later than PAT; the height is 100cm and some lodging has been observed. PF 70354/Aldan sel.3 is also a promising line. CNT 7 has been tested before 1982; small quantity of seed has been multiplied from this variety. Moncho "S" has been also tested before 1982, this line is good only on volcanic soil; being a mexican line it has a good breadmaking quality. The results with this line on acid soils was rather poor.

Different selection have been made also from the "F2 MASA (Aluminium tolerant lines) MV 80" from CIMMYT. An advanced replicated yield trial under irrigation at the station gave the following results for the best entries.

Cross parentage and number	Pedigree in Madagascar	Yield	Days to heading	Days to maturity	Septoria	Helmintho
PF 70354/Vee "S" CM 65063	2.1.2	5855	79	137	3	2
Huae/TJB 788.1038 CM 5342	-	5735	70	127	3	3
PF 70354/Vee "S" CM 65063	2.2.2.1	5715	73	126	5	4
" "	2.1.1.1	5445	74	137	3	3
PF 70100//Kvz/HD2009 CM 65031	3.2.1.2	5435	71	129	2	5
" "	5.3.2.1	5411	74	129	3	3
Ald"S"// 7C/Ald "S" CM 64294	1.1.3	5370	72	137	4	4
TiF 72.55/Imu CM 65270	2.2.1.1	5275	77	137	5	6
Mga/Pew "S" CM 59372	1.1.2	5115	71	137	2	4
Pat/On/Maya"S"/3/Ald"S" CM 59825	6.1.2	5100	67	129	6	5
PAT 7219// KAL/BB (check)	-	4775	67	125	5	5

Table 3. Best entries from the selections out of the F2 MASA Aluminium tolerant lines 1980.

Irrigated trial at the station; date of seeding 24.07.84

These lines are tested at the moment under rainfed conditions in 1985 on acid soils.

Triticale

In general Triticale is performing much better than wheat under rainfed condition. The variety grown commercially is Puppy/Beagle.

Table 3 gives a summary of the result obtained with the best Triticale lines at different sites during the rainy season 1984. The wheat variety PAT is included.

Variety or crosses	Yields Kg/ha	Test weight Kg/hl	1000 grains weight	% Flour	Zeleny sedimen-tation (ml)	Number Sites
1. Puppy/Beagle	3370	70	54	69	22	9
2. IA/M2A//PI 62/3/Bgl	3200	70	53	69	19	5
3. IA/KAL//Cal/3/BGL	3100	73	50	70	15	10
4. Beagle/Addax	2900	69	43	70	21	5
5. M2A/KTZ 12//BGL	2810	70	44	66	32	10
6. IRA/DRIRA	2760	69	41	67	28	10
7. Muskox "S"	2690	71	44	69	18	9
8. PAT 7219//KAL/BB (wheat)	2460	78	48	72	39	10

Table 4. Results of the best Triticale lines, averages of different sites, rainy season 1984.

It is clear from these results and from the previous ones that the best Triticale lines outyield the best bread wheat variety. This is a general trend for most of the acid soil areas.

At the moment; none of the tested Triticale line is better than the commercial variety Puppy/Bgl. Therefore we need some more new lines to be tested.

The policy in Madagascar is to grow mainly the Triticale during the rainy season, and wheat mainly on the rice fields. Triticale is very much appreciated by the farmers. Wheat is sold at FMG 175 per kg at the farm level and Triticale at FMG 150 per kg (1 US $ = FMG 680). Despite this difference in prices, farmers are willing to grow more Triticale than wheat.

2. Research on irrigated wheat in the paddy fields

The irrigated wheat in the paddy fields is grown during the coolest period of the year, therefore, temperature is not a problem. The wheat is planted after rice on May, thus tillering occurs in June at the coolest month of the year. In some places where frost is a problem, seeding is done from June to early July in order that flowering occurs after the frost period.

In the high plateau of Madagascar (altitude from 1400m to 2000m), there is 300,000 ha of paddy fields which can be used more or less for wheat growing depending on the availability of water and on the quality of soils.

The main problem is the time available between the rice harvest and the planting of wheat. Richard (1984) estimated that there is only 30 - 35 days available for ploughing, land preparation and seeding. In that case a farmer would be able to plant only 0,20 ha of wheat. Ploughing takes 58 man-days per ha without any implement; with an oxen driven plough, it takes 10 oxen-days per ha plus 20 man-days for irrigation and drainage canals.

Besides the effort on screening of early variety, an attempt is now made to see the effect of a minimum tillage or even a zero tillage. In general, weeds are not much a problem on the rice fields.

The wheat variety, actually grown commercially is KAL/BB (which is named BW 19 in Madagascar). It is a mexican variety which performs very well in the Antsirabe region where most of the soils are of volcanic origin. But it is well known that this variety does not perform very well on acid soils, on peat soils and it is very sensitive to the effect of water logging, one of the main problem with irrigated wheat. To illustrate this, table 5 gives the distribution of yields of BW 19 Romany and one Triticale variety from 46 trials run on different types of soils in the high plateau of Madagascar.

Range of yields	Varieties		
	BW 19	Romany	Tcl Bulk 50 MA
Less than 1 T/ha	26 %	16 %	9 %
Less than 1,5 T/ha	38 %	30 %	14 %
1,5 to 3 T/ha	40 %	55 %	41 %
Above 3 T/ha	21 %	14 %	45 %
Above 4 T/ha	12 %	0 %	19 %
Average yield T/ha	2,02	2,02	2,82

Table 5. Distribution of yields from 46 trials on the paddy fields.

BW 19 has a very wide distribution of yields : 26% of the trials yielded less than 1 T/ha : these are mainly the acid soils, the waterlogged trials and also the trials where land preparation was poor. But 21% trials yielded more than 3 T/ha.

Although the average yield of BW 19 and Romany is the same, the potential of Romany is limited (no trial yielded more than 4 T/ha).

Tcl Bulk 50 MA is a Triticale variety, early enough to fit the available growing season in the paddy fields. It has a good breadmaking quality. It is clear that the Triticale is performing much better than wheat.

Table 6 gives a summary of the best entries tested from 1980 to 1984 on the paddy fields at different sites.

Variety or crosses	Number of trials									% of BW 19	Cycle days
	4	5	5	6	6	7	8	13	15		
PF 7339/Aldan "S" sel.2							3880			116	139
BLUETIT "S"								4250		108	140
VEERY "S"						4260				108	148
TANAGER	3670									106	145
PAT7219//KAL/BB sel.2		3550								102	144
PF 70354.1				3925						99	150
CHR. MUTANT					3505					93	139
PAT7219//KAL/BB sel.1									3615	92	142
PAVON/SPARROW			2900							90	142
BW 19 (check)	3455	3530	3235	3970	3765	3920	3340	3930	3905	100	140

Table 6. Yields and cycle of the best entries tested from 1980 to 1984 in the paddy fields, 1980 - 1984.

The cross PF 7339/Aldan sel.2 is a promising line with a cycle of 139 days which is more or less the same as that BW 19. Bluetit "S" is a mexican variety which is much better than BW 19, particularly in the volcanic soils; it is the same for Veery "S" and Tanager.

Triticale :

The line used at the moment in the paddy fields is Tcl Bulk 50 MA. It is an early variety (143 days) with good breadmaking quality. Although Puppy/Bgl is good in terms of yields, it is too late (150 days) to fit available growing period.

3. Future of Wheat and Triticale production in the country

In terms of environment there is a high potential for wheat production in the country. The introduction of new varieties from the Al^{+++} tolerant nurseries has increased the yield.

The decision of the farmer to grow more wheat will depend on the input/output analysis and the security in terms of market for the product. With actual prices of inputs and outputs, the farmers need to produce 877 Kg of wheat to cover the costs of inputs. The farmer needs to produce 2 T/ha to get the minimum wage which is actually FMG 700 per day. To get an idea, the average yield achieved by 408 seed growers during 1984 was 2,6 T/ha.

At the moment, the production is still low; in 1984 it was 500 tons, but this year 1985 it is expected to be more than 1,000 tons; this was due to the fact that a big effort has been made by FIFAMANOR and KOBAMA together to collect all the product and to pay the farmers at the buying point. Furthermore, FIFAMANOR has conducted a programme to teach farmers to make local bread with very simple implements. This programme was very much appreciated by the farmers.

The actual wheat consumption is around 60,000 tons. Ths long term objective is the following in terms of production.

Year	1985	1990	2000
Wheat (Tons)	500	7,500	45,000
Triticale (Tons)	125	2,500	15,000
TOTAL...	625	10,000	60,000

CONCLUSION :

Wheat production in the high plateau of Madagascar has a high potential in terms of environment and land availability. The introduction of varieties from the "Al^{+++} tolerant lines" has increased the yield. Triticale is performing much better than wheat. The general policy is to grow mainly Triticale during the rainy season and wheat during the cool season on the paddy fields, Prices policies, security for wheat market are good incentives for the increase of the production

R E F E R E N C E S

1. FIFAMANOR

- Rapports des essais 1980 - 81, 1981 - 82, 1982 - 83
- Résultats des essais multilocaux 1984

2. ERIKSEN (A,B) et NJØS (A), 1984

Recherches en phytotron avec les sols du Vakinankaratra in "Le Blé et la Pomme de terre à Madagascar", FIFAMANOR BP 198 ANTSIRABE

3. RAKOTONDRAMANANA and RANDRIANTSAIAMA (R.A), 1983

Screening and evaluation of wheat and Triticale varieties in the Antsirabe region

Regional wheat Workshop for eastern, central and southern Africa, Arusha, Tanzania, June 13 - 17, 1983

4. RAKOTONDRAMANANA, 1984

Avenir du Triticale en complement du blé in "Le Blé et la Pomme de terre à Madagascar", FIFAMANOR BP 198 ANTSIRABE

5. RAUNET (M), 1981

Le milieu physique de la région volcanique Ankaratra - Vakinankaratra - Itasy

Institut de Recherches Agronomiques Tropicales (IRAT)

6. RAUNET (M), 1980

Les bas-fonds et plaines alluviales des hautes terres de Madagascar

Institut de Recherches Agronomiques Tropicales (IRAT)

7. RICHARD (J.F), 1984

Les contraintes socio-économiques à la production de blé de contre-saison dans la région haut-plateau de Madagascar in "Le Blé et la Pomme de terre à Madagascar", FIFAMANOR BP 198 ANTSIRABE

8. STOKKE (H), 1984

La production de blé dans le Vakinankaratra et les contraintes de production in "Le blé et la Pomme de terre à Madagascar", FIFAMANOR BP 198 ANTSIRABE.-

Synopsis of Session 5

P h y s i c a l   c o n s t r a i n t s

Chairman : M. D. P. MAINA

Rapporteur: ENDALE ASMARE

The papers presented addressed these major problems:

1 Hot and dry conditions for wheat cultivation.

To succeed in growing wheat under these conditions, it is necessary to develop early maturing varieties that can use any residual moisture, and mature before plants suffer from water stress.

2 Soil acidity;

Liming the soil achieves some positive results, but the exercise is very expensive to the point of being prohibitive in many cases. A more viable solution lies in the development of tolerant cultivars that may yield a crop under conditions. Reports from Burundi show that triticale outyields wheat and produces an adequate crop on such soils.

Current state of breeding wheat for suboptimal environments

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Increased production will have to come more and more from suboptimal environments and intensified production in favourable environments, because in most countries the reserves of good land are nearly exhausted. In many cases there is even a loss of good land for agricultural use because traditionally the densely populated areas are those which were conducive to high agricultural production in the past. Presently urbanization with all its land requirements for housing, roads, industry, etc. happens to a large extent in exactly these areas.

Increased crop production in suboptimal environments has basically two possibilities: Either improvement of the environment through agronomic melioration in the widest sense or cultivation of crops which are as well adapted as possible. Very often the choice of the crop is restricted due to the needs of the national economy or farm family and this is where it is the breeder's task to find or create the best possible variety for a target environment.

For spring wheat this presentation aims to review breeding activities and possibilities for such suboptimal environments that occur in several parts of the world, i.e. that are not confined to only one country. We will typify and discuss respective breeding efforts of some of them briefly and go into some more depth for one of them, tropical wheat growing areas.

2. A classification of important suboptimal environments for spring wheat and related breeding efforts

This classification of environments and description of breeding efforts follows pretty much what is known and done through CIMMYT's manifold cooperations with national institutions. Naturally, this cannot be complete and there are different opinions about the importance of certain stress factors.

2.1. Acid soils.

Small pockets of acid soils can be found in many countries, especially in warmer climates. Solid areas of arable land are in Brazil, where millions of hectares are already grown with wheat and a large land reserve is available in the socalled Cerrados area. This is a tree-bush-grass ecosystem with red-yellow and dark-red latosols which are "very deep with high clay content, a very low natural fertility, and a high percentage of aluminum saturation" (7). Other important areas are found in East Africa such as parts of Zambia, Tanzania, Kenya and most of Rwanda and Burundi. In addition, places in the Himalaya foothills and in some of the new wheat growing areas in Southeast Asia, e.g. transmigration areas in Sumatra, suffer from this problem.

Acid soils are chracterized by a lack of nutrients or lack of availability of nutrients (Figure 1), especially P, whereas other elements like Aluminum and Manganese reach toxic levels. Where feasible, liming up to at least pH 5.5 is recommended. Sufficient water supply also alleviates the impact of soil acidity.

Tolerant varieties provide cheaper means of overcoming this or can be used in addition to agronomic activities. Brazilian breeders have been working on this character since many years and produced tolerant lines, which are however of moderate yield potential, tall, and prone to lodging. Since 1973 CIMMYT runs a cooperative program of crossing and selection with substantial progress towards Aluminum and acid tolerant lines after two to three crossing cycles. The methodology consists in a combination of lab tests with shuttling segregating generation seeds back and forth between Brazil and Mexico. Selections made for tolerance to acid soils in Brazil are then shipped to Mexico to undergo selection for good plant type and high yield potential as well as disease resistance. Superior populations are again shipped back to Brazil, etc.

Resulting lines with proven tolerance to Aluminium can now yield within 5% of the best check in normal soil and up to 50% above the best check in many trials across acid soils in Brazil (3, 9). This led to the recent release of several varieties in Brazil derived from crosses between Mexican and Brazilian parents (13).

2.2. Dryland areas

We do not attempt to outline the areas of drought as some sort of dry spell occurs in nearly all unirrigated fields and drought tolerance is sought after even under irrigated conditions if there is limited water supply.

Critical growth stages when lack of water is specifically harmful to yield have been established in numerous trials (Table 1, Figure 2). This leads to optimum water use where irrigation is controlled but limited. Under purely rainfed conditions appropriate management can help to conserve water or reduce risks.

A considerable amount of the physiological reactions of wheat to drought stress is known and variability for some of these characters exists which makes breeding possible in theory. However, most breeders will agree that none of these characters is easy to use in selection for drought resistance and so far yield trials of relatively large plots appear to be the most practical tool (15). Other characters have three kinds of problems preventing them from being used:

(1) Some are not sufficiently closely associated with yield such as glume pubescence, wax, or stomatal regulation.

(2) Others cannot be assessed from single plants as would be necessary in segregating generations, e.g. production of fertile tillers to avoid waste of synthetates or harvest index.

(3) In many cases screening methods are too laborious to be used for an extensive number of plants as occurring in regular

breeding programs, e.g. water use efficiency, leaf thickness and others.

Consequently most breeders select segregating generations under optimum conditions and subject their advanced lines to drought stress in yield trials. It seems that breeders are confident that they are not loosing important variation due to poor performance of single plants under competition in early generation plots. Otherwise breeding methods like single seed decent which could avoid this would have to be used to a much larger extend. Nevertheless better breeding methods for drought stress including useful mass screening techniques are desirable (14).

CIMMYT has followed the same path for its selections. All advanced lines developed are submitted to reduced irrigation in one location and rainfed conditions in highlands. Experience shows that in nearly 100% of the cases the best yielder under drought is found amongst the best yielders under optimum conditions. (This does not say that all lines giving a high yield in a favourable environment continue to be among the best in dryland as well.) Some of the recently developed lines are shown in Table 2. This approach has the advantage that in a comparatively wet year farmers gain from these input efficient varieties. We are not sure whether they match with the need of all farmers in extreme drylands such as some North African areas or the barani land in Pakistan who sacrifice this chance of high yield in a wet year for the security to get a crop under nearly all circumstances through growing mixtures of tall low yielding varieties.

2.3. Tropical highlands

Substantial areas of tropical highlands occur in central America, the Andean Region and East Africa. They are characterized by a combination of typical diseases including Puccinia striiformis, Septoria sp., Fusarium sp., and BYDV.

Each of these diseases receives attention in several parts of the world. It is beyond the scope of this paper to report all the respective activities, only an incomplete enumeration of centers of research is given for each disease.

Puccinia striiformis is the only disease for which stable resistance is available in easy to use material. Cooperative monitoring is well established around the world.

Septoria resistance is not as easily identifiable and transferable as the rusts. Nevertheless considerable effort has lead to the identification of parents resistant to Septoria tritici (Table 3) and subsequent crosses incorporated this into advanced widely adapted genetic material (Table 4). Resulting lines got confirmation from several other countries where Septoria occurs every year such as Israel, Argentina, Ethiopia and Australia (12). A special screening nursery, the ISEPTON, is distributed annually and reports are published (6).

Fusarium, in contrast is still in its early stages of research, with main efforts being concentrated on Fusarium head scab in China, Brazil and Mexico. Work in Fusarium nivale is concentrated in temperate climates using genetical material which is unsuitable for short days.

BYDV has been present in many countries for a long time, but only recently its level of recognition has been risen and it is considered now one of the most important wheat diseases. As such it is undergoing research in several countries. Breeding work, however, is in its very initial stages due to the different aspects of vector and disease interaction.

It has to be pointed out that most wheat growing areas in tropical highlands will need a combination of these resistances and it will require considerable effort to bring them together into one variety.

2.4. Saline soils

Saline soils are an increasing problem, partly due to the use of marginal soils with natural salinity, partly due to increased fertilizer use in connection with unsufficiently developped draining systems. Major areas are found in the Middle East and North Africa, Northwestern Mexico and Southern Pakistan. Differences between crops in response to salt are well-known (Table 5) however there is little effort in screening variability within wheat.

CIMMYT has started to screen advanced lines by germinating seeds in petri dishes with 2.5 siemens/m of NaCl solution and then transplanting germinated seeds to pots watered with 1.2 siemens/m (4). Salt tolerant lines will be used as parents. Methods to improve screening under field conditions are also investigated. This is currently a minor part of the program but is very likely to be stepped up in the future.

3. Wheat for hot climates

3.1 Present wheat growing areas

To our knowledge 57 countries have grown wheat in the tropics at some time during the last four years either experimentally or commercially (Table 6). Adding up the 1981 wheat area of those countries which are entirely in the tropics or grow the majority of their wheat there below 1500 masl, we get 566000 ha with nearly half of this being in Sudan. The complete wheat area in the tropics can only be estimated as statistics follow political boundaries rather than the tropics of cancer and capricorn (Figure 3). However, parts of Brazil and some smaller spots like the lowlands of Bolivia, Southern Bangladesh or Queensland in Australia make us believe that there are above 3 million ha under wheat in the tropics.

3.2 Limitations for yield in the tropics

Correlating yield and latitude from all sites of the 18th ISWYN excluding tropical highland stations we get only r = .34.

A survey correlating yield of best adapted lines with relevant meteorological data of 28 stations in 15 countries between 39 and 1 degree North or South of the equator is presented in table 7. The coefficient of determination amounts to 26% for average minimum temperature during month of flowering. All six characters of table 7 account for 47% of the variation in yield leaving enough room for other causing factors such as agronomic practices, soils and germplasm. The findings confirm a hypothesis made from experience that average monthly minimum is more important than maximum temperature or mean. A subclassification of tropical climates considering more parameters has been given by R.A. Fischer (Table 8).

3.3 Breeding objectives

Major constraints to wheat growth in the tropics have been identified that can serve as breeding objectives (Table 9):

- Early heat tolerance: This includes germination in rather hot soil and tillering under high temperature and heading at normal time with reasonable size heads. (Many traditional lines give very small heads very early without tillering). Genetic variability is available in good agronomic background. Screening is done through early planting when temperatures are still high.

- Late heat tolerance: This includes the ability of the plant to fill the grain completely under hot temperature. It requires also that the leaves last long enough to produce enough assimilates. Genetic variability in agronomically acceptable lines is available. Screening is possible through late sowing so that grain filling period falls into rising temperature. Inspection of harvested grains for plumpness has to confirm field observations.

- Earliness is needed for different reasons: To fit into narrow crop rotations, to escape diseases or to avoid seasonal environmental stress, such as declining water supply or increasing temperatures. Broad genetic variability exists in good agronomic background.

- Tolerance to water logging plays an important role in rice wheat rotations where the plough pan in rice paddies often hinders drainage. The effects of excess water on crop plants are rather well known but no useable chracters for mass-screening are available (10). A few varieties are known to have some tolerance but they lack important other agronomic characters.

- Resistance to leaf rust: There are many high yielding resistant lines available and screening methods, though requiring some skill, are well established. But this is not something achieved for ever. Only continuous attention enables pathologists and breeders to cope with the changes in rust spectrum and always have resistant lines ready for release as current varieties become susceptible. As wheat area extends into warmer conditions we have to be aware of new races.

Resistance to Helminthosporium. H. sativum is by far the most common in this genus. Our knowledge about this pathogen is very limited compared to the rusts. Genetic variability exists but no complete resistance is known. Effects of several sources including other species may have to be brought together and the most resistant lines so far are not necessarily of high yield potential. Screening methods and measuring scales lack uniformity. Heavy breeding work is underway in several national programs and CIMMYT since recently. Only few lines from a first cycle of crossing are available. But a considerably higher level of resistance is needed for the expansion of wheat into hot and humid climates.

- Resistance to seedling blight caused by Sclerotium rohlfsii. This fungus can be devastating in poorly drained fields. There is little or no genetic resistance for that character, so that seed treatment or agricultural practices are the only remedies. Recent preliminary research in the Philippines indicated some variability for this character, too (11).

- Resistance to foot rots caused by Alternaria sp., Helminthosporium sp., Fusarium sp. and several other fungi can become a serious problem in hot climates. Very little is known about epidemiology and control of these soil borne fungi. Screening is difficult because uniform environments are not easy to create and therefore little is known about genetic variability.

- Resistance to aphids and stemborers is more important in hot climates than in others. Aphids do direct damage but can also transmit virus diseases. They have preference for certain varieties in experimental plots but whether there is true resistance in extended fields of one variety is not sure. Stem borers and other insects appear often in rice wheat rotations from the previous rice crop.

The problem for the breeder is to bring several of these characters together into an acceptable agronomic background so that the farmer gets reasonable yields every year. It is always easy to breed for one single character neglecting all the others. But such a line will never reach the farmers' fields.

Even for characters where we know that variability exists it is impossible to transfer knowledge about specific lines acquired in temperate climate to tropical areas. Therefore nothing can replace national research programs in target areas. Data for yield and days to flowering can demonstrate this (Table 10). Ures, Pavon and Nacozari are well above average yields in traditional wheat locations like Obregon and Lyallpur. But are below or only slightly above average in tropical areas. UP262 behaves the other way round. Sonalika and Quimori are very erratic. As we move our varieties to the tropics earliness appears to be similarly unpredictable. Pavon is 5 days later in flowering than Nacozari at Obregon and equal at Lyallpur, but 27 days later than Nacozari at Chiang Mai and 9 and 8 days later at Village Guede and Campinas, respectively. UP262 is even earlier in the tropics than in traditional areas and this fact together with the above average yield makes it certainly very interesting for tropical environments as long as there is no leaf rust. Sonalika is about constantly the same across environments and Quimori again somewhat erratic. This unpredictable behaviour can probably be shown for other characters, too.

4. Conclusions

Breeding wheat for marginal areas requires that additional characters are considered in breeding programs. Identification of variability with suitable screening technics, followed by crossing, selection of segregating generations and testing in target environments has to be performed for all of them. It was shown that there is considerable research underway which was already successful in some cases. Strong national programs and international exchange of knowledge and germplasm are prerequisits if better varieties are to reach the farmers' fields to cope with the specific stresses of marginal wheat growing environments.

References

(1) Bhardwaj, R.B.L., R.R. Singh, R.P. Singh, Vindhyachal Singh, M. Burhanuddin, H.G. Singh, S.P. Dhiman, Raj Singh, and K.S. Rathi, s.a.: Twenty Five Years of Research on Wheat Agronomy. In: Silver Jubilee, Indian Society of Agronomy, 1955-1980, pp. 203-224.

(2) Booker Tropical Soil Mannual, ed. by J.R. Candon, 1984. New York

(3) CIMMYT, 1984: 1983 Research Higlights.

(4) CIMMYT, 1984: Report on Wheat Improvement 1982.

(5) CIMMYT, 1984: Barley yellow dwarf, A Proceedings of the Workshop.

(6) CIMMYT, s.a.: Results of the thirteenth international Septoria observation nursery 1982-83.

(7) Dotto, S.R., C.A.B. Medieros, J.M.V. de Andrade, E.J. Iorczeski, 1984: A new agricultural frontier at central region of Brazil. In: Annual Wheat Newsletter, Vol. 30.

(8) Fischer, R. A., 1984: Physiological Limitations to Producing Wheat in Semi-Tropical and Tropical Environments and Possible Selection Criteria. In: Proceedings of the Symposium on Wheat for More Tropical Environments. Mexico City.

(9) IAPAR/OCEPAR, 1984: Resultados dos Ensaios Para Recomdacao de Cultivares de Trigo Parana, 1983. Trabalho apresentado na XII Reuniao Nacional de Pesquisa de Trigo - Cruz Alta - RS 16-20 de Julho 1984 (mimeo)

(10) Krizek, D.T., 1982: Plant response to atmospheric stress caused by water logging. In: Breeding plants for less favorable environments, ed. by M.N. Christiansen and C.F. Lewis. New York.

(11) Lapis, D.S., 1985: Personal communication.

(12) Mann, Ch. E., S. Rajaram and R.L. Villareal, 1985: Progress in breeding for Septoria tritici resistance in semidwarf spring wheat at CIMMYT. In: Proceedings of the International Workshop on Septoria diseases of Cereals, August 2-4, 1983, Bozeman, Montana.

(13) OCEPAR, 1984: Recomendacoes Tecnicas para a Cultura do Trigo no Estado do Parana. Programa de Pesquisa. Boletim Tecnico No. 13.

(14) Quizenberry, J.E., 1982: Breeding for drought resistance and plant water use efficiency. In: Breeding plants for less favorable environments, ed. by M.N. Christiansen and C.F. Lewis. New York.

(15) Richards, R.A., 1982: Breeding and selecting for drought resistance in wheat. In: Drought resistance in crops with emphasis on rice. IRRI, Los Banos.

D I S C U S S I O N

(A. L. DOTO):

With regard to association of climate variables to yield:

1) did the data come from standardized trials?
2) how large were the standard errors associated with the correlation coefficients?

Ans 1) We requested data on the average yield of the 5 best varieties in experimentation. This was considered a better approximation of yield potential that standardized varieties.

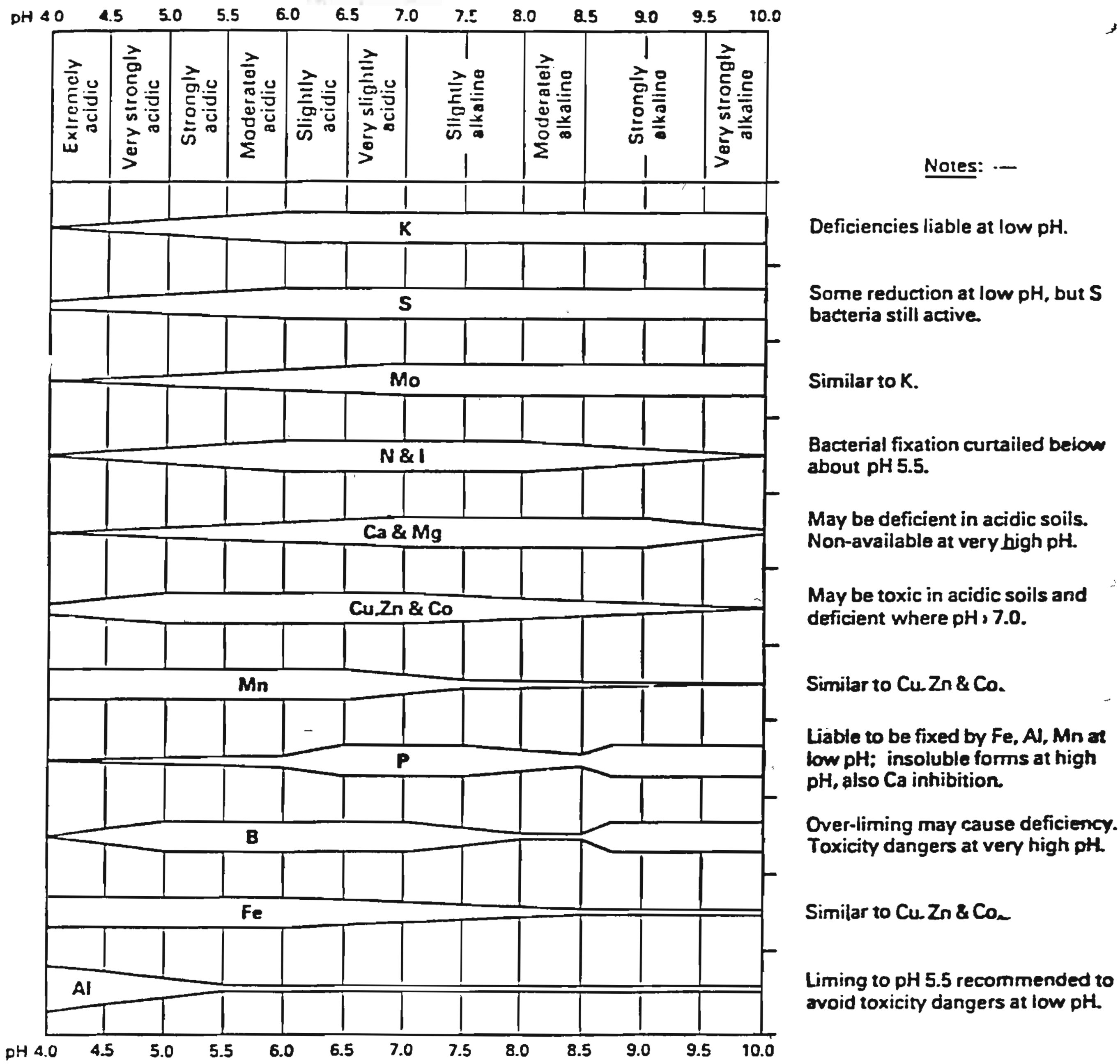
Ans 2) Standard errors were not calculated.

(A. L. DOTO):

It appears as if those areas falling under "hot" classification are also newcomers to the wheat industry. Yields in these areas would be expected to go up through research. Thus the results (r values) may apply to the current situation, but r values are likely to change with impact of research.

Ans. I fully agree with the comment.

Figure 1 : Availability of untrients in soils according to their pH.



Source : (2)

TABLE 1. IRRIGATION PATTERN FOR WHEAT TO AVOID CRITICAL PERIODS OF MOISTURE STRESS

CROP GROWTH STAGE	NUMBER OF IRRIGATIONS POSSIBLE (ACCORDING TO WATER SUPPLY)					
	1	2	3	4	5	6
CROWN ROOT INITIATION	X	X	X	X	X	X
LATE TILLERING				X	X	X
LATE STEM ELONGATION					X	X
BOOTING		X	X	X		
FLOWERING					X	X
MILK			X	X	X	X
DOUGH						X

SOURCE: (1)

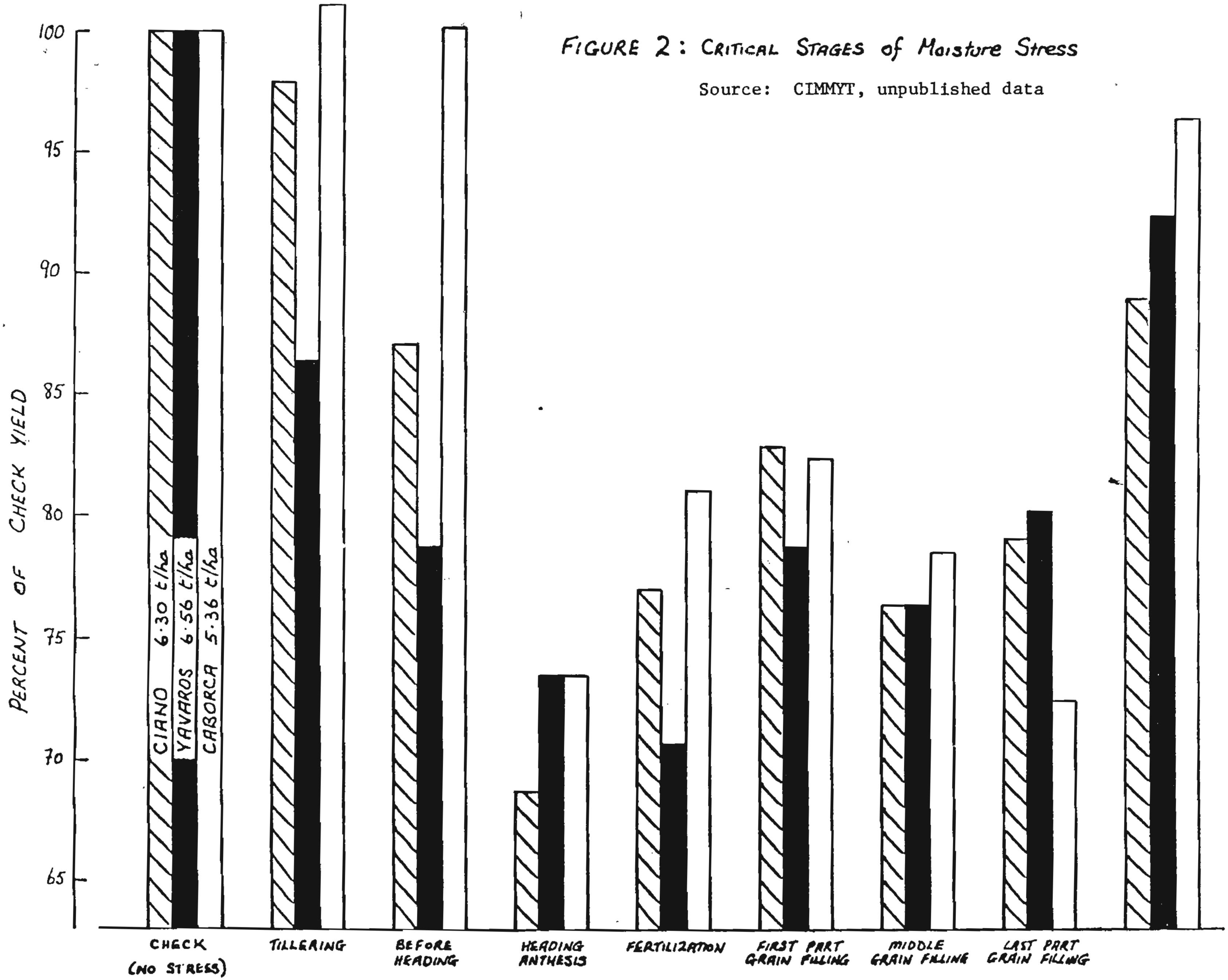


FIGURE 2: CRITICAL STAGES of Moisture Stress

Source: CIMMYT, unpublished data

Table 2. Advanced lines of bread wheat showing high yield performance (10% or more than Veery #5) grown at CIANO (40 MASL) under 2 irrigations (approximately 300 mm of water)

Cross and pedigree	Yield* (% of Veery #5)	Yield (kg/ha)
FURY-SLM75 x ALDAN"S" CM47967-H-3M-2Y-3M-1Y-1Y-0M	116	4951
AZ67xCHR-D.D.05P/F12.71-BLO"S" CM48326-A-3M-1Y-1M-2Y-1Y-0M	114	4859
MAYA74-NAC76 CM39424-1Y-1M-4Y-1M-1Y-1M-0Y	112	5188
VEE"S" CM33027-F-12M-1Y-12M-1Y-2M-0Y	111	5701
BUC"S"-BUL"S" CM50603-3Y-1M-4Y-1Y-0M	111	4744
LIRA"S" CM43903-H-4Y-1M-1Y-3M-3Y-0B	110	5306
BUC"S" CM31678-R-4Y-2M-15Y-0M-59B-0Y	110	4821
MAYA74-MON"S" CM29251-3M-17Y-4M-0Y-100Y-0B	110	4818

* Yield data from different experiments

Source : (4)

Table 3 Sources of resistance to *Septoria tritici*

Russian winter wheats	Spring wheats from southern cone
Aurora	Carazinho
Kavkaz	CNT 7
	CNT 8
American spring wheats	Gaboto
Chris	IAS 55
Era	IAS 58
Frontana-Kenya x Newthatch	IAS 62
	Lagoa Vermelha
	Maringa
	PF 70354
	TZPP

Source: (3)

Table 4. *Septoria tritici*-resistant semidwarf bread wheat cultivars with good yield and good agronomic type

Variety	Toluca 1982 *S. tritici* 1/ 75 days	96 days	Ht. (cm)	CIANO 1982-1983 Yield (kg/ha)	% of best check	Best check
	(0-9)	(0-9)				
KVZ-HD2009	2	3	95	6198	97	CIANO
BOW "S"	1	3	85	6759	95	URES 81
SNB "S"	2	3	90	6509	98	URES 81
LIRA "S"	1	3	80	6650	100	GLENNSON 81
TZPP (Resistant check)	2	3	110			
CIANO 79 (Susceptible check)	4	9	80			

1/ Two readings were taken at 75 and 96 days after sowing.
0-9 scoring scale used: 0 = completely resistant; 9 = completely susceptible.

Source : (3)

Table 5. Crop yield reduction at different levels Exchangeable Sodium Percentage (ESP)

Sensitive 50% yield reduction at ESP < 15%		Semi-tolerant 50% yield reduction at ESP 15-25%		Tolerant 50% yield reduction at ESP 35%	
Avocado	Persea americana	Dwarf kidney bean	Phaseolus sp	Alfalfa	Medicago sativa
Green bean	Phaseolus vulgaris	Ladino clover	Trifolium repens	Barley	Hordeum vulgare
Corn	Zea mays	Carrot	Daucus carota	Sugarbeet	Beta vulgaris
Tall fescue	Festuca arundinacea	Lemon	Citrus spp	Cotton	Gossypium hirsutum
Peach	Prunus persica	Lettuce	Lactuca sativa	Dallis grass	Paspalum dilatatum
Sweet orange	Citrus spp	Oats	Avena sativa	Onion	Allium cepa
Grapefruit	Citrus paradisi	Rice	Oryza sativa	Bermuda grass	Cynodon dactylon
		Sorghum	Sorghum vulgare		
		Wheat	Triticum vulgare		
		Sugarcane	Saccharum spp		

Table 6. Countries growing wheat in the tropics and respective commercial area in 1981. (Brackets indicate that majority of wheat area is outside the tropics or above 1500 masl.)

America:	Area 1000 ha*	Africa (cont'd.)	Area
Mexico	(861)	Burundi	(6)
Guatemala	(64)	Angola	(16)
Honduras	1	Zambia	(3)
Nicaragua		Malawi	1
Costa Rica		Mozambique	3
Dominican Republic		Madagascar	
Colombia	(39)	Zimbabwe	41
Venezuela	(2)	Namibia	1
Guyana		Botswana	3
Brazil	(1921)		
Peru	(100)	**Asia:**	
Ecuador	(37)		
Bolivia	(77)	Saudi Arabia	85
Paraguay	(70)	Yemen, Arab Rep.	66
		Yemen, DPR	10
		Oman	0.3
Africa:		Fed. of Arab Emirates	0.4
Mauretania		India	(22104)
Mali	2	Sri Lanka	
Niger	2	Bangladesh	(591)
Chad	3	Burma	88
Sudan	240	Thailand	
Ethiopia	(523)	Vietnam	
Senegal		China	(29201)
Upper Volta		Taiwan	
Ghana		Philippines	
Nigeria	13	Malaysia	
Cameroon	2	Indonesia	
Somalia	4		
Zaire	(5)	**Australia**	(12041)
Uganda	(4)		
Kenya	(120)		
Tanzania	(50)		
Rwanda	(4)		

* Source: FAO Production Yearbook 1981

Figure 3 : Wheat production in the tropics

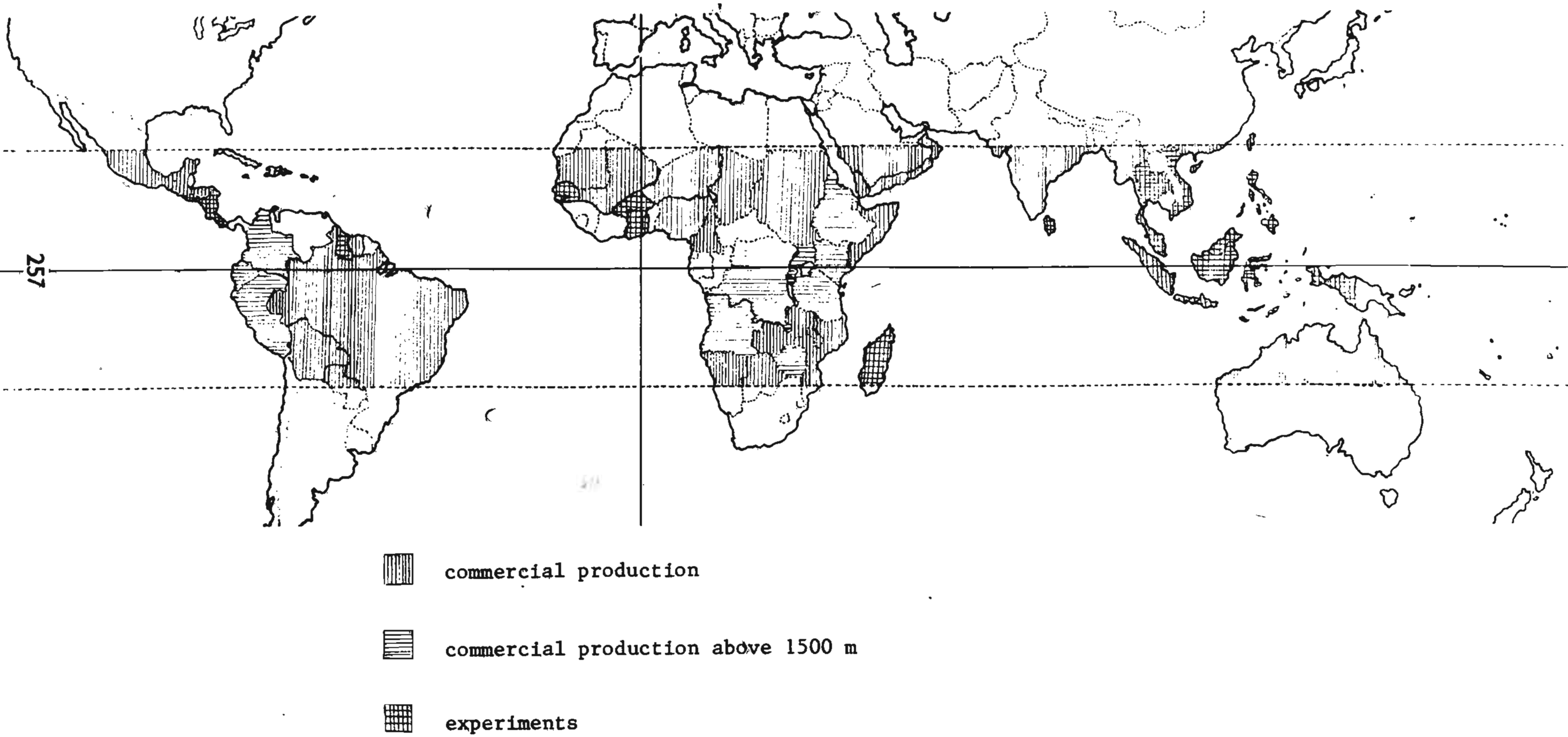


Table 7. Correlation coefficients between yield and climatological parameters from 28 locations in 15 countries

Parameters	Range	Correlation coefficient with yield
Yield	800-10100 kg/ha	-
Average minumum temperature at month of sowing	3.7-23.6°C	-.40*
at month after flowering	8.7-20.8°C	-.51**
Average maximum temperature at month of sowing	12.0-36.1°C	-.16
at month after flowering	14.8-32.4°C	-.33
Average relative humidity at month of sowing	37-86%	-.45*
at month after flowering	38-89%	-.40*

*,**: significant at the 5 and 1% level, respectively.

Table 8. Actual and possible wheat growing locations in and near the tropics and principal features of their temperature and humidity regimes in the month of January (July in southern hemisphere).

Thermal and humidity regime	Location			Mean daily January weather				Total rain		Locations with approx. similar wheat climate
	Site	Lat-itude	Altitude (m)	Temperature Mean	Temperature Range	VPD (mb)	Solar radiation ($MJ/m^2/d$)	Dec-Feb (mm)	Year (mm)	
1a. Very hot, humid	Los Banos, Philippines	14N	40	24	5	6	15	230	2040	Jakarta
	Phitsanulok, Thailand	17N	50	25	14	8	-	32	1354	
1b. Very hot, dry	Khartoum, Sudan	16N	380	24	16	22	20	0	164	
	Kununurra, Australia	17S	30	23	17	19	21	5	745	
2a. Hot, humid	Chiang Mai, Thailand	18N	313	21	16	6	-	28	1246	Mandalay
	Dacca, Bangladesh	24N	8	19	14	6	15	51	1928	Poza Rica, Villa Queda
	Formosa, Brasila	16S	911	19	14	8	-	17	1595	Santa Cruz, Asuncion
2b. Hot, dry	Kano, Nigeria	12N	470	22	17	20	21	1	873	Hyderabad (I), Taiz
	Indore, India	23N	555	18	17	12	16	16	876	Tlaltizapan
3a. Warm, humid	Lima, Peru	12S	11	15	4	1	21	5	10	
	Emerald, Australia	23S	179	15	16	5	-	108	591	
	Harare, Zimbabwe	18S	1470	14	15	7	18	9	868	Lusaka
	Canton, China	23N	18	14	9	4	-	126	1720	
4. Warm, (lat 25-30)	Riyadh, S. Arabia	25N	594	15	14	6	-	42	105	New Delhi, Kufra
	CIANO, Mexico	27N	40	15	16	3	13	40	267	Cairo

Source : (8)

Table 9. Wheat breeding objectives for tropical environments

	Genetic Variability Available	Screening Methods Available	Advanced Lines Available
- Early heat tolerance	+	+	-
- Late heat tolerance	+	+	±
- Earliness	++	+	+
- Tolerance to water logging	±	+	-
- Resistance to	±	+	-
- leaf rust (Puccinia recondita)	++	+	++
- leaf blotch (Helminthosporium sp.)	±	+	-
- seedling blight (Sclerotium rohlfsii)	-	-	-
- foot rots	?	-	-
- aphids, stem borers	?	?	-

Table 10. Relative yields and days to flowering in traditional (Mexico, Pakistan) and tropical (Thailand, Sénégal, Brazil) wheat growing areas.*

Variety / Location	Yield as % of location mean						Days to flowering as % of location mean					
	Ures	Pvn	Nac	UP262	Ska	Qui-mori	Ures	Pvn	Nac	UP262	Ska	Qui-mori
Cd. Obregón, Mexico	120	115	114	90	104	82	107	101	96	90	82	86
Lyallpur, Pakistan	108	112	127	92	95	101	105	97	97	93	87	89
- - -	-	-	-	-	-	-	-	-	-	-	-	-
Chiang Mai, Thailand	70	96	96	144	83	180	117	110	83	87	80	81
Village Guede, Sénégal	96	101	87	105	87	81	113	98	89	89	81	93
Campinas, Brazil	94	108	104	112	117	94	114	98	90	87	80	88

* Data from 18th ISWYN

The inheritance of aluminium tolerance in wheat

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INTRODUCTION

The first objective of this study was to identify varietal differences to aluminium (Al) toxicity of various cultivars of wheat. The second was an attempt to investigate some aspects of the genetics of Al tolerance in wheat from crosses of four wheat cultivars.

1. SCREENING FOR Al TOLERANCE MATERIALS AND METHODS

Initially twelve varieties of wheat were screened for Al tolerance using (i) the ability of roots to regrow after exposure to Al (ii) the visual detection of Al tolerance by hematoxylin. Using the regrowth technique seedlings were first grown in nutrient solution and then transfered to another containing 1.7mm $AlCl_3$ (CIMMYT). The nutrient solution was made up of:- 5.0mM $CaCl_2$; 6.5mM KNO_3; 2.5mM $MgCl_2$; 0.1mM $(NH_4)_2$ SO_4 and 0.4mM NH_4NO_3 (Polle et al., 1978). After the Al treatment the seedling roots were stained with hematoxylin and then allowed to recover in an Al free nutrient solution for 24 hours. Measurements were taken of the new growth of the longest root of each seedling. In the other method, the seedlings of each cultivar were grown in three different $AlCl_3$ concentrations (0.18, 0.36 and 0.72mM) then stained with hematoxylin (Polle et al., 1978). Scoring was based on the amount of staining of roots.

RESULTS

The data on root recovery and amount of staining are shown in Table 1. Both methods of testing indicated varietal differences in their response to Al toxicity.

DISCUSSION

The results showed a general relationship in that the varieties with the shortest roots by the recovery method were classified as the most sensitive while those with the longest roots were the most tolerant by the hematoxylin test (Table 1).

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* The work reported here was part of a study carried out as partial requirement for the degree of Master of Science at the University College of Swansea.

Table 1. Mean Root lengths and Tolerance levels of Hematoxylin Staining

Variety	Root length* (mm)	Tolerance level by Hematoxylin staining
Jupateco	0.00a	Sensitive
PF 7668	0.05b	Sensitive
Veery's'	0.07b	Moderately sensitive
Limpopo	0.92b	Moderately
IAS 64-Aldan's'	2.08c	Intermediate
Pel 73280-Art(TzppxIRN46-Cno's'/Protor)	3.32d	Tolerant
IAS 63-Ald's'xGto-Lv	4.15d	Tolerant
PF 7748	4.70d	Intermediate-Tolerant
B 7901	5.02d	Tolerant
Mascarenhas	6.56e	Tolerant
IAS 58-Mad's'	10.78f	Tolerant
IAC 21	11.56f	Tolerant

Mean root lengths, followed by the same letter are not significantly different by Duncan's new multiple range test at 0.05 level of significance.

2. Genetic Study Materials and Methods

Of the varieties tested above four were selected as parents and crossed in a diallel manner. There were:-

A80 Veery's' CM 33027-F-15M-500Y-0M = Loerie
B59 PF 7748 N.D. 81/IAS59//IAS 58
B209 IAS 58-Mad's' CM 50472-1Y-4F-70Y-2F-0Y
C104 B7901 = B26/CNT6

From the F_1 seed obtained some of the seeds were grown to give an F_2 generation. All parents, F_1 and F_2 generations were tested together for Al tolerance using the root recovery method.

Results

Analysis of variance of the parents with the F_1 progeny showed significant differences among genotypes, among and within generations. All the reciprocal crosses showed significant differences except the reciprocals of PF 7748 and IAS58-Mad's' (Table 2). However, the pooled data in the diallel analysis showed that there were no reciprocal differences when the reciprocal mean squre was compared with the error mean square. Lack of replication could have contributed to the fact that different results were obtained using different methods of comparison.

Table 2. F_1 root length means ($\bar{x}$) following growth after Al exposure, mid-parent values and degree of dominance

Parents and Cosses	$\bar{x}$* (mm)	Mid-parents value	Dominance
Veery's'	0.23a		
PF 7748	3.12b		
IAS 58-Mad's'	11.70e		
B 7901	4.88c		
Veery's' x PF 7748	2.62c	1.67	0.67
PF 7748 x Veery's'	1.94a	1.67	0.18
Veery's' x IAS 58-Mad's'	6.33d	5.96	0.06
IAS 58-Mad's'xVeery's'	15.08f	5.96	1.58
Veery's' - B7901	4.22b,c	2.55	0.72
B7901-Veery's'	1.98a	2.55	-0.25
PF 7748xIAS58-Mad's'	6.57d	7.41	-0.20
IAS58-Mad's'xPF7748	8.35d	7.41	0.22
PF7748-B7901	4.52c	4.00	0.59
B7901-PF7748	2.17a,b	4.00	-2.08
IAS58-Mad's' x B7901	6.03c,d	8.29	-0.66
B7901xIAS58-Mad's'	1.52a	8.29	-1.99

*Means followed by the same letter are not significantly different by Duncan's new multiple range test at 0.05 level of significance.

The results showed that the F_1 means of all crosses where IAS58-Mad's' was the female parent were higher than when it was the male parent. The other parents did not show this characteristic.

The degree of dominance for each cross ranged from -2.08 to 1.58. Analysis of variance of the diallel table (Table 3) indicated significant differences between the female parents but not between the male parents.

The half-diallel, variance (Vr) and covariance (Wr) were estimated to provide a measure of dominance and gene interaction. These values are presented in Table 4.

Table 3. Root length means (mm) in the diallel set of crosses

Male Parent	Female Parent A80	B59	B209	C104	Mean
A80	0.2340	1.9379	15.0769	1.9796	4.8079
B59	2.6182	3.1205	8.3529	2.1667	4.0646
B209	6.3333	6.5714	11.7024	1.5152	6.5306
C104	4.2250	4.5185	6.0333	4.8807	4.9144
Mean	3.3526	4.0371	10.2924	2.6356	5.0792

Table 4 Half-diallel with array means, Vr and Wr

	A80	B59	B209	C104	Mean	Vr	Wr
A80	0.2340	2.2782	10.7051	3.1023	4.0799	21.0791	20.9615
B59		3.1205	7.4622	3.3426	4.0509	11.7463	5.3745
B209			11.7024	3.7743	8.4110	4.4877	12.8318
C104				4.8807	3.7750	1.2941	0.6207

Linear regression of Wr on Vr was 0.75 ± 0.42. The relationship between Wr + Vr and the mean of the common parent was used to determine whether the distribution of dominant alleles is correlated with the phenotype of the common parents. There was a negative correlation between Wr+Vr and the means of the common parents (r=0.48). The least tolerant variety, Veery's', showed the highest Wr+Vr value, and B7901 the most tolerant had the lowest value.

Parent-progeny relationships were low for Al tolerance as judged by root regrowth from the regression of F_1 on mid parent values and F_2 on F_1 values, 0.28 and 0.29, respectively. The regression of F_2 means on the mid-parent values, 0.41, was intermediate. The F_2 root distributious fell within the range of the parents involved in each cross. With the exception of the progeny of the cross Veery's' x-PF7748 which had a wider root length distribution than both parents.

Discussion

The results of this study indicated that additive genes are involved in the control of Al tolerance as measured by root regrowth following exposure to Al. This was inferred by non significant difference of the means between the male parents in the diallel analysis. Significant differences for female parents were observed implying the maternal factors or the contribution of non-additive variation to the control of root regrowth. Close comparison of the means from the corresponding arrays from the female parents shown in Table 3, confirms this, particularly with the variety IAS58-Mad's', which always gave higher progeny means when it was the female parent than when it was the male parent. The possibility that IAS58-Mad's' may have maternal factors in further substantiated by the regression of Wr+Vr on the parent means. Mather and Jinks (1960) state that genotypes carrying few genes of a dominat character tend to have higher Wr+Vr values and those carrying several dominant genes will have low values. This implies that if all the parents in a diallel cross carry only nuclear genes for the character, then the arrays of the parents would all lie along a straight line except for random sampling variation in the estimates of Wr and Vr. In this study IAS58-Mad's' which has the highest mean root growth has an intermediate Wr+Vr value and was placed quite a distance away from the straight line formed by the arraya of the other three parents (Fig 2). It shows that in this variety different genes for root regrowth can show both dominance and necessivity or that there may be interaction or extranuclear factors.

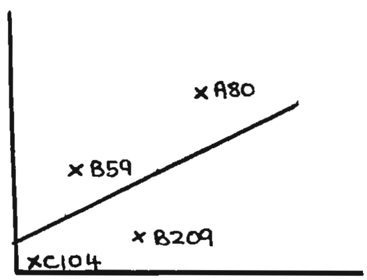
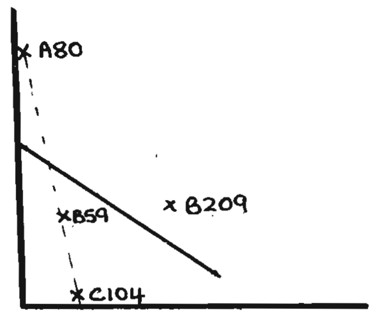


Fig 1 The Wr/Vr graph for root growth in the diallel. The parental line giving rise to each array repre-nted by each point is re-presented by the code against it



Parent means

Fig 2 Wr+Vr from each array of the diallel plottted against parental root growth means

The negative correlation of Wr+Vr on parent means showed that Veery's' which was the least tolerant of the parents, had the least number of dominat root regrowth alleles, B7901 had the highest number, while PF 7748 and IAS 58-Mad's' had an intermediate number. The regression line of Wr on Vr showed the order of the parents from the highest to the lowest parent with regard to the number of dominant alleles was estimated as B7901, PF7748, IAS 58-Mad's' and Veery's' (Fig 1).

The foregoing discussion had indicated dominance of root regrowth although a closer examination of F_1 root length means show various degrees of dominance, Some of the F_1 progeny showed the absence of dominance, others displayed partial dominance and dominance (Table 2). The degree of dominance appeared to be greatest in most crosses involving the most sensitive parent Veery's', and the inter-mediate parent PF 7748. Negative values for the degree of dominance were observed in five of the crosses. Suggesting hybrid depression. The significant difference between IAS58-

Mad's' x Veery's' (F_1) and IAS 58-Mad's' indicated heterosis in this cross. Complete dominance was illustrated by those F_1 values greater than their mid-parent values. Partial and no dominance were shown by those F_1 means slightly greater than or equal to the mid-parent value.

The F_2 root length distribution of the cross Veery's' - PF7748 was broader than either parent. About 20 per cent of the seedlings produced longer roots than either parent. The dispersion could have been caused by segregation of Al tolerance genes or segregation for factors affecting root l length but not related to Al response. This was the only cross where there appeared to be transgressive segregation.

Heritability estimates based upon parent-progeny regressions were low and intermediate. Lafever and Campbell (1978) had also obtained a low heritability (0.03) and suggested that differences in root lengths of the progeny were not related to the genetic differences in the ability to tolerate Al. In view of this observation root growth may not be a very reliable indicator of Al tolerance.

The results of this study were in general agreement with observations made by other investigators. It is evident that Al tolerance in wheat is dominant and will therefore enable its transfer into genotypes possessing other favourable characters.

References:

CIMMYT: Screening method for wheat aluminium tolerance used at CIMMYT's laboratory (Unpublished report).

Lafever, H.N. and Campbell, L.G. 1978. Inheritance of aluminium in wheat. Canadian Journal of Genetics and Cytology 20:355-364.

Mather, K. and Jinks, J.L. 1977. Introduction to Biometrical Genetics. Chapman and Hall, London, pp 68-90

Polle, E., Konzak, C.F. and Kittrick, J.A., 1978. Visual detection of aluminium tolerance levels in wheat by hematoxylin staining of seedling roots. Crop Science 18:823-827.

C O M M E N T S

(K. G. BRIGGS):

The conclusion that seedling root regrowth may not be a very good method for assessing aluminum tolerance may be true for the way you evaluated the material. A major problem is that the parents differ in root size and root growth potential in absence of aluminium, and thus a "relative growth ratio" is preferable. Such a ratio takes into account the root growth rate of materials in solution without aluminium, and removes scale effects and other confounding factors. This root regrowth index is used commonly in Dr. Foy's laboratory at Deltsville as well as in the U. of Alberta. It may also be that differences in intrinsic (unstressed) root growth be responsible for some of the reciprocal effects you picked in your study.

Soil reaction as a criterion to identify farmland at suitable for wheat and triticale in the Mugamba region of Burundi

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Summary

Results from on-farm experimentation in the Mugamba region of Burundi have shown that wheat and triticale respond differentially to soil reaction. This could be linked to a lesser sensitivity of triticale to high aluminum concentrations. Triticale appears to be advantageous only when soil pH fall below 5.0. Under these conditions, triticale can outyield wheat by 30 to 80% according to the level of acidity. Triticale should be limited to regions typified by humiferous hygrokaolisols which are usually very acid and poor.

Introduction

Wheat is grown in Burundi since the beginning of the 20th Century, whereas triticale was introduced just in 1975. Out of these two cereals, only wheat is grown commercially, triticale is limited to research and demonstration plots. Wheat cultivation is restricted to the highlands of the Zaire-Nile Sierra (1900 m altitude) where climate is cool and humid (average daily temperature is 16° C; annual rainfall is about 1500 mm). The most common soils in the wheat area are hygrokaolisols and humiferous hygrokaolisols ((NEAC classification, 5). These soils are frequently acid, and may contain significant amounts of free aluminum.

Wheat and triticale variety trials conducted since 1976 at different research sites in Burundi have shown that triticale outyields wheat in very acid soils. Thus, in the 1980 multilocation variety trials, triticale yielded 30-40% above Romany, the wheat local check (4). The hypothesis tha triticale is less sensitive to aluminum toxicity is supported by data from Mugwira and Elgawhary (2) who have proven that the root system of triticale is less sensitive to high concentration of aluminum than that of wheat.

This study aimed at determining the comparative advantages of triticale over wheat under farmer's conditions and in relation to the physico-chemical properties of soils. Results may allow to classify farmland as suitable for wheat or triticale in the Mugamba. Trials were conducted in the second crop season (March to August) of 1984 and 1985. This paper reports data from 1984 only.

Materials and Methods

Ninety-six on-farm trials were established in March-April 1984, comparing wheat cv Romany with triticale cv Beaver/Armadillo (Bvr/Arm) and Mizar. Sites were distributed throughout the Mugamba, from 1900 to 2200 m of altitude. At each site, varieties were planted in single, non-replicated but randomly allocated plots 10 m^2 each. Cultural practices resembled those followed by farmers: seed was broadcasted at a density of 100 kg/ha, no fertilizer was applied and weeding was seldom done. Physical and chemical soil analysis were carried out at each site on a composite of subsamples taken at the root horizon (Ap) and the one immediately below. The INEAC soil classification (5) has been used throughout. The terms of this system are not closely related to the US classification (6).

Out of 77 sites retained as reliable sources of data, 7 were established on brown soils, generally of kaolinitic nature; 36 on hygrokaolisols (ferrisols); and 34 on humiferous hygrokaolisols (29 ferisols and 5 ferralsols). Brown soils and hygrokaolisols are comparable to subgroups agrudalf and tropudult, and humiferous hygrokaolisols to palehumults, haplohumox and sombrihumox (3). Brown soils and hygrokaolisols are generally more fertile than humiferous hygrokaolisols. "Ap" horizon of brown soils has an effective cation exchange capacity (CEC) in excess of 25 me/100 g. In the experimental sites the degree of saturation (V) of this horizon was on the average 65% with carbon content of 2.3%; by contrast, hygrokaolisols had CEC values below 25 me/100 g, saturation of 62% and carbon content of 1.8%; finally, humiferous hygrokaolisols had less than 25 me/100 g CEC, a very thick humus layer (up to 100 cm), a degree of saturation of 26% and carbon content of 4.4%. As a whole, experimental sites range in pH from 4.4 to 6.6, and in saturation of aluminum expressed as proportion of CEC (Kamprath's 'm' index (1)) from 0 to 78%.

To determine whether wheat and triticale have a differential response to soil acidity, yields of triticale relative to those of wheat were analyzed vis-a-vis soil pH disregarding soil type. Sites were assigned to one of six classes according to their pH, with the intent that classes had a similar number of sites (n=12 or 13). The next step was to group sites for soil type, with soil pH as a second criterion for subdivision; yield analysis in this scheme is expected to allow a classification of farmland for wheat and triticale that can be based on soil mapping. Groups were arranged so that the number of sites assigned to each group remained similar (n=7 - 9).

Results

Yields of triticale cv Bvr/Arm and Mizar relative to wheat cv Romany are given in Fig 1 and 2, respectively, for each of six levels of soil reaction. These figures illustrate that triticale outyields wheat on very acid soils. Yields of Mizar and Bvr/Arm are superior by 61% and 100% to that of wheat at soil pH ranging from 4.6 and 5.0; when soil pH exceeds 5.0, none of the triticales is more productive than wheat. It is also noticeable that the lower the pH the higher the Kamprath index.

The advantage of triticale over wheat is more apparent on humiferous hygrokaolisols, which have more acid reaction than hygrokaolisols and brown soils (Table 1). Within this soil type, yields of triticale relative to wheat are higher to the extent that soils are more acid. When soil pH drops from 5.7 to 4.7, the advantage of triticale over wheat increases from 18 to 83% for Bvr/Arm, and from 9 to 55% for Mizar.

Conclusions

Hardiness of triticale to soil acidity has been confirmed in this study. These results set the base for land classification in the Mugamba using physico-chemical soil properties. Within the limits of this study, triticale does not appear to be advantageous over wheat on hygrokaolisols and brown soils. On humiferous hygrokaolisols, however, triticale is more productive than wheat, and the more so as the soil pH is lower. This special adaptation of triticale to acid soils may be due to less sensitivity to aluminium toxicity.

Fig. 1

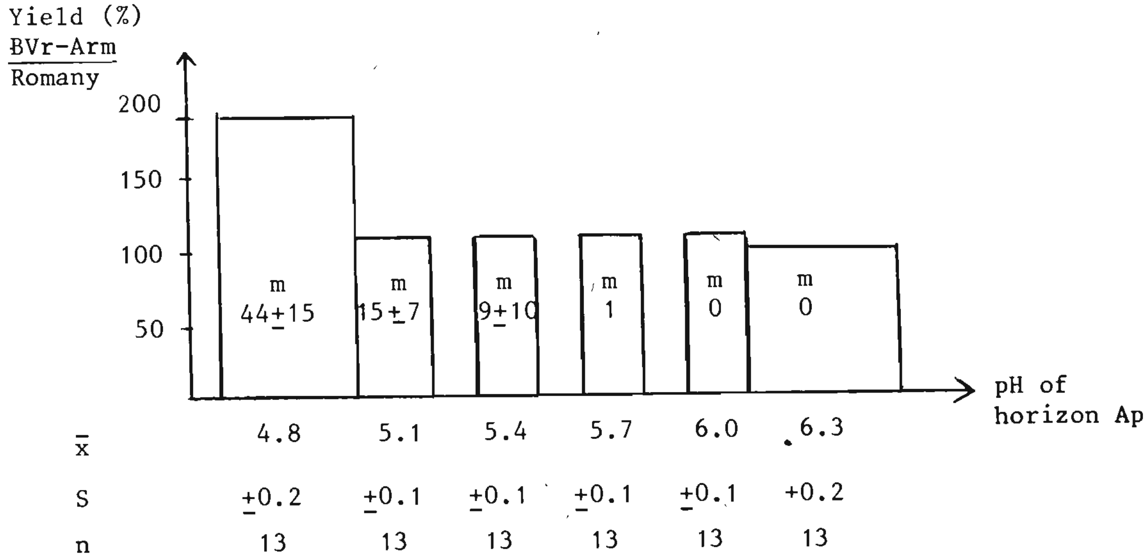

Fig. 2

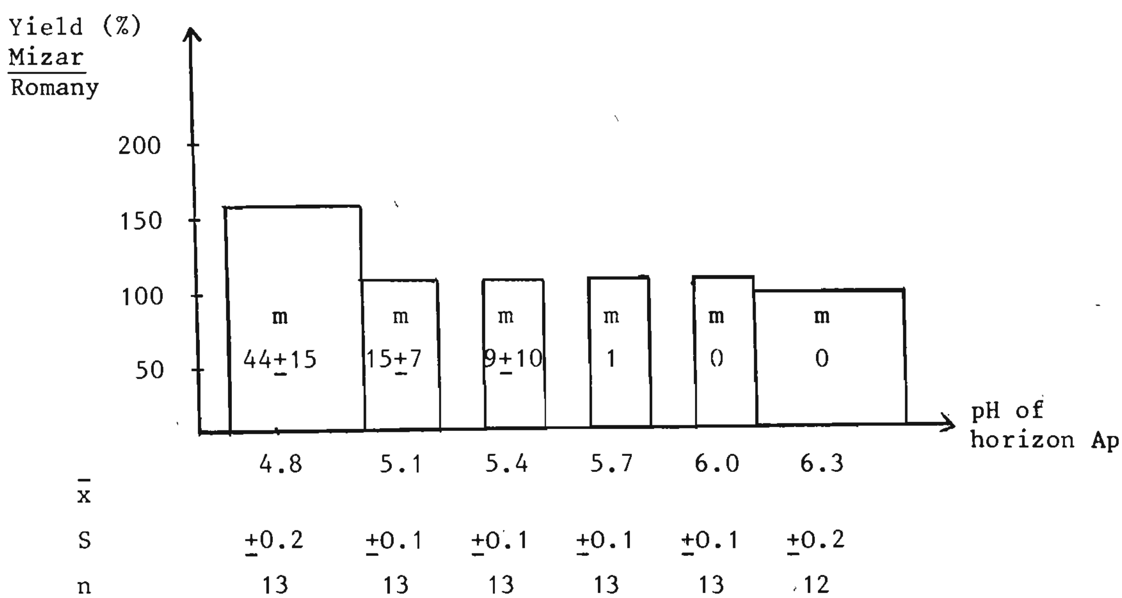

Fig. 1 and 2: Yield ratios of triticale (BVr/Arm and Mizar, respectively) to wheat (cv. Romany) as affected by soil acidity and aluminium saturation (m) in Ap horizon.

Table 1. Yields of wheat cv. Romany and triticale cv. BVr/Arm and Mizar analyzed by soil type, soil acidity and aluminium saturation index (m) in horizon Ap

Soil pH	m	Number	Romany	BVr/Arm		Mizar	
$\bar{x}$ and S	$\bar{x}$ and S	(of trials)	kg/ha	kg/ha	%Romany	kg/ha	%Romany
Humiferous Hygrokaolisols							
4.7 ± 0.2	48 ± 14	9	1182	2169**	183	1836*	155
5.0 ± 0.1	22 ± 9	9	1149	1669	145	1484	129
5.3 ± 0.1	17 ± 12	8	1073	1388	129	1296	121
5.7 ± 0.2	3 ± 3	8	1190	1410	118	1294	109
$\bar{x}$			1150	1674***	146	1488**	129
Hygrokaolisols							
5.3 ± 0.2	14 ± 16	9	1140	1055	93	1060	93
5.8 ± 0.1	<1	9	1702	1573	92	1686	99
6.1 ± 0.1	0	9	1780	1622	91	1732	97
6.4 ± 0.2	0	9	1372	1608	117	1352	99
$\bar{x}$			1498	1465	107	1458	97
Brown soils							
5.8 ± 0.3	<1	7	1857	2176	117	2180	117

*, **, *** Significantly different from wheat cv. Romany at 5, 1 and 0.1% respectively

Acknowledgements

The author expresses his appreciation to all those who took part in this study of wheat and triticale productivity in the Mugamba: the directors and agronomists of project CVHA, Messrs. J.F. Lays and D. Sindayigaya from ISABU pre-extension programme, Messrs. R. Ntukamazina and R. Baragenga from ISABU wheat and triticale programme, Mr. L. Opdecamp from ISABU soil fertility team, Messrs. Gourdin, P. Hollebosch and Mrs. Kibiriti from ISABU laboratory of Agricultural Chemistry, and to the innumerable peasants of the Mugamba who made this study possible.

Bibliography

1. Kamprath, E.J.; 1967. Soil acidity and response to liming. Rech. Bull. 4 International Soil Testing series, N.C. State Univ. Agri. Exp. Sta. Raleigh, North Carolina.

2. Mugwira, L.M. and S.M. Elgawhary; 1979. Aluminium accumulation and tolerance to triticale and wheat in relation to root cation exchange capacity. Soil Sci. So. Am. J., Vol. 43: 735-740.

3. Opdecamp, L.; 1984. Rapport annuel, Institut des Sciences Agronomiques du Burundi, Vol. 3.: 2-5.

4. Schalbroek, J.J.; 1982. Les assais varietaux de triticale (*X Triticosecale*) et de ble (*Triticum aestivum*) conduits au Burundi en 1980. Interactions varietes x environnements. Institut des Sciences Agronomiques du Burundi, Publ. No. 14.

5. Tavernier, R. and C. Sys; 1965. Classification of the Soil of the Republic of Congo (Kinshasa). P 91-136. *In* Pedologie. Int. Symp. 3. Soil classification (Gent).

6. U.S. Department of Agriculture; 1967. Soil classification. A Comprehensive system. 7th approximation, Suppliment.

DISCUSSION

(J. E. BRANDLE):

Have you evaluated aluminum tolerant wheat varieties?

> Ans. We have tested CIMMYT/Brazilian materials which have aluminum tolerance. Unfortunately they tend to be susceptible to yellow rust.

(W. C. JAMES):

Now that you have demonstrated that triticale is advantageous in humiferous soils in Burundi, what is the potential area for its cultivation?

> Ans. Potential area for triticale production can be estilated around 6,000 ha.

(G. L. RICHARDSON):

Do you have any information as to why triticale is more tolerant of acid soils?

> Ans. One hypothesis is that triticale actually raises pH in the rhizosphere and decreases aluminum solubility. The other hypothesis is that triticale is simply less sensitive to aluminum toxicity.

COMMENTS

(K. G. BRIGGS):

The check variety used in this study has a well known tolerance to acid soils in East Africa. If comparisons had been made to any other non- tolerant wheat, the advantage of triticale would had been much higher than the values reported above. The value of Romany in breeding programs should not be overlooked, particularly in East Africa, where acid conditions exist but not at an acute level for wheat.

Response of wheat to temperature as influenced by altitude

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INTRODUCTION

Wheat (<u>Triticum</u> <u>aestivum</u> L.) is grown as an irrigated winter crop in all regions of Zimbabwe, the largest area being in the highveld (> 1200 m a.s.l.) followed by the lowveld (300 - 900m a.s.l.) where yields are about 50 to 60% of those obtained in the highveld. The main cause of yield differences between the highveld and lowveld is temperature, with the latter region experiencing relatively higher temperature at the beginning and end of the season. The adverse effects of high temperature at both ends of the season can be reduced by the use of short-duration cultivars. Alternatively, high-temperature tolerant cultivars with longer duration may be useful and suitable for all regions. A genotype that can translocate and redistribute assimilates formed during the pre-anthesis phase (Aggarwal <u>et</u> <u>al</u>, 1984) or that responds to acclimation at moderately high temperatures resulting in stimulation rather than inhibition (Weidner <u>et</u> <u>al</u>, 1975) and/or responds to vernalization or photoperied (Midmore <u>et</u> <u>al</u>, 1982) may be adapted to growing conditions experienced in the lowveld. These mechanisms of tolerance to high temperature may be manifested in high number of ears per unit area, grain number per ear and weight per grain which lead to higher grain yield under high temperature conditions. This study was to investigate how wheat genotypes respond to different temperature regimes experienced in the wheat growing regions of Zimbabwe.

MATERIALS AND METHODS

Thirty wheat (<u>Triticum</u> <u>aestivum</u> L.) cultivars, representing commercially grown cultivars and experimental lines, were used in this study. The cultivars were planted in a 5 x 6 rectangular lattice design replicated three times at seven sites (Table 1). Daily minimum and maximum temperatures were collected at each site except at Gwebi where data from the nearest meteorological station was used.

Records on days to 50% anthesis and maturity, ear height, number of ears per square metre, grains per ear, weight of a thousand grains and grain weight per nett plot were determined at each site. Grain filling duration was taken as the duration from anthesis to maturity.

RESULTS AND DISCUSSION

CLIMATIC CONDITIONS

The altitude and daily mean temperature (°C) during the pre-and post-anthesis phases of each site are given below:

	Harare	Gwebi	Matopos	Kadoma	Panmure	Chiredzi	Chisumbanje
Altitude (m a.s.l.)	1506	1448	1338	1157	881	430	421
Pre - anthesis	14,2	15,0	13,1	17,2	17,1	18,4	19,1
Post - anthesis	18,4	20,3	20,8	20,9	17,6	19,2	18,6

Daily mean temperature (DMT) during the pre-anthesis phase depended on altitude of the site ($r = -0,89$, $P < 0,001$) while that during the post-anthesis phase did not. At Gwebi, Harare, Kadoma and Matopos DMT increased sharply from that experienced during the pre-anthesis to the post-anthesis phase.

EFFECT OF GENOTYPE

Grain yield and related traits. The correlation between grain yield and its components (Table 1) showed that there was no yield component that consistently influenced grain yield at all sites. The effect of lodging resistance on genotypic variation in grain yield varied with site (temperature conditions), accounting for 13% of the variation at Kadoma, 14% at Chiredzi and Chisumbanje, 61% at Harare and 64% at Gwebi. The extent of lodging and ear height of the genotype were positively associated at Chiredzi, Gwebi, Harare and Kadoma ($P < 0,05$).

This may explain the association of ear height and grain yield at Gwebi, Harare and Kadoma ($P < 0,05$). Days to anthesis or maturity negatively influenced grain yield at Gwebi, Harare, Kadoma and Panmure ($P < 0,05$). DMT during the pre-anthesis inversely affected grain yield ($P < 0,05$) at Harare, Kadoma and Panmure while that during grain filling negatively accounted for 64%, 49% and 29% of the genotypic variation in grain yield ($P < 0,01$) at Gwebi, Harare and Kadoma, respectively, probably through its effect on duration of grain filling at these sites and/or grain size at Gwebi and Harare ($P < 0,05$).

Basing on averages over all sites the genotypes could be divided into three maturity groups differing in yields (Table 2), viz the early group maturing in about 122 days (yield = 6 094 kg/ha), the intermediate group maturing in 126 days (yield = 6 191 kg/ha) and the late group maturing in 130 days (yield = 5 085 kg/ha). Of interest were F78106 in the late group and F82024 in the intermediate group that flowered late at all sites as shown below:

	Harare	Matopos	Gwebi	Panmure	Chiredzi	Chisumbanje	Kadoma
Mean (30 cultivars)	84	98	91	75	63	70	67
F78106	98	102	105	79	70	77	81
F72024	99	106	108	95	77	88	84

Days to anthesis and DMT were positively associated ($P < 0,001$) and as a result these varieties experienced higher temperatures than other varieties. F78106 and F82024 were consistently low yielding at sites that had DMT during pre-anthesis below 18°C but had high grain yields at sites with DMT above 18°C. The two genotypes experienced some of the highest temperatures during pre-anthesis (18,4°C for F78106 and 18,3°C for F82024) and the grain filling period (19,6°C and 20,2°C, respectively) at Chiredzi and yet produced high grain yields at this site while those that flowered and matured early experienced lower temperatures but yielded poorly. Some varieties (F83068, F83071 and SC79358-9-1) in the late maturing group yielded below average at this site. Because of this anomalous behaviour there was no relationship between the duration planting to anthesis or maturity and yield, and between DMT during these phases and yield at Chiredzi. This behaviour suggests a response by F78106 and F82024 to pre-acclimation at high temperature during the pre-anthesis phase resulting in stimulation rather than inhibition during latter growth stages. This does not however explain the behaviour of SA79014-9-11 (regression coefficient, b = 1,46), Rusape (b = 1,00) and S75110-2-3 (b = 1,33) that performed above average at all sites and showed a yield response to improvement in temperature conditions though the first and last might perform poorly under worse conditions. In a separate study SA79014-9-11 showed general adaptability to frost, high temperature, drought and optimum conditions while Rusape (f78208-2) featured mainly under frost and high temperature conditions (Mashiringwani _et al_, 1985).

CONCLUSIONS

Yield differences between sites were accounted for by temperature differences during the growing period. The results indicate genetic differences in response to temperature regimes. Genotypes that were intermediate in maturity and ear height with lodging resistance appear to show high yield and stable performance across the environments studied. It is however not understood at this stage which mechanisms account for better performance of some genotypes under high temperature conditions as those experienced in the lowveld of Zimbabwe.

REFERENCES

Aggarwal, P. K. and Sinha, S. K., 1984. Effect of water stress on grain growth and assimilate partitioning in two cultivars of wheat contrasting in their yield stability. Annals of Botany 53 : 329 - 340.

Mashiringwani, N. A. and Harahwa, G., 1985. The response of twenty wheat varieties to growing conditions in Zimbabwe. Zimbabwe Agric. J., 82 : 1, 11-15.

Midmore, J., Cartwright P. M. and Fischer, R. A., 1982. Wheat in tropical environments. I. Phasic development and spike size. Field Crops Research 5. : 185 - 200.

Weidner, M. and Ziemens, C., 1975. Pre-adaptation of protein synthesis in wheat seedlings to high temperature. Plant Physiology, 56 : 5, 590 - 594.

Table 1 Correlation coefficients between grain yield and related traits, determined from genotypic variation at 7 sites in 1984

Agronomic trait	Harare	Gwebi	Matopos	Kadoma	Panmure	Chiredzi	Chisumbanje
Ear height	-0,49 **	-0,67***	-0,25	-0,63***	-0,42*	0,02	-0,15
Days to anthesis	-0,69***	-0,83***	-0,12	-0,61***	-0,54**	-0,05	0,09
Days to maturity	-0,64***	-0,58***	0,03	-0,44*	-0,29	-0,08	0,15
% Lodging	-0,78 ***	-0,80***	-0,03	-0,36*	0,00	-0,37*	-0,37*
Ears m^{-2}	-0,12	0,11	0,16	0,36*	-0,03	-0,02	0,16
Grains per ear	0,03	0,05	0,34	0,27	-0,01	0,33	0,38*
1 000 grain weight	0,65***	0,39*	0,21	0,17	0,62***	0,20	-0,01
Grain filling duration	0,57***	0,59***	0,23	0,52**	0,18	0,04	0,02

* P$<$0,05 ** P$<$0,01 *** P$<$0,001

Table 2 Mean grain yield (kg/ha) of 30 varieties at seven sites in 1984

Variety		Harare	Matopos	Gwebi	Panmure	Chiredzi	Chisumbanje	Kadoma	Maturity* Group
1	F83066	6710	6814	6682	6470	5607	3831	3246	E
2	S76003 R	6440	7973	6533	7010	5966	4725	4786	I
3	Tokwe	8813	7573	7829	6580	5115	4667	5328	I
4	SA79014-9-11	9217	8141	9546	7401	5936	5354	5603	I
5	SC79520-2-3	7666	6171	6822	6825	5951	4665	4018	I
6	F82024	5157	6614	4347	5904	6417	4878	2847	I
7	Angwa	8080	7065	8025	7184	5914	4143	5472	E
8	S78298-21-2	5141	6749	5795	6237	4833	3506	4014	I
9	F83069	7852	5345	5609	6722	3969	3700	3563	I
10	F83056	4800	7080	4155	6078	5420	4648	3558	L
11	S78297-1-2	7573	6293	8370	6342	5227	5806	4462	I
12	Chiwore	7684	7531	7102	7335	5582	4529	5326	I
13	F83068	6485	5856	5475	7041	5185	5082	3811	L
14	SA79012-3-2	9085	7423	7868	7636	5936	4031	4544	E
15	F83059	8050	7460	8365	7750	5610	4361	3581	I
16	S78301-5-3	5789	6440	6635	5788	5291	3601	3414	E
17	Gwebi	7851	5845	7781	7256	4791	4537	4788	E
18	SW79184-4-4	6857	5925	8385	7608	5060	4179	3102	E
19	F81012-4	8228	7823	7061	7789	6487	5315	4429	I
20	Torim 73	8235	6183	7149	7523	4798	4424	4935	E
21	F83071	4208	4157	3420	4996	3937	3727	2632	L
22	SC79371-6-3	5927	6025	8418	7203	4519	4646	3793	I
23	F78006	4738	6690	3947	4964	5657	4346	3075	L
24	Rusape	9584	7004	7811	6472	5643	6097	4962	E
25	S77021-7-4	8663	6626	8791	7394	6797	4653	3812	I
26	F83067	8047	5634	6833	6857	4536	4533	4172	E
27	Limpopo	8886	6433	7105	6186	5331	4035	4450	E
28	F78106	4974	6950	4432	6333	6094	4760	3768	L
29	S75110-2-3	8695	7505	8263	7534	5780	4751	4602	I
30	SC79358-9-1	7068	6752	6726	6852	4941	4336	4406	L
Mean		7217	6669	6843	6776	5411	4529	4116	
Standard Error		628,5	579,6	563,0	465,9	291,0	309,5	563,3	

*E = Early maturity I = intermediate maturity L = late maturity group

Effect of drainage types on grain yield of breadwheat

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INTRODUCTION

Approximately 3.2 million metric tons of grain of breadwheat (TRITICUM AESTIVUM L.) is produced annually. This quantity of grain is mainly obtained from high-yielding breadwheat cultivars grown on fairly well drained soils of the highlands of Ethiopia. Some breadwheat is also grown on the vertisols of the highlands of Ethiopia. Extending the production of this high-yielding species to the fertile gently sloping vertisols is limited by poor drainage. About 6.3 million hectares of the Ethiopian highlands are characterized by heavy, dark clay soils that suffer from poor drainage in the rainy season. At present nearly 25% is cropped consisting of mainly durum wheat (TRITICUM TURGIDUM L.), Tef (ERAGROSTIS TEF), and chickpea (CICER ARIETINUM L.). Farmers traditionally practice in growing these crops and some breadwheat on residual moisture planted towards the end of the rains. As a result low yield is obtained.

With improved drainage system farmers can grow high-yielding breadwheat cultivars on many of the vertisols in Ethiopia. The use of drainage can help to utilize the uncultivated areas and increase total production and production per unit area. It can also help the crop to efficiently utilize fertilizers.

Looking the prospect of this potentially productive area, a preliminary experiment, using different sizes of camberbeds/broadbeds and furrows, was carried out at Holetta Research Station experimental field and at Sheno in the early seventy's (1,3). From the latter experimental site grain yield increases ranging from 52 to 134% was obtained (3).

The drainage experiment was extended to a more representative area, Ginchi; and in addition other relatively simple methods of drainage that are relatively inexpensive and could be done by the small farmers using locally available materials and labor were included (2). Hence, experiments were conducted to determine the effect of various drainage types on grain yield of breadwheat.

EXPERIMENTAL

A 3-year experiment was carried out at Ginchi characterized by pellic vertisol. The different drainage types used were: Camberbed, open trench, subsurface trench, and a control. These drainage systems were constructed as follows: Camberbeds were made by disc plough and disc harrow. The open trench was prepared by ox-drawn plough. On the other hand, subsurface drainage was constructed using eucalyptus poles and branches. The drains were dug 40 cm wide and 60 cm deep. Filling materials occupied about 40 cm deep and the top soil was returned to the top 20 cm. The poles, roughly 15 cm in diameter and 3 m in length, were placed side by side in pair with small pieces of wood and branches on the top so as to have a channel between the top layer and the bottom soil through the length of the drain.

The camberbeds, open trenches, and subsurface trenches were 4,6, and 8 m wide and 72 m. long. The control strip was 18 m by 72 m. In each year, recommended seeding date, seed rate and fertilizer rates were used. Two breadwheat varieties were planted in un replicated parallel strips. Grain yield measurement was taken from 48 m^2.

The experimental result indicated that all the drainage types were effective in increasing grain yield ranging from 48 to 110% (Table 1). This yield increments were as a result of better soil aeration and efficient utilization of fertilizer. The comparison of grain yields indicated that the 4 m wide open trench was more effective than other drains. This drain yielded 110% more than the control strip. The 8 m camberbed yielded 11 and 30% higher than 6 and 4 m camberbeds, respectively. The 8 m open trench yielded 1 and 10% lower than the 6 m and 4 m open trenches, respectively, while the 8 m subsurface trench yielded 5 and 45% lower than the 6 and 4 m subsurface trenches, respectively. Though there was very little difference in yield in the range of 11 to 15.5 q/ha among the best of the drainage types, the 4 m open trench yielded 17 and 11% higher than the 4 m subsurface trench and the 8 m camberbed.

SUMMARY AND CONCLUSION

The 3 year period result suggested that drainage types were fully effective in increasing grain yield in pellic vertisols that are poorly drained. However, the type of drainage that can be used by small farmers depend on low cost and ease of adoption. Here, the open trench which is relatively less expensive and easy to construct by small farmers would be recommendable. However, to increase efficiency a modification of the traditional plough at low cost awaits investigation to be used for this purpose. On the other hand, camberbeds, particularly, the 6 m and 8 m camberbeds can be used by State Farms and Cooperatives. However, subsurface drainage would be labor consuming and expensive to construct; and this could not be either used by large farmers or small peasant farmers. Nevertheless, the long term effect of the drainage types particularly camberbed and subsurface drainage have to be determined. Thefpre, it can be concluded that early planting can be done by using improved drainage systems in pellic vertisol conditions thereby reducing the risk of crop failure and increasing production both in terms of yield per unit area and total area cultivated.

DISCUSSION

(W. C. JAMES):

As an average over 3 years, the open trench 4 m was the best treatment. Was it the best treatment for each of the 3 years?

No, only for 2 years. In one year the 8 m camber bed was best.

(J. BRANDLE):

Was land preparation difficult due to the drainage?

It was difficult only the first year.

Table 1. Effect of improved drainage on grain yield of breadwheat at Ginchi (2200 m. a. s. l*)

Drainage types	Yield Q/ha^{-1}, 3 year average		change as Control %
	Width		
Camberbed	4 m	12.5	69
	6 m	13.9	88
	8 m	14.7	98
	4 m	15.5	110
Open trench	6 m	14.2	91
	8 m	11.1	90
	4 m	14.3	93
Subsurface trench	6 m	11.3	53
	8 m	11.0	48
Control strip		7.4	

*Meters above sea level

Synopsis of Session 6

C r o p   h u s b a n d r y

Chairperson: F. C. MUNTHALI

Rapporteur : M. E. MOFOKA

Agronomic practices are location specific , and the technological package that is apt to lead to maximum yields must be determined locally. Salient points from the papers presented that can stimulate local research are summarized now.

1 Increased plant density resulted in increased yields. The component contributing to the added yield appears to be number of harvested ears, rather than ear size.

2 To improve plant stand it is appropriate to use good seed, effect operations timely and have the best possible bed preparation.

3 Higher yields may be realized through selection of light sensitive cultivars.

Modifying the developmental pattern of a wheat crop in the lowveld areas of Zimbabwe for increased yields

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Introduction

In Zimbabwe wheat is grown in all the provinces of the country, but more so in some than others. The average grain yield per hectare differs with province depending on whether the province is in the highveld (900 - 1 500 m a.s.l.), middleveld (500 - 900 m a.s.l.) or lowveld (300 to 500 m a.s.l.). The highveld has a higher yield potential compared to the middleveld and lowveld, due to the cooler conditions which prevail during the development of the wheat crop. Yield values of 6 500 to 8 500 kg/ha and 4 000 to 5 500 kg/ha typify the extent of the seasonal variation found in the highveld and lowveld respectively (Cackett and Wall, 1971). Cackett and Wall (1971) concluded in their study that the higher maximum temperatures experienced in the lowveld reduced grain number per ear and weight per grain.

The reduction in weight per grain was induced by high temperatures whose onset occurs earlier in the lowveld than the highveld towards the end of the growing season causing premature senescence. The mean maximum temperatures and photoperiod at two sites representing the highveld and lowveld in 1969 and 1970 as reported by Cackett and Wall (1971) are given below:

	Temperature		Photoperiod
	1969	1970	in May
Highveld (Harare)	22.7°C	27.1°C	11.2 hours
Lowveld (Chiredzi)	25.1°C	29.6°C	11.0 hours

Inspite of the low yields obtained in the lowveld, up until 1975/76 the greatest acreage of wheat was grown in this area. This has however changed in favour of the high yield potential highveld areas. A very small percentage of the national crop is grown in the lowveld now, as other better paying crops have taken over. However if wheat yields were increased, and compete favourably with the other crops in terms of money invested, more land could be released for wheat production, and the country could attain self sufficiency in wheat grain.

Two hypotheses are proposed for increasing wheat yields in the lowveld,

(i) In a hot/short day environment such as that found in the lowveld in winter, a cultivar which is comparatively sensitive to photoperiod may develop slowly despite the high temperature and so produce a comparatively large number of spikelets per ear. However, development should be rapid once the ear is formed so that ear emergence takes place fairly early in the short cool season. This would give a relatively long period of grain growth before leaves senesce, owing to rising temperature at the end of the cool season. However too short a period between ear formation and ear emergence could result in some spikelets being sterile (Bingham 1972).

(ii) In view of the early onset of high temperatures in the lowveld which invariably shorten the grain filling period, and consequently weight per grain, it has been hypothesized that an appreciable grain size can be achieved by developing a variety which combines all other desirable characteristics and a high growth rate of the grain.

<u>Increased photoperiod sensitivity during the spikelet initiation phase</u>

The period between germination and flowering can usefully be divided into three phases.

Firstly an initial phase during which leaves are formed on the shoot apex and tillers are initiated. Second a phase when the primordia formed on the shoot apex give rise to spikelets instead of leaves. Under the microscope the beginning of this phase is recognized as an elongating apex. The spikelet initiation phase ends with the formation of the terminal spikelet, while the appearance of double ridges occurs at about the middle of this phase. During the third phase the ear develops further, a number of florets being formed in most if not all the spikelets. At the same time the stem elongates, thus pushing the ear upwards until it emerges to mark the ending of the third phase. The same sequence of phases takes place in both main stem and tillers though each stage may be reached slightly later in tillers than in main stem.

One way in which plant breeding can mould a wheat cultivar is by altering the duration of one or more of the three successive phases between germination and flowering. Number of leaves and perhaps size of leaves, and number of tillers, hence potential number of ears, will be influenced by the duration of the first phase. The number of spikelets per ear will be partly determined by the duration of the second phase, while the proportion of fertile spikelets may be influenced by the duration of the third phase (Bingham, 1972).

Wheat is a quantitative long day plant i.e its development up to the time of flowering is hastened by an increase in day length (Kirby, 1969). Accordingly, changes in day length can be used to vary the duration of each of the phases between germination and ear emergence. Also, an increase in day length increases the rate at which spikelet primordia are formed (Allison and Daynard, 1976), and genetic differences may exist in rate of spikelet initiation (Allison and Daynard, 1976, Halse and Weir, 1974).

The response to photoperiod differs with cultivars. Wall and Cartwright (1974), and Allison and Daynard (1976) showed that the Zimbabwean cultivar, Tokwe, was comparatively less sensitive to photoperiod during the period from sowing to ear emergence than temperate cultivars such as Marquis. Allison and Daynard (1976) have however demonstrated that the response to photoperiod during the whole period between sowing and ear emergence may differ with the developmental phase; for example, the sensitivity of Tokwe to photoperiod during the interval between formation of the terminal spikelet and emergence of the ear was somewhat greater than the earlier developmental phases. These results would seem to be consistent with the conclusion of Pinthus (1963) that the length of the interval up to ear formation is under separate genetic control from that of the interval between ear formation and ear emergence. Therefore breeders can modify the developmental pattern of cultivars.

In an experiment conducted in growth cabinets in Winter 1976, Whingwiri (1977) demonstrated that spikelet number per ear could be increased under warm night conditions provided a short daylength is imposed on a photoperiod - sensitive temperate variety called Waldron (Table 1). The results in Table 1 agree with Ormrod (1963) and Wall and Cartwright (1971) on daylength having more pronounced effect on development than temperature since plants under short days in spite of the warm night conditions took a longer time to reach the terminal spikelet stage than under long days.

High potential grain size

In the lowveld the reduction in grain yield due to reduced grain number and size could in a way be reduced by developing varieties with a high potential grain size i.e. individual grain weight (Pinthus, 1980), to compensate for the reduction in grain number.

In a study by Pinthus and Sar-Shalom (1978), the differences in grain weight between cultivars with light grains and those with heavier grains were associated with differences in the rate, rather than in the duration of dry matter accumulation in the grain. Therefore, an appreciable grain size could be achieved by incorporating a high rate of grain growth in the cultivars.

Conclusion

It appears that grain yield in the lowveld areas of Zimbabwe can be increased through modifying the development pattern of wheat cultivars. However, it must be borne in mind that yield components are in general inversely related, that is if one is increased the other may decrease. This constraint would require investigation if the two hypotheses are to result in significant yield increases.

References

Allison, J.C.S. and Daynard, J.B. (1976). Effect of photoperiod on development and number of spikelets of a temperate and some low latitude wheats. Ann. Appl. Biol. 83 : 93 - 102

Bingham, J, (1972). Physiological objectives in breeding for grain yield in wheat. Proceedings of the sixth Eucarpia Congress Cambridge, 1971, pp. 15 - 29.

Cackett, K.E. and Wall C.P. (1971). The effect of altitude and season length on the growth and yield of wheat (*Triticum aestivum* L.) in Rhodesia. Rhod. J. Agric. Res. 9, 107 - 120.

Halse, N.J. and Weir, R.M. (1974). Effects of temperature on spikelet number of wheat. Aust. J. Agric. Res. 25, 687 - 695

Kirby, E.J.M. (1969). The effects of daylength upon the development and growth of wheat, barley and oats. Field Crop Abstracts 22, 1 - 7.

Pinthus, M.J. (1963). Inheritance of heading date in some spring wheat varieties. Crop Sci. 3. 301 -304.

Pinthus, M.J. (1980). Breeding for winter grain under dryland conditions. World Crops 32. 47 - 48.

Pinthus, M.J. and Sar-Shalom, Y. (1978). Dry matter accumulation in the grains of wheat (<u>Triticum</u> <u>aestivum</u> L.) cultivars differing in grain weight. Ann. Bot. <u>42</u>, 469 - 471.

Wall, P.C. and Cartwright, P.M. (1974). Effects of photoperiod, temperature and vernalization on the phenology and spikelet numbers of spring wheats. Ann. Appl. Biol. <u>76</u>, 299 - 309.

Whingwiri, E.E. (1977). Effect of photoperiod, temperature ~~and applied~~ gebberellic acid on the growth and development of wheat and triticale. M. Phil. Thesis. University of Zimbabwe.

Table 1 Effect of night temperature and photoperiod on duration of the spikelet initiation phase and spikelet number per ear. (The four compartments used provided the following environments: 16h photoperiod with night temperature 5°C warmer than ambient (HL); 10h photoperiod with night temperature 5°C warmer than ambient (HS), 16h photoperiod at ambient night temperature (CL), and 10h photoperiod at ambient night temperature (CS).

Environment during the period from sowing to double ridge stage.	Environment during the period from double ridge stage to terminal spikelet formation	Duration of the period from sowing to double ridge stage (days)	Duration of the period from doble ridge stage to terminal spikelet formation (days)	Spikelets per ear
HL	HL	17	15	15.5
	HS	17	18	18.5
	CL	17	16	15.8
	CS	17	25	20.1
HS	HL	21	18	17.2
	HS	21	*	20.6
	CL	21	19	16.0
	CS	21	*	22.2
CL	HL	17	15	16.3
	HS	17	18	18.5
	CL	17	18	15.3
	CS	17	25	20.8
CS	HL	24	18	not available
	HS	24	*	17.3
	CL	24	18	not available
	CS	24	*	21.2

* Duration of the phase could not be determined because of very erratic development.

Phosphorus nutrition in wheat on the Hanang complex, Tanzania

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INTRODUCTION:

Fertility trials as well as surveys of plant nutrient levels in both soils and plants conducted on the 25,000 - hectare Hanang Wheat Complex fror 1971 though 1985 have revealed that the most predominate soils (mollisol or grassland or upland soils and vertisol or mbuga soils) supply sufficient levels of both macro-and micronutrients so that fertilization does not increase yields under the prevailing system of rainfed or dryland wheat production (2). However, approximately 1000 hectares of predominately alfisol-inceptisol (red) soils but including some inceptisol-alfisol (brown soils on one of the seven farms (Setchet) are deficient in phosphorus.

Research was conducted from 1982 through 1985 on the Setchet Farm to determine the

I. influence of soil P level and fertilizer P on P response in wheat in order to determine soil and plant P critical levels;

II. influence of P carrier, rate and method of application on P response in wheat; and

III. the levels plant available soil P and plant P over all of the Setchet Farm so that P deficient areas could be precisely delineated.

MATERIALS AND METHODS:

The research was carried on during 1985 and will be continued through 1986. However, only those results from 1982 through 1984 will be reported. Mbuni (T23-73) wheat was seeded with a press drill at 110 kg/ha into six-rov one-metre by six-metre treatment sub-plots arranged in randomized complete block designs replicated four to six times. All treatments received 50 kg N/ha broadcast as ammonium sulphate at seeding in order to eliminate possibl interference of N deficiency. Phosphorus was extracted from soil with 0.5 M $NaHCO_3$(3) although many soils were also analyzed by the Bray I method (3) for purposes of comparison. Total P in wheat shoots at early heading was determined by dry ashing. All experiments conducted through 1984 were located on brown (inceptisol-alfisol) and red (alfisol-inceptisol) soils (4) having pH values (I:I,soil: water) ranging from 6 to 7 whereas most mollisols and vertisols on the remainder of Setchet and on the other six farms are neutral to alkaline.

RESULTS AND DISCUSSION:

I. Soil and plant P critical levels:

Phosphorus fertilization (20 kg P/ha as triple superphosphate drilled with the seed) significantly increased wheat grain yields in only five of 12 experiments from 1982 through 1984 (Table 1). But, there were apparent yield increases in a further five experiments and the average yield increase for all 12 experiments was 0.41 t/ha.

Table 1 - Soil p levels, yield increases when fertilizer P applied and plant P levels in P critical level experiments on Setchet Farm.

SEASON	0.5 M $NaHCO_3$ Extr.P(ppm) (0-15cm)	Wheat grain yield of control (t/ha)	Yield* increase for 20 kg P/ha T.S.P.drilled.	% P in shoots of control treatment
1982	6.0	1.69	0.71 S	0.27
1983	10.6	1.09	0.55 NS	0.21
1983	5.6	1.50	0.05 NS	0.11
1983	3.0	0.98	0.62 S	0.18
1983	4.9	1.06	0.35 S	0.19
1984	5.8	2.23	0.44 S	0.22
1984	5.4	1.97	0.26 NS	0.19
1984	6.7	1.21	0.96 S	0.22
1984	4.6	1.24	0.40 NS	0.19
1984	4.2	1.36	0.43 NS	-
1984	7.1	1.48	0.02 NS	0.21
1984	4.0	1.25	0.18 NS	-

ave.increase .41 t/ha.

* S-Wheat grain yield increase as result of 20 kg P/ha as triple superphosphate (T.S.P.) drilled with seed statistically significant at 5% level.
NS-Yield increase not statistically significant.

Despite great effort to locate experiments on soils varying greatly in available P, all experiments were located upon soils containing relatively low 0.5 M $NaHCO_3$ extractable P levels, so that it was not possible to determine soil and plant P critical levels. Nevertheless, it can be stated with reasonable certainty that if soils on the Hanang Wheat Complex contain less than about 10 ppm 0.5 M $NaHCO_3$ extractable P, a very economical yield increase of about .4 t/ha can be expected from P fertilization. Results from the 1985 P experiments on the Setchet Farm should more precisely define soil and plant P critical levels as there was greater range in extractable soil P levels.

The $NaHCO_3$ (Olsen) method for estimating plant available soil P is likely the most appropriate method for the predominant (mollisols and vertisols) soils on the Hanang Complex because they are neutral to alkaline, have high cation exchange capacities and sometimes contain carbonate (1,5). The Bray I method might be more appropriate on the slightly acid (pH 6 to 7) alfisols and inceptisols on Setchet (1,5). Nevertheless, the linear correlation coefficients between Olsen extractable soil P or Bray extractable soil P and P response or plant P level in 11 experiments on the Setchet Farm were all equally very low (Table 2). Neither method for estimating plant available

Table 2; Correlation coefficients between Olsen extractable soil P or Bray I extractable soil P and P response or P concentration in wheat shoots at early heading in 11 experiments at Setchet in 1983 and 1984.

Soil P extraction method	P response	Shoot P concentration
	---------r values	-------------
Olsen	-.24 NS	.24 NS
Bray I	-.12 NS	.21 NS

NS = Not significant at 5% level.

soil P seemed satisfactory.

As the relatively high cation exchange capacities and occasional calcium carbonate in Setchet soils might consume the acid in the extracting solution of the conventional Bray I method where the soil to solution ratio is one to seven, the modified method including a soil to solution ratio of one to fifty might be more appropriate (1,5). The three methods were used to estimate available P in the surface soil closely associated with the roots of a one - metre length of a row of wheat at early heading from each of forty locations on the Setchet Farm in 1985. The linear correlation coefficients between extractable soil P and plant P concentrations as well as P uptake were significant at the 5% level for all three methods but the r values did not differ appreciably among the methods (Table 3).

Table 3: Correlation coefficients between Olsen soil P or Bray I soil P or modified Bray I soil P and P concentration or P uptake into wheat shoots at early heading at 40 locations at Setchet in 1985.

Soil P extraction method	Shoot P concentration	P uptake into shoots
	------------ r values ---------	
Olsen	.62 S	.39 S
Bray I (1:7,Soil:Soln)	.54 S	.50 S
Modified Bray I (1:50)	.72 S	.43 S

S = Significant at 5% level.

Correlations will be carried out in 1986 for about 100 locations over the entire Hanang Complex in 1986 to determine more precisely which method is most appropriate for each soil on the Complex. Soils from past P experiments will also be extracted according to the modified Bray method.

II. Influence of P carrier, rate and method on P response;

Triple superphosphate drilled with the seed was more effective in increasing wheat grain yield than triple superphosphate mixed with surface 10 cm of soil prior to seeding (Table 4). The results also indicated that P deficiency of wheat on the Setchet Farm is corrected satisfactorily by drilling 20 kg P/ha as triple superphosphate with the seed (Table 4).

Table 4: Influence of P rate, carrier and method of application on wheat grain yield on Setchet Farm.

P rate (kg P/ha), carrier, application method.		Grain Yield (ave.5 expt) ($NaHCO_3$ P=9ppm) (t/ha)	Grain Yield (1 expt) ($NaHCO_3$ P=5ppm) (t/ha)
	O P	1.45	1.97
20P,	TSPD	1.92	2.23
20P,	TSPM	1.09	
40P,	TSPD	1.90	2.13
60P,	TSPD	2.06	2.38
80P,	TSPD	2.02	2.63
80P,	RPD		1.96
80P,	RPM		2.09
		S	NS

TSPD = Triple superphosphate drilled

TSPM = Triple superphosphate mixed with surface 10 cm before seeding

RPD = Finely divided rock phosphate drilled

RPM = Rock phosphate mixed with surface 10cm before seeding

S = Significant at 5% level

NS = Not significant at 5% level.

Finely divided rock phosphate from Minjingu, Tanzania at 80 kg P/ha drilled with the seed as well as the same amount with the surface 10cm before seeding was not effective in increasing wheat grain yields.

III: Plant and soil P levels throughout Setchet Farm.

Levels of P in wheat shoots at early heading were not useful in predicting which areas were deficient in P. As mentioned earlier, somewhat less than 1000 hectares of land Setchet including mostly red (alfisol-inceptisol) with some brown (inceptisol-alfisol) soils contained less than 10 ppm 0.5 M $NaHCO_3$ extractable P. Grassland soils (mollisols) contained an average of 34 ppm 0.5 M $NaHCO_3$ extractable P whereas the brown soils contained 21 ppm P and the red soils 15 ppm P. The vertisol soil areas on the Setchet Farm were not large enough to be considered.

SUMMARY:

Most soils on the 25,000 - hectare Hanang Complex in Tanzania supply sufficient macro-and micronutrients for dryland wheat production. But, somewhat less than 1000 hectares on one farm in the Complex contain less than 10 ppm 0.5 M $NaHCO_3$ extractable P and on that land 20 kg P/ha as triple superphosphate drilled with the seed has increased wheat grain yields by 0.4 t/ha. Yields have not been increased further by application of more than 20 kg P/ha. Broadcast and incorporation of triple superphosphate has not been as effective as drilling. Finely divided rock phosphate has been totally ineffective, regardless of method of application.

REFERENCES:

1. Kamprath,E.J. and M.E. Watson.1980.Conventional soil and tissue tests for assessing the phosphorus status of soils, pp. 433 - 469. In F.E. Khasawneh, E.C. Sample and E.J. Kamprath (ed), The Role of Phosphorous in Agriculture. American Society of Agronomy, Madison,Wisconsin, U.S.A.

2. Nyaki,A. and L.A. Loewen - Rudgers. 1983.
Nutrient status of wheat in Northern Tanzania. Paper presented to the Regional Wheat Workshop for Eastern, Central and Southern Africa held in Arusha, Tanzania, June 13 - 17, 1983.

3. Olsen, S.R. and L.A. Dean. 1965. Phosphorus, pp. 1035-1058.
In C.A. Black (ed). Methods of Soil Analysis, Part 2. American Society of Agronomy. Madison, Wisconsin, U.S.A.

4. Stonehouse, H.B. and J.P. Duff. Report on soils of the Setchet area, Tanzania for the Agronomic Research Project (Wheat) sponsored by the Canadian International Development Agency.

5. Thomas, G.W. and D.E. Peasleee. 1973. Testing soils for phosphorus pp. 115 - 132. In L.M. Welsh and J.D. Beaton (ed), Soil Testing and Plant Analysis.
American Society of Agronomy. Madison, Wisconsin, U.S.A.

Effect of seeding density in yield and yield components in wheat

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World record of highest wheat yield continues to remain that of the winter wheat cv. Gains. In 1964-65, a yield of 14,100 kg/ha was obtained in a two hectare plot in the State of Washington, U.S.A. Although physiologists estimate theoretical maximum yield of 20,000 kg/ha under optimum growing conditions, yield potential of best spring wheat cultivars has been estimated to be 8500-9500 kg/ha under experimental conditions (1). Attempts to increase yield potential in wheat continues by way of developing cultivars having longer spikes, more number of grains per spike and larger grains i.e. ultimately more grain weight per ear but often progress in on factor is offset by losses in another.

Another important component of yield is density of stand i.e. number of ears per unit area, which can be manipulated to a certain extent by seeding density. No response to seeding densities in wheat varying from 40-150 kg/ha has been generally reported (3). Partly this is because of higher densities, tiller production and tiller survival is reduced due to inter-and intra-plant competition effect. Competition also has a negative effect on net realisable grain weight per ear. However, differences between cultivars appear to exist.

In intensive agriculture, where nutrient and water are not limiting, possibly minimising the competition effect, a high density of stand plus same level of net realisable grain weight per ear (a function of grain number and grain size) is expected to give maximum yield. Therefore, it would be desirable to have cultivars, in which higher density of stand is not accompanied with a reduction in grain weight per ear. No information is available if such a variability exists between cultivars. It was with this objective that this study was undertaken. Once it is established that such a variability exists, it may be used as a method at an appropriate stage in the final selection of cultivars for commercial production under conditions of intensive agriculture.

MATERIALS AND METHODS

The experiment was conducted under irrigated conditions during the dry winter seasons 1982 and 1983 at the University of Zambia's Farm in Lusaka situated at about 1140 m above mean sea level. The experimental site has Kankola sandy clay loam soil type. Six wheat, one durum and one triticale cultivars, each at three seeding densities viz. 200 (D_1), 300 (D_2) and 400 (D_3) per m^2 corresponding to approx. 80, 120 and 160 kg/ha seed rate were studies. The wheat cvs were of diverse parentage. Durum and triticale entries were included for comparison but these will not be discussed in this report. A Randomised Complete Block Design with three replications was used. Planting was done by hand on June 6 in 1982 and on May 30 in 1983 and harvested at maturity around mid-October. Plot size was 3.5m x 1.2m (6 rows) and were kept clean by hand weeding.

Recommended cultural practices were followed except fertilizer rate. A higher fertilizer rate (N150, P96, K54 kg/ha) than recommended was used to optimise plant growth and ensure that it was not limiting for full expression of the genetic potential of the cultivars. Following observations were recorded:

1. Tillering: In each plot, an area of two rows, one meter long ($0.4m^2$) was marked. Repeated tiller counts were taken starting six weeks after planting at an interval of two weeks. After flowering, only ear-bearing tillers were counted. The final tiller count was taken at or around physiological maturity. In this report only initial and final tiller counts are included.

2. Number of spikelets and number of kernels per spike and kernel weight: About 15 spikes were randomly taken from each plot; of these ten complete spikes were used for recording these observations and averaged. Kernel weight from ten spikes was converted to thousand kernel weight.

3. Grain yield per plot: At maturity the plots were trimmed to 3m length and middle four rows were harvested to get grain yield/plot (2.4m^2). This was converted to kg/ha.

The data were analysed using analysis of variance (ANOVA) and mean comparison was done using Least Significant Difference (LSD) Tests at PO.05 level.

RESULTS AND DISCUSSION

Growing conditions during the two seasons were similar except for temperatures. In 1983, temperatures were somewhat higher in May-June and more so in September-October at the ripening stage and seem to have affected crop growth and ultimately yield (Table 1).

Effect of Seeding Density: Seeding densities had no effect on grain yield in both the seasons (Table 1), and is in agreement with several previous studies in Zambia and elsewhere (2,3). Laloux et al (2), reported no difference in yield from 69 to 153 kg/ha seed rate under Belgium conditions and recommends a seed rate of about 100 kg/ha. In Zambia, yields of around 4t/ha were obtained using 90,120 and 150 kg/ha seed rate (4). Recommended seeding rate in Zambia is 100 kg/ha. Under Canadian prairies conditions (rainfed), farmers use 50-85 kg/ha seed rate (7). Read and Warder (7), working at Swift Current, Saskatchewan found that reducing the seeding rate to 20 kg/ha for wheat and barley on stubble caused no significant reduction in yield. Earlier Pelton (5), working at the same Station reported highest yields from 22 kg/ha and significantly reduced yields from 100 kg/ha seeding rates for wheat grown on a clay loam soil on both stubble and fallow. In India following several

TABLE 1 Effect of seeding density on yield and yield components in wheat and triticale

Seeding density	Yield (Kg/ha)	Spike-lets/ spike	Kernels/ spike	1000 K wt. (g)	Initial tiller count	Final tiller count	Tiller survival (%)
			1982 Experiment				
D_1	5190.0	20.31^{a+}	46.16	45.58^a	228.9^a	152.3	66.5
D_2	5129.0	19.31^b	44.33	44.70^{ab}	271.1^b	157.6	58.1
D_3	5114.0	19.10^b	43.05	43.91^b	293.1^c	161.3	55.0
Change % D_1 to D_3	-1.5	-6.0	-6.7	-3.7	+28.0	+5.9	-17.3
LSD(0.05)	N.S	0.97*	N.S	0.94**	16.8***	N.S.	-
			1983 Experiment				
D_1	4306.0	19.50	51.9^a	51.31^a	259.4^a	157.8^a	60.8
D_2	4396.0	19.40	49.5^b	48.20^b	301.6^b	169.8^b	56.3
D_3	4434.0	19.00	47.4^c	49.9^{ab}	325.8^c	183.7^c	56.4
Change % D_1 to D_3	+3.0	-2.6	-8.7	-2.8	+25.6	+16.4	-7.2
LSD(0.05)	N.S.	N.S.	2.0***	2.1*	13.3***	9.9***	-

+ Means followed by same letter do not differ significantly at P.05.

(*,**,***) refers to level of significance at P.05, P.01 and P.001 respectively experiments, recommended seed rate for irrigated wheat is around 100 kg/ha.

Performance of the yield components at different seeding densities explains the lack of response to higher seed rates (Table 1). Number of spikelets/spike, kernels/spike and 1000 K wt. decreased with increasing densities, the extent of decrease was not the same in the two seasons indicating that the two environment affected differently expression of these characters. Of particular interest is the tillering pattern. Even in intial tiller count, relative differences in seeding densities were not reflected indicating that interplant competition started quite early in the growth stage and continued till maturity as reflected in a much smaller difference in final tiller count at different densities. Finally, differences in percent tiller survival at different densities were narrow, reflecting lower survival of tillers at higher seeding densities. The final tiller count remained somewhat higher at higher densities; the advantage was offset by the corresponding reduction in other yield components and the net result was no increase in yield.

Effect of cultivars : For all the characters studied, highly significant differences between cultivars were observed in both the seasons and their performance also differred (Table 2). In 1982, V_6 gave highest yield being statistically at par with V_5 and V_3 whilst V_4 gave lowest yield. In 1985, V_5 was highest yielding and V_6 was lowest yielding. These results, therefore, show a strong genotype x environment interaction often observed and reported by several workers. The two seasons were different in as far as temperature was concerned. It appears that V_6 is better adapted to lower temperatures, whereas V_5 is more widely adapted. Over both the seasons V_5 was highest yielding followed by V_3 and V_6 (Table 3). The good performance of V_5 (Loerie=Veery # 5 in both the seasons, substantiates the high yielding potential and wide adaptation of Veery selections reported earlier (8).

Comparing yield components, in 1982, V_6 was low in the three yield components but had highest number of tillers at maturity, which seem to be ultimately responsible for it's high yield. On the other hand, V_3 and V_5 were relatively

TABLE 2 Effect of cultivars on yield and yield components in wheat and triticale.

Cultivars	Yield (kg/ha)	Spike-lets/ spike	Kernels /spike	1000 K wt. (g)	Initial tiller count	Final tiller count	Tiller survival (%)
			1982 Experiment				
Emu (V_1)	4655^{c+}	18.8^{cd}	41.6^{de}	41.0^{de}	262.4^{b}	171.3^{ab}	65.3
Mexipak (V_2)	5057^{b}	17.7^{e}	52.2^{ab}	39.6^{e}	269.3^{b}	158.0^{cd}	58.7
Canary (V_3)	5617^{a}	20.0^{bc}	45.9^{cd}	44.0^{c}	268.8^{b}	149.3^{e}	55.5
UNZA-W-3 (V_4)	4197^{d}	20.3^{bc}	46.0^{cd}	42.4^{d}	232.1^{c}	144.9^{ef}	62.4
Leorie (V_5)	5502^{a}	20.4^{b}	56.6^{a}	44.0^{c}	281.4^{ab}	158.1^{cd}	56.2
UNZA-W-21 (V_6)	5660^{a}	18.2^{de}	36.4^{ef}	42.3^{d}	273.9^{ab}	178.7^{a}	65.2
UNZA-D-1 (V_7)	4934^{bc}	16.7^{e}	32.6^{f}	54.7^{a}	297.8^{a}	161.6^{bc}	54.3
UNZA-T-1 (V_8)	5520^{a}	24.5^{a}	48.1^{bc}	49.7^{b}	229.1^{c}	134.6^{f}	58.7
	***	***	***	***	***	***	
LSD.05	356	1.6	5.2	1.5	27.5	12.0	-
			1983 Experiment				
Emu (V_1)	4195^{bc}	18.6^{bc}	47.6^{d}	45.9^{d}	284.1^{cd}	172.6^{bc}	60.7
Mexipak (V_2)	4252^{b}	16.7^{d}	52.0^{bc}	44.2^{d}	318.1^{ab}	162.0^{cde}	50.9
Canary (V_3)	4183^{bc}	19.6^{b}	53.0^{b}	49.6^{c}	280.4^{cd}	149.2^{de}	53.2
UNZA-W-3 (V_4)	4321^{b}	19.7^{b}	49.5^{cd}	45.9^{d}	301.9^{bc}	165.7^{cd}	54.9
Loerie (V_5)	4724^{a}	18.6^{bc}	53.4^{b}	50.9^{bc}	325.7^{a}	193.8^{a}	59.5
UNZA-W-21 (v_6)	4013^{c}	18.3^{c}	42.5^{e}	50.1^{c}	291.1^{c}	188.1^{ab}	64.6
UNZA-D-1 (V_7)	4701^{a}	16.9^{d}	39.8^{e}	57.4^{a}	298.1^{bc}	186.3^{ab}	62.5
UNZA-T-1 (V_8)	4610^{a}	26.1^{a}	58.9^{a}	54.2^{ab}	265.2^{d}	145.8^{e}	55.0
	***	***	***	***	***	***	
LSD.05	225	1.10	3.3	3.5	21.7	16.2	-

+ Means followed by same letter do not differ significantly at P.05.

*** Significant at P.001 level.

higher in the three yield components but relatively low in final tiller number. The lowest yielding variety V_4 was intermediate in the yield components and had lowest final tiller number. Similar relationship between yield components, final tiller number and yield was present in the 1983 season but the nature of relationship in different cvs. differred. For example, in this season, V_5 had fairly high yield components as well as highest final tiller number and significantly highest yield, whereas performance of the cvs. V_3 and V_6 was similar to the previous season.

Differences among cultivars in tiller survival were present in both seasons. In 1982, V_1 and V_6 had highest tiller survival (65.3%) and V_3 had the lowest (55.5%), while in 1983 V_6 again had highest and V_2 had the lowest tiller survival. The better performing cv. V_5 had lower tiller survival in both the seasons.

<u>Seeding Density x Cultivars</u>: ANOVA revealed significant D x Cv interactions for yield, kernels/spike (only in 1982), 1000K wt and the two tiller counts. Pooled statistical analysis over the two seasons has not been done and only the mean performance will be discussed (Table 3). No apparent reduction in kernels/spike at higher seeding densities was observed in V_3 and V_5, whereas maximum reduction was observed in V_4. These cultivars (V_3 and V_5) were also the highest yielding and are the two recently released commercial cultivars in Zambia. These cultivars had 10-16% higher final tiller number in D_3 over D_1. Thousand kernel weight showed no reduction in V_1, V_5 and V_6, at the highest density, whereas 6 to 8% reduction was observed in V_2, V_3 and V_4. No real increase in yield in V_3 and V_5 at higher densities was observed; only V_3 gave higher yield at D_2 but D_3 yield was similar to D_1. Over all densities, highest initial tiller number was observed in V_5 followed by V_6 but final tiller number was highest in the later because of higher tiller survival. In V_3, although initial tiller number was similar to V_1, V_2 and V_4, the final tiller number was lowest because of lowest percent tiller survival. Despite their higher yields, lower tiller survival in these cultivars should

be considered an undesirable attribute. All cvs. had higher tiller survival at lower seeding densities as expected.

GENERAL DISCUSSION AND CONCLUSION

Seeding density in wheat is not a determining factor controlling ultimately density of stand and can vary widely without affecting final yield. This,because the various yield components show inter-component compensation. Wheat plant has tremendous tillering potential, which is expressed depending on density of stand. This compensates for lower plant density and thereby making use of the additional space available. Practical seeding rate is depehdent upon factors such as seed bed preparation, germinability, seedling survival and moisture availability. Interestingly enough, in many countries e.g. of Europe, USA, Asia and Africa, around 100 kg/ha seed rate is recommended for conditions where moisture is not limiting. This seed rate, therefore, may be considered an 'Universal Seed Rate' for wheat under such conditions. All this suggests that often many experiments on seeding rate in wheat are not necessary and only through adaptive research,it should be possible to determine an approriate seeding rate for a specific environment.

Yield, yield components and final tiller number interact differently with environments and nature of this interaction differs in different genotypes. Although final tiller number i.e. number of ears per unit area, is an important determinant of yield, higher percent tiller survival is important from physiological efficiency point of view and should be considered a desirable characteristic. Although there is translocation of photosynthate from the dying tillers to those that survive, it is not complete (6). High tillering genotypes, in which many tillers fail to bear ears are counter productive. In the selection of cultivars, therefore, beside high yield, ability to maintain a higher level of the three yield components and higher percent tiller survival in different environment are important and should be considered.

Differences between cvs. appear to exist in maintaining nearly the same number of kernels per spike and kernel weight at higher density of stand, which is a desirable attribute for obtaining maximum yield under conditions of intensive agriculture. Cultivar Loerie appears to possess this desirable attribute but no increase in yield at higher densities was obtained. The ultimate advantage in yield in such cultivars, however, will depend upon a higher tiller retention ability and ultimately a higher number of ear bearing tillers. Further studies need to be undertaken to confirm these results.

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REFERENCES

1) Hanson, H., Borlaug, N.E. and Anderson, R.G. 1982 Wheat in the third world.

2) Laloux, R., Falisse, A. and Poelaert, J. 1980 Nutrition and fertilisation of wheat in Wheat:Documenta CIBA GEIGY; pp 19-24.

3) Lungu, D.M., Sisodia, N.S., Mbewe, D. and Temba, J. 1985. Agrotechnology Transfer: The Case of Wheat. Presented at the XI Forum on Soil Texanomy and Agrotechnology Transfer, Lusaka, July 15-31, 1985.

4) Ministry of Agriculture and Water Development (MAWD) Annual Report, 1977-78

5) Pelton, W.L. 1969, Influence of low seeding rate on wheat in southwestern sasketchwan. Can. J. Plant Sci. 49: 607-614.

6) Rawson, H.M. and Donald C.R. 1969. The absorption and distribution of nitrogen after floral initiation in wheat. Aus. J. Agric. Res. 20: 799-808.

7) Read, D.W.L. and Warder, F.G., 1982. Wheat and barley responses to rates of seeding and fertilizer in southwestern Sasketchwan. Agron. J. 74: 33-36.

8) Sisodia, N.S. 1983. A review of wheat and triticale research at the University of Zambia. Proc. Regional Wheat Workshop for Eastern, Central and Southern Africa, Arusha, Tanzania, pp. 65-75.

C O M M E N T S

(K. G. BRIGGS):

Under conditions of adequate moisture and intensive production, seeding rates much higher than those used in your study are being commercially exploited in Europe, China, and, more recently, in North America. Rates of 500 - 600 plants/m^2 with 9 cm between rows are commonly used, where yield potential is high. Under such conditions, yield is achieved mostly by high tiller number and large seeds, rather than from large heads. Spatial arrangements as well as plant density are important.

Effect of seeding date on grain yield of breadwheat grown at different altitudes

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INTRODUCTION

Ethiopia produces wheat (Triticum sp.) on about 600 thousand hectares each year. Of this breadwheat (Triticum aestivum L.) occupies about 250 thousand hectares. This results in a crop of near 3.2 million metric tons for an average yield of 12.8 q/ha. Almost all of this wheat is produced on the highlands of Ethiopia; and the demand for breadwheat increases so as production from year to year. This low yield, though high-yielding cultivars are available, is accounted to poor management practices. One of the major constraints of wheat production is date of seeding next to seedbed preparation. Farmers in the highlands of Ethiopia widely practice late seeding mainly for controlling weeds. As a result, low grain yields due to frost damage, dessication, and low moisture during the grain filling period. Hence, more information is needed to establish optimum date of seeding for the various environments of the wheat growing highlands of Ethiopia.

Date of seeding elsewhere have been shown to have a large influence (2,3). It has been reported that early and late dates of seeding result in low grain yield (1,3). In this paper, the effects of seeding date on grain yield of breadwheat in some environments in Ethiopia are reported.

EXPERIMENTAL

Field experiments were conducted at a total of 6 locatins at different years. These locations are situated at different altitudes ranging from 2150 m to 2800 m above sea level (Table 1).

Prior crops were those which commonly precede wheat in these areas. Seedings, at each environment, were made as early as the on set of rainfall except at Sheno where seeding was done before the rainfall started. For each environment, the recommended fertilizer and seeding rates were used.

Grain yield was substantially influenced by date of seeding (Table 1). At Bekoji, the late-sown wheat averaged 34.4% lower than the optimum date of seeding June 25, and 28.5% than the early sown wheat. Though yield difference between June 11 and June 25 were essentially narrow, June 25 date of seeding is optimum for the area. On the other hand, at Robe July 16 date of seeding produced a higher grain yield than the rest of the seeding dates (Table 1). Reductions caused by late seeding averaged 41% . At Kulumsa due to unreliable onset and distribution of rainfall the response of seeding dates were inconsistent when individual years were looked at. However, on the average seeding dates of June 15, 29 and July 12 yielded more than July 27 date of seeding (Table 1). Hence, the optimum date of seeding of breadwheat at this environment would be the 2nd week of June to the 2nd week of July depending on the timing of rains. At Holetta red soil (RS), yield obtained from June 25 seeding date was higher by 19.9% and 29.2% than June 15 and July 16 seedings, respectively. On the other hand, the optimum date of seeding at Holetta black soil (BS) differed than that of the red soil. Grain yields ranged from 38.7 to 49.1 q/ha

(Table 1). The highest yield, 49.1 q/ha, was obtained from July 6 date of seeding.

At the high altitude location, Sheno, yields obtained from May 30 to June 30 seedings were higher than early seeding, May 15 (Table 1). Yields were essentially uniform except May 15 date of seeding. The difference in yield of the optimum date of seeding June 15 and the early date of seeding was 73.8%.

SUMMARY AND CONCLUSION

The influence of date of seeding was assessed in six environments of the highlands of Ethiopia. Results of these studies have demonstrated that optimum date of seeding differ among environments. Seeding dates have shown a large influence on grain yield of breadwheat. Thus, grain yield per unit area can be increased by using recommended optimum date of seeding for a given environment/agroecology.

TABLE 1

Effect of date of seeding on grain yield (q/ha)
of wheat grown at different altitudes

Location	Yield q/ha^{-1}; 3-year average	
	Date of Seeding	Mean Yield
Bekoji	11 June	52.9
(2760 m.a.s.l)	25 June	57.6
	9 July	46.6
	23 July	37.8
Robe	1 July	29.0
(2420 m.a.s.l.)	16 July	36.6
	30 July	28.3
	13 August	21.6
Kulumsa	15 June	27.7
(2150 m.a.s.l)	29 June	26.8
	12 July	27.7
	27 July	21.6
Holetta (RS) (2400 m.a.s.l)	15 June	24.9
	25 June	31.1
	6 July	23.0
	16 July	22.0
Holetta (BS)	15 June	38.7
(2390 m.a.s.l.)	25 June	39.7
	6 July	49.7
	16 July	43.1

Location	Yield q/ha $^{-1}$, 3 year average	
	Date of Seeding	Mean Yield
Sheno	15 May	8.0
(2800 m.a.s.l.)	30 May	26.7
	15 June	30.5
	30 June	29.3

*m.a.s.l. - meters above sea level

REFERENCES

1. Institucte of Agricultural Research, 1970 Wheat variety x sowing date trials. Holetta Progress Report for the period April 1969 to March 1970.

2. Ciha, A.J. 1983. Seeding rate and seeding date effects on spring seeded small grain cultivars. Agron. J. 75: 795-799

3. Pittman, U.J., and J.E. Andrews, 1961. Effect of seeding on winter survival, yield and bushel weight of winter wheat grown in Southern Alberta Can. J. Plant Sci. 41: 71-80

Soil and water conservation on the Hanang wheat complex, Tanzania

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Introduction

It is fortunate that soils and other environmental conditions on the 25,000 - hectare Hanang Wheat Complex in Tanzania are quite similar to those of the Canadian Praires, allowing Canadian farmers and researchers to transfer much of Canadian wheat production technology to the Hanang Complex without alteration. Nevertheless, the many similarities between the Canadian Praires and the Hanang Complex also resulted in some of the few dissimilarities being overlooked. During the early development of the complex in the early 1970's,the relatively flat, open grassland similar to the Canadian Praires led to clearing into large rectangular fields characteristic of Western Canada and very convenient for the use of large equipment. It was not realized, however, that the soils, particularly the sloping vertisols, on the Hanang Complex are more susceptibile to erosion and the rainfall more intense than on the Canadian Praires.

Despite frequent recommendations from soil survey and other evaluation teams beginning as early as 1968 that the soil erosion potential on the Complex was great and that soil conservation measures were needed in addition to minimum tillage which had been used since the early years, little was done until 1983 when soil erosion was so widespread that it was evident to most everyone that something had to be done. At that time the Soil Survey and Land Use Planning Section of TARO Selian Agricultural Research Institute, Arusha took the responsibility of implementing soil erosion control measures.

Approach

Controlled clearing of land leaving the native vegetation (mixed rhodes and thatching grasses under an open bushland of thin spindly gall thorn and scattered acacia) in five-metre contour (grass) strips as well as in the natural drainage ways (grass waterways) would have been the most suitable and economical approach to soil erosion control on the Hanang Complex because it (1) would have minimized soil erosion from the time of clearing, (2) would have resulted in a vegetative cover in the contour grass strips and waterways capable of controlling erosion well without expensive re-seeding or without waiting 1 or 2 years for grass to re-establish itself, and (3) would have eliminated the necessity of expensive re-organization of farm layouts later on. Consequently, the Soil Survey Section decided in 1983 to initiate the soil conservation program as controlled clearing of the 8000 hectares on the Gidagamowd and Warret Farms, the newest of the seven 4000-hectare farms on the Hanang Complex. It was hoped that this "pilot" work would encourage implementation of conservation measures on the five remaining already established farms. Most of the Gidagamowd Farm has been control cleared and within about two years the Warret Farm will be completed. The "pilot work" has indeed stimulated interest in erosion control as diversion channels, contour grass strips and grass waterways were installed on much of the Murjanda Farm and some of the Setchet Farm in 1984 and 1985. These two farms are the most erosion prone of the five established farms. It is expected that work will be initiated on the remaining three farms, Basotu, Mulbadow and Gawal later in 1985 and will be completed within the next three years.

Most potentially arable land on the Gidagamowd and Warret Farms includes long (1 to 4 km), wide (accommodating fields as long as 1.5 kilometres) uniform slopes averaging approximately 3% but ranging from 1% to 8%, the upper limit for mechanized dryland wheat production. The predominate soils (clay and clay loam vertisols and vertic mollisols) are not particularly susceptible to sheet erosion (or to large uniform losses of topsoil) but are very susceptible to gulley erosion because of large runoff volumes resulting from their low permeability and long slopes. The highly erosive nature of the land on Gidagamowd and Warret also contributed to the decision to implement "pilot" soil conservation measures on these farms rather than on the established farms.

Width of the cultivated strips between the 5-metre contour grass strips varies from 50 to 100 metres, depending upon slope and soil type. Although only a few diversion channels (on the contour) and no terraces were installed, it is expected that tillage over the years will convert the strips into terraces. Nevertheless, often it was necessary to make field width three to four times that calculated by the most common formulas (which assume grass terraces are the principal control devices) in order to accommodate large machinery. More contour diversion channels are planned for the remaining uncleared portion of Warret and many diversion channels have already been installed on the Murjanda and Setchet Farms. It is hoped that a mixture of contour diversion channels and grass strips will provide better erosion control than grass strips alone but allow the 50 to 100 metre cultivated strips, very convenient for large equipment.

Much gulley erosion has taken place along roads on the original five Hanang farms because the roads are often oriented up and down the slope. Consequently, most roads on Gidagamowd and Warret have been located on 10 to 15 metre contour grass strips. Occasional absolutely necessary up-and-down slope roads are located along grass waterways.

Observations.

Although contour grass strips have not been entirely effective in controlling erosion (as evidenced by damming up of water above strips during heavy rains followed by sudden releases of large volumes of very erosive water), the strips have at least forced cultivation on the contour. Furrows resulting from this contour cultivation seem to decrease rapid runoff and promote infilteration.

Preliminary results from a grass strip demonstration on Murjanda as well as observations by the manager on the Gidagamowd farm suggest that wheat grain yields may be slightly higher on grass-stripped land than on adjacent unstripped land. This in conjunction with the decrease in production in the long term by erosion damage on land which has not been contour stripped should compensate for the 10 to 15% decrease in land under production through installation of contour grass strips and grass waterways.

It appears that it may not be necessary to seed grass on newly established (grass) contour strips on land which has been under cultivation for a number of years. Although it took one to two years, grass re-established itself in the grass strip demonstration as well as newly demarcated contour strips on the Murjanda Farm. This will greatly simplify and decrease the expense associated with implementing erosion control measures on the older Hanang farms.

Farm managers were concerned that the grass strips might increase bird damage by serving as nesting, breeding or simply roosting areas. Thus far there has been no evidence that bird damage is greater in grass stripped areas. There was also concern that the grass strips would harbour weeds. But, most strips are not occupied by large trees or shrubs, so that sprayer booms can usually pass over the strips, allowing control of at least broadleafed weeds.

Contour grass strips undoubtedly have slowed field operations, particularly aerial spraying. However, the inconceniences have been minimized by the relatively wide (no less than 50 metres) and long (often 1.5 kilometres) cultivated strips. Besides, tolerance for the added inconvenience seems to be increasing as farm managers become more aware of the short and long term benefits of soil erosion control.

Some agronomic practices for wheat production in Northern Tanzania

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INTRODUCTION:

The Selian Research Institute with the assistance of the Tanzania Canada Wheat Project has conducted over the past several years a series of agronomic experiments designed to improve wheat yields. These experiments are conducted both on the Research Farm near Arusha and on various wheat production farms operated by NAFCO in the Hanang region of northern Tanzania. Operating procedures on these farms have been modified over the years on the basis of these experimental results with impressive gains in production. Average yields have increased from 0.5 tonnes/ha in 1976-77 to 1.6 t/ha in 1981-82 and an expected average for 1985 of 2.1. These improved yields together with an increase in cropping area have raised total production from 38,000 tons in 1983 - 84 to probably over 54,000 tons this year.

These agronomic experiments are continuing with two main objectives:

1. To develop cultural practices designed to further increase yields and the reliability of obtaining these yields.
2. To reduce the costs of production while maintaining satisfactory performance.

Currently five experimental field trials are in progress at Arusha and on the farms including date of planting,degrees of tillage, types of seeder, time of swathing and alternate or rotation cropping. Only the first two will be discussed in this paper.

MATERIAL AND METHODS:

1. Times of planting. Three trials were conducted at Basotu, Setchet and Gidagamowd wheat farms in Hanang wheat complex and at Arusha Research farm. On the production farms the experimental design was a non-randomised, non-replicated strip plot with plot size of 150m x 5m. At Arusha the experimental design was a randomised complete block replicated four times with plot size of 16m x 4m. In all 4 sites weeds were controlled using 2,4-D amine at the rate of 840g/ha and Illoxan was used to control grass weeds at Setchet site at the rate of 3 l/ha. Data collected were yield, available soil moisture at seeding and harvest,available nitrate nitrogen at seeding and relationship between time of planting and weed control was observed. The variety "Mbuni" was planted in all sites at the rate of 110 kg/ha.

*Presenting Paper.

2. Methods of seeding. For the effects of the methods of seeding on wheat produced on various degrees of tillage, one field trial was conducted at Arusha Research Farm. The experimental design was a split block with randomised degrees of tillage operations which were conventional tillage, tillage reduced to 60% and zero tillage treatments representing the main plots. The methods of seeding were (i) Discer (ii) Press Drill or Haybuster and (iii) Air Seeder representing the sub-plots. Main plot size was 21m x 25m and sub-plot size was 7m x 25m. The conventional tillage and reduced tillage operations were done using spikes for the first operation followed by shovels on other operations. The Zero tillage (no-tillage) treatment was designed to maintain maximum crop residues on the surface. It did not receive mechanical cultivation to control weeds or prepare the seed-bed. Weeds are chemically controlled by application of Roundup and gramo-xone (Paraquat) at the rate of 3 l/ha. The wheat variety "Mbuni" was planted in Mid-April at the rate of 110 kg/ha.

RESULTS AND DISCUSSION:

The times of planting results showed that the period between February to March was found to be optimal seeding date at Setchet and Gidagamowd respectively (2-3) Table 1. In Arusha the optimal date to begin planting for the long rains wheat crop was the first part of April to early May. (Table 1). At Basotu optimal date was found to be between mid January to February (1) Differential responses to time of planting have been obtained with wheat varieties. In Northern Tanzania, reductions in wheat yield were observed with early maturing varieties planted after mid-April. A marked reduction of 30-40% in wheat yield was obtained with medium maturing wheat varieties planted after mid April (4). Further detailed trials have shown that the response of most annual crops including wheat to the time of planting is associated with the moisture availability at certain critical periods of crop and that seeding without adequate soil moisture is unreliable.

Table 1: YIELD RESULTS IN KG/HA FOR THE VARIOUS DATES OF PLANTING AT SETCHE GIDAGAMOWD AND ARUSHA SITES IN 1983 IN 1983 - 1984.

DATE	SETCHET	GIDAGAMOWD	ARUSHA	
	1983	1984	1983	1984
MID JAN.	619	-	+	+
FEB 1ST	981	-	+	+
MID FEB	760	2130	350c	*
MAR 1ST	1054	2060	480c	*
MID MAR	941	1200	1710b	1820b
APR.1ST	1169	*'	2580a	2630a
MID APRIL	+	+	2360ab	1750b
MAY 1ST	+	+	2710a	2180b
MID MAY	+	+	1810b	2730b
LSD 0.05			610	654
CV			24.1%	19%

- Not planted because of heavy rains.

* Not harvested because of bird damage and/or heavy weed infestion.

*' Data Not available.

The preliminary results from the degrees of tillage and methods of seeding experiments have indicated that reduced tillage and zero tillage consistently reduced yield by an average of 7% and 22% respectively (Table 2). Seedbed condition at seeding time is very critical for the air seeder and discer. In 1983 there were significant yield differences due to the three degrees of tillage operations and there was a significant interaction between the degrees of tillage and the methods of seeding. In 1984 only the degrees of tillage resulted in significant differences in yields and there was no significant interaction between the degrees of tillage and methods of seeding.

TABLE 2: WHEAT YIELD IN KG/HA FROM THE DEGREES OF TILLAGE EXPERIMENT AT ARUSHA IN 1983/1984.

DEGREES OF TILLAGE	METHODS OF SEEDING						
	PRESS DRILL		AIR SEEDER		DISCER		MEAN
	1983	1984	1983	1984	1983	1984	
CONVENTIONAL TILLAGE	2630	2980	2910	3510	2860	3320	3035
60% REDUCED TILLAGE	2420	3540	2160	2810	2550	3410	2820
ZERO TILLAGE	2070*	3130*	1780	2490	1960	2720	2360

* HAYBUSTER

CV (a) 21.99% 13.3%

CV (b) 8.41% 15%

CONCLUSIONS.

There is a relationship between wheat yield and certain soil and climatic factors such as level of moisture storage, distribution and amount of precipitation. Since rainfall is the sole source of water in dry land farming, this parameter needs a thorough understanding with a given location. At this stage of the study more work is required to determine the growth period at which the wheat plant will be more responsive to growing season rainfall in these sites.

There is an indication that zero tillage treatment reduces the yield and there was no significant yield difference between conventional tillage plots and the 60% reduced tillage treatment. The low yields obtained from the zero tillage treatment, were due to poor performance of the air seeder and the discer during seeding due to erratic and uneven penetration of the shovels and discs into the soil which resulted in poor seed placement. Specific recommendation for crop production under reduced/minimum tillage or zero tillage remain to be identified. The rewards in terms of moisture conservation are there to be gained but it will need cooperation between research workers, agronomists and engineers over a number of years before reliable techniques can be recommended with confidence especially to the now increasing number of new farms.

<u>REFERENCES</u>:

(1) - Annual Reports of Agric. Res. Project (Wheat) 1975-82.

(2) - Crop Mgmt. Sec. (1983) Progress report Presented to Wheat Coordinating Meeting.

(3) - crop Mgmt. Sec. (1984) - do -

(4) - Fuggles - Couchman,N.R. (1961) Wheat production in Tanganyika. Min. of Agric. Bull. No. 9.

Session 7

B U S I N E S S   M E E T I N G

Chairman : A. MOSHA

Rapporteur: N. A. MASHIRINGWANI

1 Presentation, by Regional CIMMYT Wheat Staff

2 Conclusions and adoption of recommendations, by Workshop participants

Germplasm evaluation by Regional CIMMYT personnel

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In terms of worldwide agricultural cooperation, the concept of "International Nurseries" has evolved from an expedite way to expose nationally generated germplasm to a broad range of environments, and has become a medium to disseminate newly developed elite germplasm. This trend has been followed with unparalleled success by the CIMMYT Wheat Program.

One reason for this success is that wheat has excelled as a "green immigrant", being a crop of high genetic stability and very low quarantine risk; another is the availability of high yielding spring wheat cultivars with enhanced adaptability over a range of growing conditions. Of these two reasons, the former is a natural feature, whereas the latter reflects a breakthrough in breeding, a credit to Borlaug and his colleagues in Mexico. Widely adapted varieties allow greater flexibility to policy makers in extending wheat cultivation beyond traditional latitudes, and to growers in choosing the sowing dates best fit to their needs. This kind of flexibility did not exist in spring wheat before the advent of CIMMYT cultivars. Equipped with such a wide adaptability, "Mexican Wheats" have been amply accepted in the Indian subcontinent, Northern and Southern Africa, the Middle East, the southern tip of South America, and more and more in tropical South America, Asia, Eastern and Central Africa.

The dramatic expansion of wheat consumption in subSaharan Africa has caused the region as a whole to rely upon grain or flour imports. The burden in the balance of payments has initiated or stimulated national interest for wheat research aimed at increasing productivity and total production. Researchers have approached this goal primarily through varietal development.

Many stress factors, of rare occurrence in well established wheat growing areas elsewhere, conjugate in subSaharan Africa and islands of the Indian Ocean to constrain wheat yields and wheat production: problem soils, unreliable rainfall regimes, rare and ravaging diseases, suboptimal temperature profiles during critical stages of crop development, to name only the major local constraints, plague most of the potential wheat growing areas of the region.

Viable wheat varieties must combine a highly productive plant type with earliness or some mechanism of drought tolerance and resistance to preharvest sprouting under rainfed cultivation, tolerance to acid soils or to Aluminium toxicity for vast expanses in Burundi, Ethiopia, Kenya, Madagascar, Rwanda, Tanzania and Zambia, and heat tolerance to thrive in new areas with otherwise high possibilities for wheat cultivation, such as the low highlands of Kenya, Mauritius, and Mozambique. Cultivars must have resistance against the gamut of races of stem rust throughout the region, and of yellow rust in the medium and upper highlands, against septoria blotches everywhere, and against ear scab and tan spot under warm, moist conditions such as those prevailing in northern Zambia and in Trans Nzoia, Kenya. Clearly, developing this kind of cultivars is not an easy task: it is one that calls for international cooperation.

With this understanding, wheat breeders at CIMMYT, Mexico, started including many of the above constraints as explicit targets of their hybridisation and selection strategies. This new phase has stimulated varietal exchange and shuttle breeding between Mexico and key screening sites such as southern China, Brazil, Paraguay, Zambia and South East Asia. Fruit of this concern is the recently initiated series of specialised screening nurseries for tolerance to drought, resistance to scab and tan spot, fitness for highland and lowland cultivation, and early maturity to fit in tight rotation schemes. Besides, a few sets of special F2 populations continue being available from crosses aimed at generating variability in the response to these and other constraints.

A major duty of CIMMYT staff at outposts is to assist national scientists in the region in achieving their goals, within their area of expertise. In this regard, the authors are expressly committed to evaluate exotic wheat germplasm for possible use in Kenya or other national programs in the East African region. We follow the procedures established since the inception of CIMMYT involvement in Kenya, that is, we screen those foreign nurseries received by the Kenyan National Wheat Program, in association with and as part of Introductions Section of the Wheat Project at National Plant Breeding Station, Njoro. The target of this screening is to identify lines with all round performance for immediate use in commercial production, or with specific attributes to withstand the constraints listed above, for use in hybridisation programs.

Multilocation testing is a time-efficient approach to screen for multiple characters. We have implemented a modest multilocation testing strategy in Kenya by adding to Njoro, five supplementary sites selected from the locations where NPBS conducts performance trials. Sites have been chosen on the basis of a high probability for differential expression of one or more useful characters. The box contains a brief listing of the characters expected to be expressed at each of the six sites.

Narok:	earliness, drought tolerance, resistance to septoria (speckled blotch)
Timau:	resistance to septoria (speckled blotch)
Uasin Gishu:	tolerance to acid soils/aluminium toxicity
Trans Nzoia:	resistance to scab and tan spot
Mau hills:	resitance to yellow rust
Njoro:	desirable plant type, resistance to stem rust, resistance to preharvest sprouting)

Basic nurseries are planted during the long rains season (main season) at all sites, and specialised nurseries at Njoro and the site where the specific character is likely to be expressed (e.g. aluminium screening nursery is planted at Njoro and Uasin Gishu, scab screening nursery, at Njoro and Trans Nzoia).

Lines selected at Njoro are promoted to one of two sets, selections from International Nurseries (SIN), or Preliminary Observation for Parental Collection (Pre-OPC), to be planted during the short rains season under supplementary irrigation (off-season). SIN includes entries of superior agronomic type with R-MR reaction to stem rust and low to moderate infection of yellow rust. Pre-OPC comprises lines with acceptable agronomic type and nil to TR infection levels of stem rust or yellow rust. Therefore, discards at Njoro are those entries with poor plant type or medium to high levels of infection of stem rust and yellow rust. Selections from Narok and Timau enter the Pre-OPC set, and are further assessed for earliness, disease resistance and plant type.

During the off-season at Njoro, SIN and Pre-OPC sets are rigorously assessed for plant type and disease resistance. Pre-OPC lines that retain the valuable character for which they were selected (earliness, disease resistance) are planted in the main season as Observation for Parental Collection (OPC) at all sites. Selections from UasinGishu, Trans Nzoia and Mau hills are harvested too late to be included in the off-season planting. Therefore, they enter directly OPC to assess their performance at Narok and Timau and elsewhere. SIN is also retested for superior plant type, resistance to stem rust and moderate resistance to yellow rust; successful prospects are planted as Multiplication Plots for SNACWYT (MPS) at Njoro in the main season. Lines with mediocre plant type but outstandingly resistant to stem rust or yellow rust are transferred to OPC. Conversely, Pre-OPC lines with superior plant type and adequate resistance to rusts are moved to MPS.

The final move for successful lines in MPS is to enter that year's SNACWYT, a nursery that is distributed regionally by request; for OPC, to Parental Collection, a comprehensive set for which a listing of useful characters will be issued annually.

Chairpersons and rapporteurs from the various sessions prepared recommendations for consideration at the Business Meeting. The Workshop adopted the following

CONCLUSIONS

1 Having considered that more effort is needed to persuade Governments to improve wheat prices and to establish a positive approach towards triticale through marketing policies,

the Workshop recommends to national officers and regional CIMMYT Economics Program to raise the awareness of the various Governments in the Region on the need to review wheat prices and to establish positive policies regarding marketing triticale.

2 Acknowledged the useful role played by the regional office of the CIMMYT Wheat Program in bringing closer wheat researchers in the Region and availing germplasm for local evaluation, it is felt that more direct communication among researchers is needed. In this connection,

the Workshop recommends

a to the Regional CIMMYT Office in Nairobi,

i the establishment of a Wheat Newsletter to serve as a medium to disseminate results of wheat researchers in the Region; and

ii the exploration of using the Scientific Phytopathological Laboratory of Ambo, Ethiopia, for identification of BYDV samples and races of the rust fungi. And

b to National Wheat Researchers in the Region;

the development of procedures to facilitate exchange of wheat lines in early stages of evaluation, with the aim of extending the useful life of a cultivar before its resistance becomes ineffective to new pathogenic biotypes.

3 Taken into consideration that barley is a crop of substantial importance in the Region, and that the research responsibilities have been shifted from CIMMYT to ICARDA,

the Workshop requests to the Regional CIMMYT Wheat Office to assist barley researchers in their attempts to liaise with ICARDA International Nurseries in demand of barley germplasm.

4 Considering that the next Workshop should take place in 1987 and that the Malagasy delegation has volunteered to host the Meetings,

The Workshop accepts the generous offer of Madagascar to arrange the next Regional Wheat Workshop.

REGIONAL WHEAT WORKSHOP
FOR EASTERN, CENTRAL AND SOUTHERN AFRICA

September 2-5, 1985

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Complement

Effects of liming on Wheat Performance in Northern Zambia

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Chilanga, ZAMBIA

INTRODUCTION

Land areas which at present are identified as being suitable for rainfed wheat production in Zambia are outlined by zones 26-34 on the accompany map. (Figure 1). The levels of precipitation (1000 mm/annum), the seasonally even distribution of precipitation and the cooler late season temperatures associated with these areas are conditions which promote the production of rainfed wheat. Unfortunately, over 80% or 24,000,000 ha. of the soils in these areas are described as being oxic Paleustults, loamy or clayey, Kaolinitic, hyperthermic; by definition inherently infertile and acidic. The soils specific to this study are generally characterized by the following: cation exchange capacities (CEC) less than 16 meq per 100 g of clay, base saturation percentage (BSP) below 35%, pH ($CaCl_2$) between 4.0 and 4.5, Al^{+3} concentrations of 30 to 45 ppm(1). As aluminium toxicity is one of the major inhibitors to rainfed wheat production in Zambia experiments in ways to overcome this problem using lime, have being ongoing at Mbala since 1979.

ALUMINIUM TOXICITY

Symptoms of aluminum toxicity are a swelling and thickening of the root tips, a lack of root hairs and a lateral growth of the roots which results in very shallow rooting. This shallow rooting limits the plants access to nutrients and moisture, resulting in stunted vigourless plants which are unable to withstand drought stress.

In 1982 studies were carried out to determine the relationship in Zambia between pH and Al^{+3} and between Al^{+3}

and wheat yield using the aluminium intolerant variety Jupateco 73 (2). Soil samples, taken from 9 areas where crop vigor ranged from poor to good, were analyzed for pH and Al^{+3} pH and Al^{+3} extracted with dilite Calcium Chloride (3) show a very good correlation at r = 0.83 (fig 2). A correlation of r = 0.78 between Al^{+3} and wheat yield suggest that aluminium toxicity is the main inhibitor to wheat growth in these soils (fig 3). The liming of such soils should result in a decrease in soluble aluminium levels and an increase in yield.

LIMING TRIALS

In 1979 trials were begun near Mbala in Northern Zambia to study the effects of liming on Al^{+3} behaviour in the rooting zone and wheat yield. Liming rates from 0 to 8 t/ha were applied in single and split applications and incorporated to 15cm. The effects of the various treatments on yield and soil chemistry during the 1985 season are shown in figure 4.

Virtually no yield was obtained without lime even though the wheat variety used (Whydah) is considered to be aluminium tolerant. Aluminium values in the check plot are about twice the tolerable levels for Whydah and twenty times the tolerable levels for varieties more susceptible to aluminium toxicity problems.

Single applications give very similar yields when compared to the same rate as a split application. This observation has been consistent from year to year and indicates that availability of capital and economics would dictate which method should be used (4,5,6,7,8,9).

The downward movement of lime is more pronounced in the 6 and 8 t/ha treatments and the single 4 t/ha treatment. However, the reduction of Al^{+3} levels and increase of Calcium, Magnesium and pH to a depth of 60cm has not resulted in increased yields. Further work is being carried out to find out why plants are not taking advantage of this greater rooting depth.

In 1982 a trial was begun to investigate the effects of deep incorporation of lime. Rates of 3, 6 and 9 t/ha of lime were incorporated to depths of 15, 30 and 45cm respectively (7, 8, 9). The results of this trial for 1985 are shown in figure 5. To date there has been no apparent yield benefit of deep lime incorporation as compared to shallow incorporation to 15cm.

During 1985-86 a trial will be started which will look at finding a practical and economic method of partial lime incorporation to 30cm so that the first year crop can derive the full benefit of the lime. If this cannot be achieved, deep liming on a commercial scale is questionable at best.

Currently, yields of about 2.6 t/ha are being obtained using lime. These trials were designed as long term trials in order to evaluate which rates or type of application is most economical, however, it will be several years before this can be commented on.

<u>References</u>

1) Kalima, C. (1983) The characterization, distribution and extent of major soils of the high rainfall areas of Zambia. Proceedings of the Seminar on Soil Productivity in the High Rainfall Areas of Zambia, Lusaka. (8-10 February 1983) Occasional Paper No. 6 International Development Programs Agricultural University of Norway AAS Ed. H. Svads

2) Penney, D.C., Hodgins, L.W. and Aulakh, B.S. (1982) Miscellaneous Report of Zambia Canada Wheat Report (October 1981).

3) Hoyt, P.B. and Nyborg, M. 1972
Use of dilute Calcium Choloride for the extraction of plant available aluminium and Manganese from acid soils. Can. J. Soil Sci. 52: 163-167

4) Zambia-Canada Wheat Project Annual Report 1979

5) " " " " " 1980

6) " " " " " 1981

7) " " " " " 1982

8) " " " " " 1983

9) " " " " " 1984

Mt. Makulu Research Station Chilanga, Zambia

Agro-Ecological Map - Soil Survey Unit. Mt. Makulu Research Station Chilanga, Zambia

FIG. 4

Rates of Lime Trial - Wheat

Trt. No.	Treatment Lime kg/ha	cumulative yield Total	kg/ha	Depth Cm	pH $CaCl_2$	Soluble Al-PPm	Ca Meg/100g	Mg
1	0	0	30	0-15	4.0	35	.5	.1
				15-22	4.0	38	.4	.1
				22-30	4.0	41	.4	.1
				30-45	4.0	37	.4	.1
				45-60	4.1	37	.3	.1
				60-75	4.1	34	.3	.1
2	1000 + 500 annually	4000	2654	0-15	5.0	2	2.5	.3
				15-22	4.3	14	1.0	.2
				22-30	4.2	21	.7	.2
				30-45	4.2	23	.5	.1
				45-60	4.2	27	.4	.1
				60-75	4.2	28	.4	.1
3	2000 + 500 annually	4000	2750	0-15	4.8	2	2.1	.4
				15-22	4.2	15	.8	.2
				22-30	4.2	23	.6	.2
				30-45	4.2	24	.6	.1
				45-60	4.2	26	.5	.1
				60-75	4.1	25	.4	.1
4	4000	4000	2125	0-15	4.9	2	2.4	.4
				15-22	4.4	12	1.0	.2
				22-30	4.3	17	.7	.2
				30-45	4.2	20	.6	.2
				45-60	4.2	23	.6	.1
				60-75	4.2	25	.4	.1
5	6000	6000	2650	0-15	5.4	1	3.2	.5
				15-22	4.7	3	1.6	.3
				22-30	4.3	15	.8	.2
				30-45	4.4	12	.8	.2
				45-60	4.3	18	.6	.1
				60-75	4.3	22	.4	.1
6	8000	8000	2636	0-15	5.8	1	4.1	.6
				15-22	4.8	2	1.8	.3
				22-30	4.4	10	.9	.2
				30-45	4.4	12	.8	.2
				45-60	4.4	14	.8	.2
				60-75	4.3	17	.6	.2

FIGURE 2

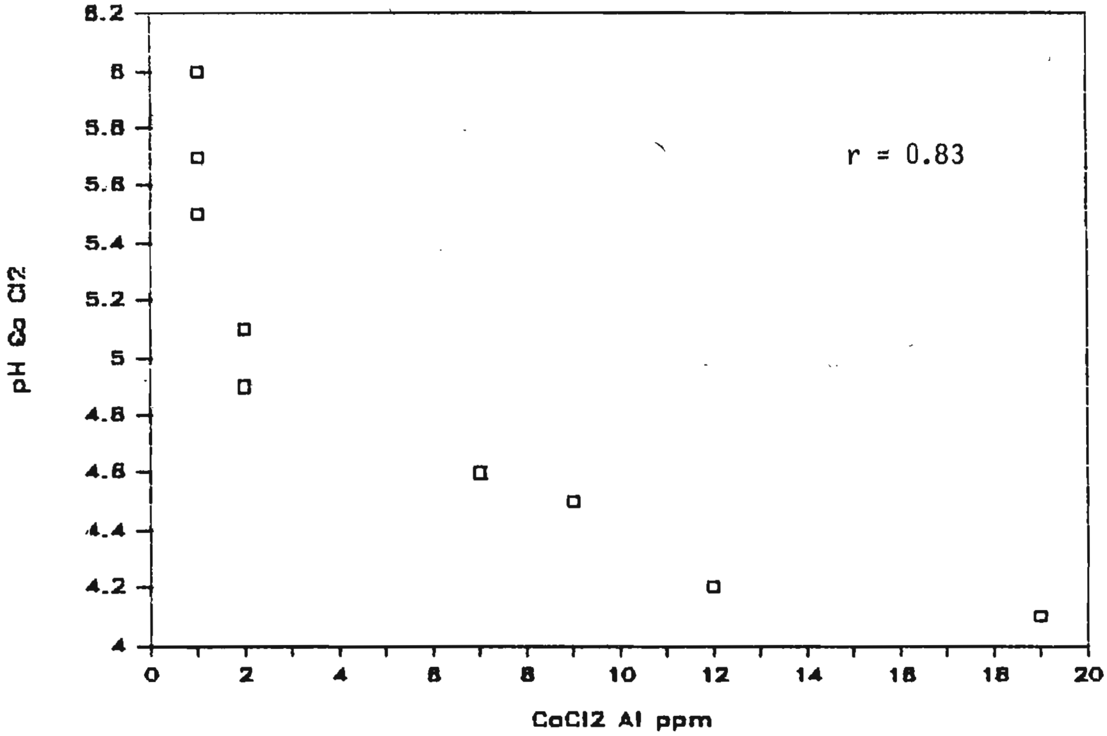


FIGURE 3

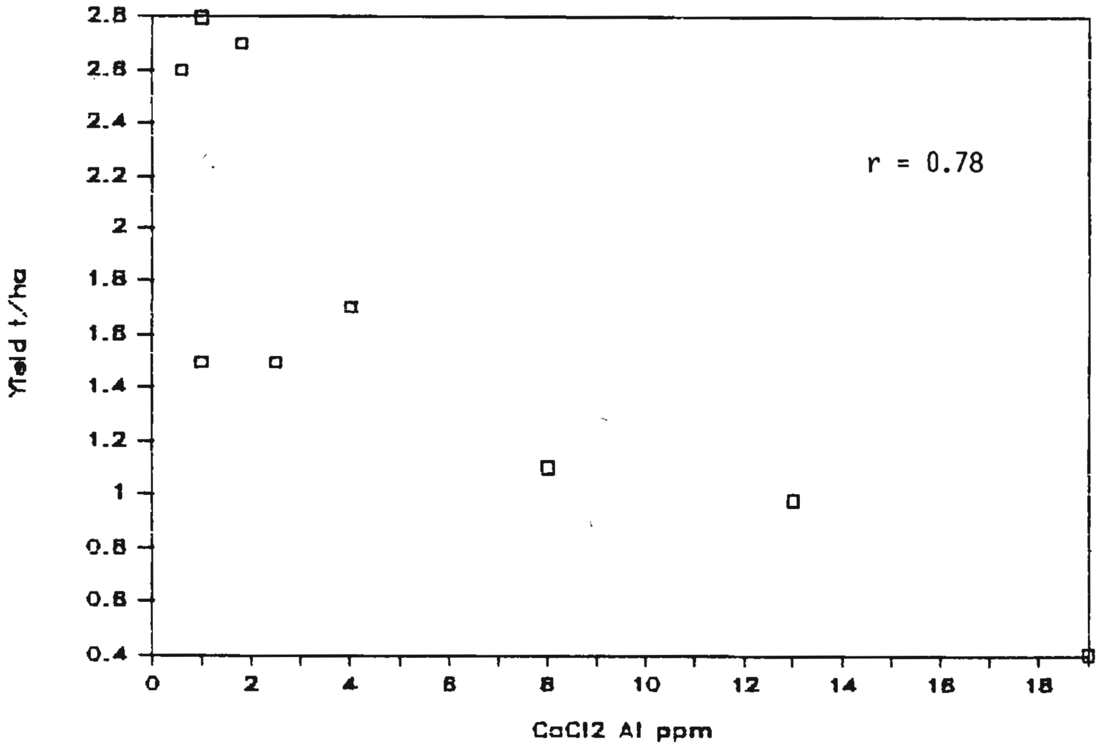
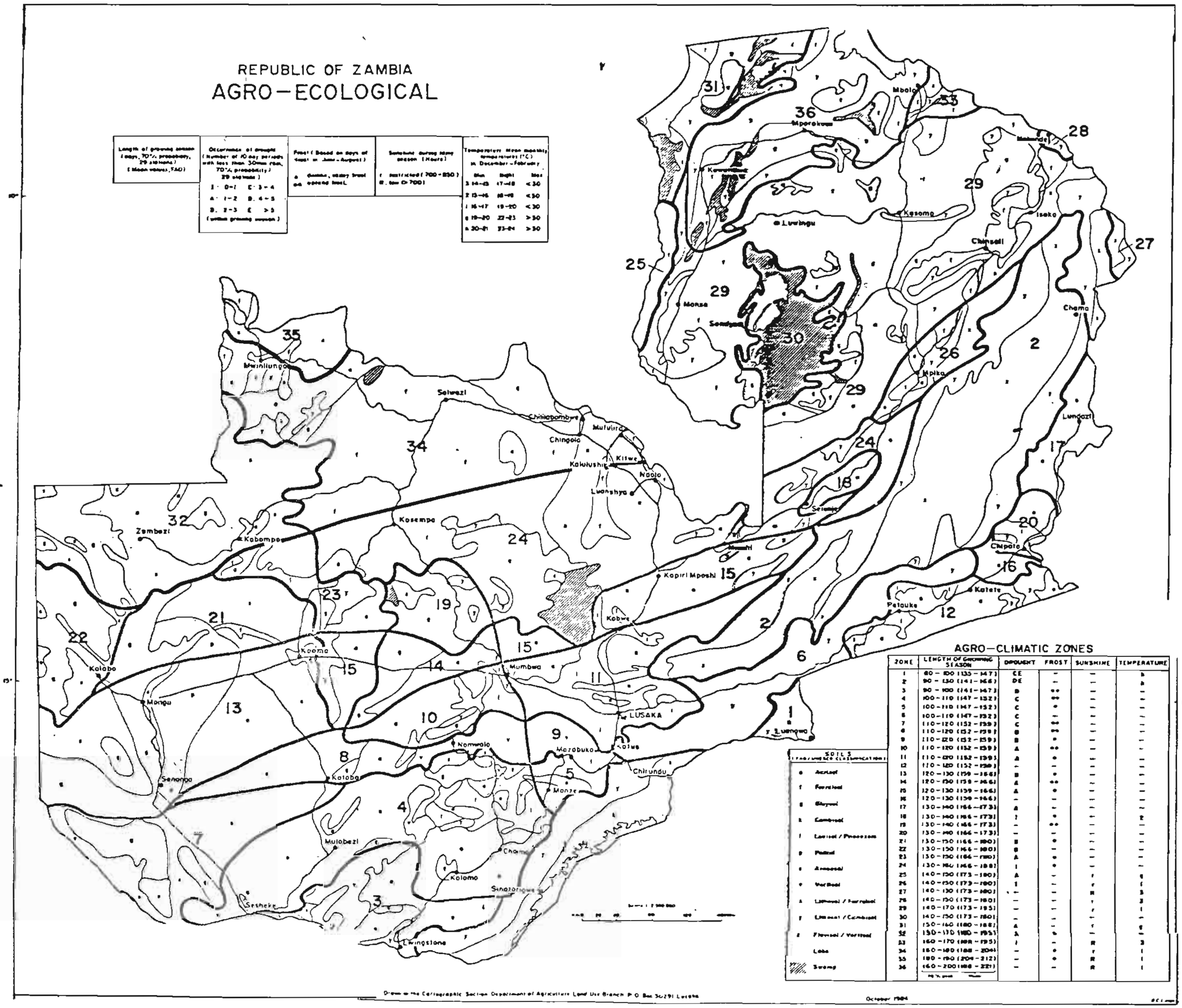


FIGURE 5

DEEP LIMING TRAIL - 1985

Lime	Yield kg/ha	Sample depth cm	pH $CaCl_2$	Al ppm	Ca meq/100g	Mg meq/100g	meq/100g Ca	meq/100g Mg
0t/ha	1317	0-15	4.2	16	.6	.4		
		15-22	4.2	24	.4	.3		
		22-30	4.2	24	.5	.3		
		30-45	4.1	27	.3	.2		
		45-60	4.2	23	.4	.2		
		60-75	4.2	25	.3	.3		
3t/ha	1874	0-15	4.8	3	1.7	.6		
0-15cm		15-22	4.2	18	.6	.4		
		22-30	4.2	23	.4	.4		
		30-45	4.2	22	.5	.3		
		45-60	4.2	23	.3	.2		
		60-75	4.2	22	.4	.3		
6t/ha	1763	0-15	5.5	1	2.5	.8		
0-30cm		15-22	4.8	6	1.3	.7		
		22-30	4.4	11	.7	.5		
		30-45	4.2	22	.4	.3		
		45-60	4.3	19	.5	.4		
		60-75	4.2	18	.4	.3		
9t/ha	1771	0-15	5.9	1	2.9	.8		
0-45cm		15-22	5.4	1	2.1	.7		
		22-30	4.8	3	1.1	.6		
		30-45	4.4	10	.8	.4		
		45-60	4.4	12	.8	.3		
		60-75	4.4	10	.6	.3		



ZONE	LENGTH OF GROWING SEASON	DROUGHT	FROST	SUNSHINE	TEMPERATURE
1	80 – 100 (135 – 147)	CE	–	–	b
2	90 – 130 (141 – 166)	DE	–	–	b
3	90 – 100 (141 – 147)	D	••	–	–
4	100 – 110 (147 – 152)	C	••	–	–
5	100 – 110 (147 – 152)	C	•	–	–
6	100 – 110 (147 – 152)	C	–	–	–
7	110 – 120 (152 – 159)	C	••	–	–
8	110 – 120 (152 – 159)	B	••	–	–
9	110 – 120 (152 – 159)	B	•	–	–
10	110 – 120 (152 – 159)	A	••	–	–
11	110 – 120 (152 – 159)	A	•	–	–
12	110 – 120 (152 – 159)	–	–	–	–
13	120 – 130 (159 – 166)	B	•	–	–
14	120 – 130 (159 – 166)	A	••	–	–
15	120 – 130 (159 – 166)	A	•	–	–
16	120 – 130 (159 – 166)	–	–	–	–
17	130 – 140 (166 – 173)	A	–	–	–
18	130 – 140 (166 – 173)	1	•	–	2
19	130 – 140 (166 – 173)	–	••	–	–
20	130 – 140 (166 – 173)	–	–	–	–
21	130 – 150 (166 – 180)	B	•	–	–
22	130 – 150 (166 – 180)	B	–	–	–
23	130 – 150 (166 – 180)	A	•	–	–
24	130 – 160 (166 – 188)	1	•	–	–
25	140 – 150 (173 – 180)	A	–	r	[illegible]
26	140 – 150 (173 – 180)	1	–	r	[illegible]
27	140 – 150 (173 – 180)	–	–	R	3
28	140 – 150 (173 – 180)	–	–	r	3
29	140 – 170 (173 – 195)	–	–	r	1
30	140 – 150 (173 – 180)	–	–	–	–
31	150 – 160 (180 – 188)	A	–	r	[illegible]
32	150 – 170 (180 – 195)	A	[illegible]	–	–
33	160 – 170 (188 – 195)	1	–	R	3
34	160 – 180 (188 – 204)	–	•	r	1
35	180 – 190 (204 – 212)	–	•	R	1
36	160 – 200 (188 – 221)	–	–	R	1

Z/GEN/92

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