The Fifth Regional Wheat Workshop

For Eastern, Central and Southern Africa and the Indian Ocean

Antsirabe, Madagascar, October 5-10, 1987

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Editors

Sponsored by:
Canadian International Development Agency (CIDA)
and the International Maize and Wheat Improvement Center (CIMMYT)

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CIMMYT receives core support through the CGIAR from a number of sources, including the international aid agencies of Australia, Austria, Brazil, Canada, China, Denmark, Federal Republic of Germany, Finland, France, India, Ireland, Italy, Japan, Mexico, the Netherlands, Norway, the Philippines, Spain, Switzerland, the United Kingdom, and the USA, and from the European Economic Commission, Ford Foundation, Inter-American Development Bank, OPEC Fund for International Development, UNDP, and World Bank. CIMMYT also receives non-CGIAR extra-core support from Belgium, the International Development Research Centre, the Rockefeller Foundation, and many of the core donors listed above.

Correct citation: Van Ginkel, M., and D.G. Tanner, eds. 1988. Fifth Regional Wheat Workshop for Eastern, Central, and Southern Africa and the Indian Ocean. Mexico, D.F.: CIMMYT.

ISBN 968-6127-03-8

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ACKNOWLEDGMENTS

We would like to thank the following groups, organizations and individuals for contributing to the success of the Fifth Regional Wheat Workshop for Eastern, Central and Southern Africa and the Indian Ocean:

* The Government of the Malagasy Republic and, in particular, the Ministry of Agricultural Production and Agrarian Reform (MPARA) through its agencies FIFAMANOR and FOFIRA for hosting the workshop.

* The management of the Hotel des Thermes, Antsirabe, for providing the conference facilities, food and accommodation.

* The Canadian International Development Agency (CIDA) for its generous financial contribution in meeting a major portion of the travel and per diem expenses of the 56 delegates, participants and observers from 14 countries.

* Maria Kamau, secretary, CIMMYT/Nairobi, for initiating all correspondence, ticketing and logistical support for the workshop.

* Aklilewerk Bekele, secretary, CIMMYT/Addis Ababa, for typing the proceedings on the microcomputer.

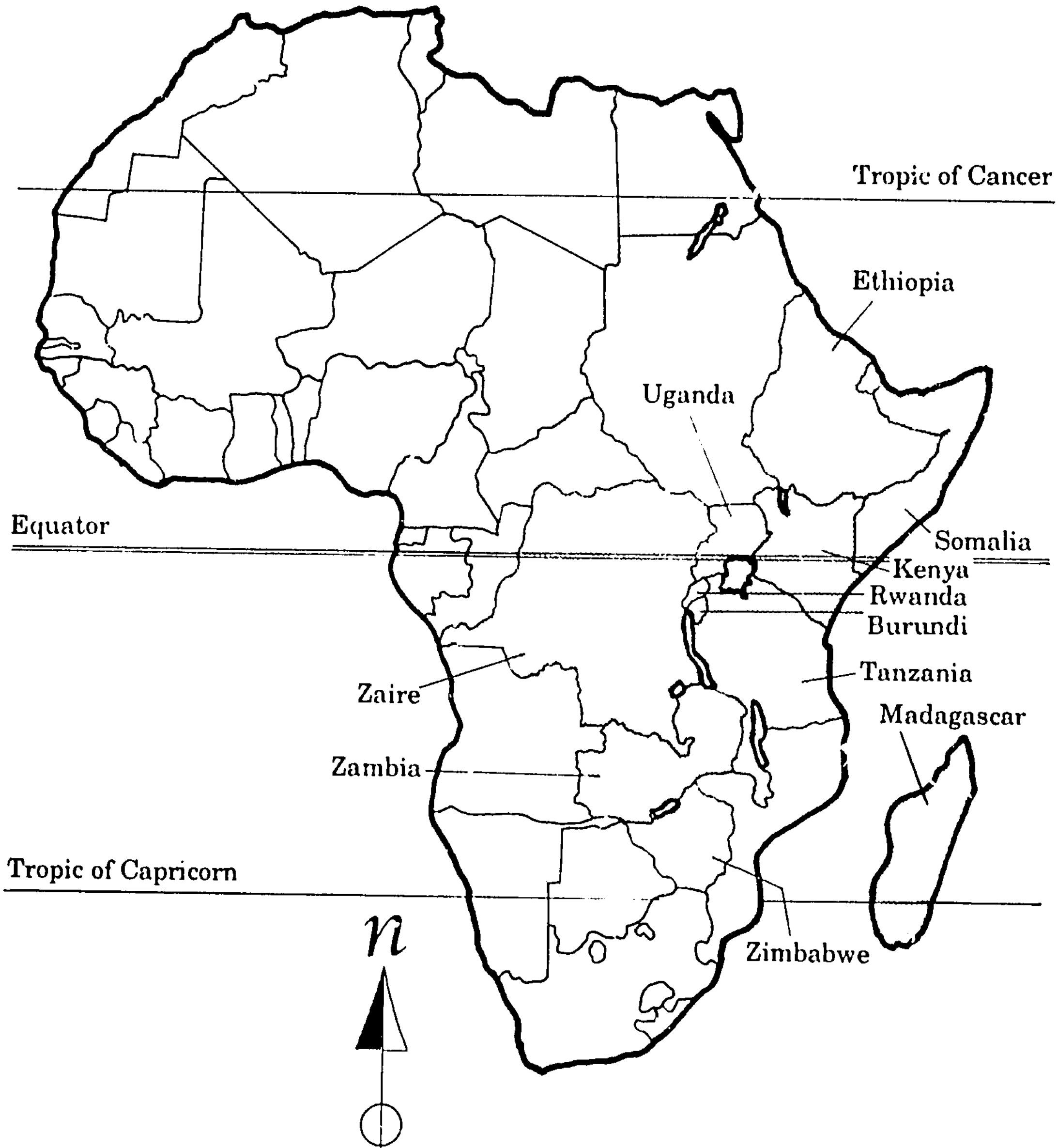
* The participants themselves who continue to pursue scientific excellence under what are often quite challenging conditions.

Workshop Organizers

Rakotondramanana
FIFAMANOR, Madagascar

Douglas G. Tanner
Maarten van Ginkel
CIMMYT/Addis Ababa, Ethiopia

PARTICIPATING COUNTRIES IN THE FIFTH REGIONAL WHEAT WORKSHOP FOR EASTERN, CENTRAL AND SOUTHERN AFRICA AND THE INDIAN OCEAN.



OPENING REMARKS

Andrianoelison Jose

Minister of Agricultural Production
and Agrarian Reform
Madagascar

Ladies and gentlemen:

I have the honor of being with you today to inaugurate the symposium on wheat in East Africa. It is a privilege for our country to host such an important international event where 34 participants from 13 countries will discuss, during 1 week, wheat research and production problems in East Africa. Our national researchers and technicians will thus benefit from the experiences of other countries and of high-level researchers who have been especially invited to this seminar.

Wheat and triticale have again become part of the agricultural practices of Malagasy farmers and production has increased in the last few years.

However, two major wheat problems appeared in 1986: wheat rust and the exceptionally harsh frost that destroyed a large part of the out-of-season crops. Thanks to the maintenance of an important collection and CIMMYT's continued support through sending rust resistant varieties and its on-the-spot team of specialists, resistant varieties have been developed and are now being multiplied.

Triticale is thriving because it is disease resistant and adapted to acid soils. It already occupies farmlands of the Malagasy high plateaus, and its production is bought by the flour milling industry to be mixed with wheat flour.

It must be pointed out that in Madagascar, farmers are taught to use their production for their own consumption. Wheat and triticale are thus opening the way to food self-sufficiency.

Grown out of season on rice paddies, wheat and triticale generate supplementary income for the farmer. They will thus be able to honorably face their responsibilities as economic agents, rural savings will develop and it is logical to expect that agriculture will at last be able to finance itself.

It is not a dream. It is a reality which is progressively taking shape and becoming clearer.

I hope that in the course of this symposium there will be a sufficient amount of fruitful exchanges between specialists and developers. "The best function of the intellect is to stimulate the intellect," said Seneca.

I take this occasion to thank CIMMYT in particular, through its delegation present here today, for the enormous efforts it has made to develop the cultivation of wheat and triticale.

I also thank all the participants in this event and wish them the greatest joys of heart and mind during their stay in Antsirabe.

I officially inaugurate this international symposium on wheat and triticale.

DISCOURS DU MINISTRE DE PRODUCTION AGRICOLE ET REFORME AGRAIRE

Mesdames et Messieurs:

L'honneur m'échoit aujourd'hui d'être parmi vous pour inaugurer le Colloque sur le blé en Afrique de l'Est. C'est un prestige pour notre pays de pouvoir abriter un colloque international d'une grande envergure où 34 participants venant de 13 pays vont discuter des problèmes de la recherche et de la production du blé en Afrique de l'Est pendant une semaine. Nos chercheurs et techniciens nationaux bénéficieront ainsi des expériences des autres pays et surtout de celles des chercheurs de hauts niveaux invités spécialement à ce Colloque.

Le blé et le triticale sont rentrés dans les pratiques culturales des paysans malgaches et la production a augmenté durant les dernières années.

Cependant, deux problèmes majeurs sont apparus en 1986 sur le blé. La rouille sur le blé et le gel exceptionnel qui a détruit une bonne partie des récoltes de contre-saison. Grâce à la maintenance d'une collection importante et au soutien continu du CIMMYT par l'envoi de variétés résistantes à la rouille, par les missions sur place de spécialistes, des variétés résistantes ont été développées et sont en cours de multiplication.

Le triticale connaît un essor considérable de par sa résistance aux maladies et son adaptation aux sols acides. Il occupe déjà les terroirs agricoles des hauts plateaux malgaches et la production est achetée par la minoterie pour être melangée à la farine de blé.

Il y a lieu de signaler qu'à Madagascar, les paysans producteurs sont éduqués à utiliser leur propre production dans leur alimentation. Le blé et le triticale ouvrent ainsi la voie vers l'autosuffisance alimentaire.

Cultivés en contre-saison sur rizières, le blé et le triticale génèrent un revenu supplémentaire aux paysans. Ces derniers pourront alors faire face honorablement à leurs responsabilités d'agents économiques; l'épargne rurale se développera et il est permis d'espérer que l'agriculture pourra enfin s'autofinancer.

Ce n'est pas un rêve. C'est la réalité qui, progressivement, prend forme et se précise.

J'espère qu'au cours du Colloque il y aura suffisamment d'échanges fructueux entre spécialistes et développeurs. "La meilleure efficacité de l'esprit, disait Sénèque en son temps, est d'éveiller l'esprit".

Je profite de l'occasion pour remercier en particulier le CIMMYT, au travers de sa délégation ici présente, pour les efforts immenses qu'il a déployés pour développer la culture du blé et du triticale.

Je remercie également tous les participants à ce Colloque et leur souhaite les plus grandes joies du coeur et de l'esprit au cours de leur séjour à Antsirabe.

Je déclare ouvert le Colloque international sur le blé et le triticale.

A REVIEW OF THE MAJOR CONSTRAINTS TO WHEAT PRODUCTION IN EASTERN, CENTRAL AND SOUTHERN AFRICA AND THE INDIAN OCEAN

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Abstract

A synthesis and analysis is presented of the major agronomic and pathological constraints in the region. In order to emphasize the common constraints and better highlight common or specific solutions, five wheat-producing subenvironments are characterized, as follows:

I. HIGHLANDS, COOL, WET: Comprising the major wheat areas; constraints are weeds, soil acidity, drainage limitations, stripe rust and Septoria tritici.

II. MID ALTITUDE, IRRIGATED, COOL, DRY (WINTER SEASON): Second largest subenvironment; constraints are high cost of production, stem and leaf rust.

III. MID ALTITUDE, WARM, HUMID (RAINY SEASON): "Tropical wheat" environment; constraints are acid, infertile soils, foliar blights and stem rust.

IV. LOW ALTITUDE, VERY HOT, DRY (IRRIGATED): "Tropical wheat" environment; potential for increasing cropping intensity; constraints are high temperatures and land management practices, while diseases are virtually absent.

V. LOW ALTITUDE, VERY HOT, HUMID: Tropical environment; short season crop cycle; constraints are unfamiliarity with wheat production and probable foliar blights.

The similarity of constraints between countries in the same subenvironment is discussed, and sharing of experiences amongst wheat scientists in the region is promoted.

Introduction

In the four regional wheat workshops held during the last seven years, more than one hundred papers have been presented by agricultural scientists from twenty countries. The total attendance has been more than two hundred and fifty cereal workers. Today, the fifth regional wheat workshop has begun. Given this high level of commitment to improving the production of wheat in East, Central and Southern Africa, my colleague and I felt that it might prove valuable to synthesize our experience and observations in this review of production constraints in the region.

We should emphasize from the outset, however, that generalization is extremely difficult as wheat is found in several agro-ecological zones and under virtually every conceivable system of production in some part of the region. Wheat is grown under rainfed conditions (in areas receiving unimodal or bimodal distribution of precipitation), on residual moisture in river basins or seepage depressions, and under irrigation (flood and sprinkler). Some countries, such as Ethiopia, have a cultural association with wheat extending back through their recorded history, while for others wheat was a crop introduced by the Arab traders, the missionaries or the colonialists. Wheat seed is sown and covered by hand, by ox plough or by grain drill and harvested by sickle or by combine harvester. Wheat is grown on state farms or on private plots managed by large or small-scale operators. Wheat fields are mixtures of biotypes or monocultures. Weeds are left intact, manually removed or chemically controlled.

Notwithstanding this amazing degree of diversity, allow us to present two hopefully indisputable generalizations:

1) Despite the fact that most countries in the region produce some wheat (Table 1), none are self-sufficient. In fact, due to high rates of population growth and urbanization, the shrinking unit landholding and policy constraints, wheat importation in the region has grown at a faster rate than domestic production in the past decade. Additional constraints to wheat output have been imposed by nature: in 1984, wheat yields in many regions were halved due to severe drought, and even under irrigated production systems, such as in Zimbabwe, wheat acreages were drastically reduced because of shrinking reservoir and ground water levels.

2) FAO agro-climatic suitability assessments of Africa classify 38 million ha, mostly in the East African highlands, as suitable for wheat production. Since approximately 1 million hectares of wheat are currently grown in the region, there is some potential for increasing wheat production in "traditional" wheat growing agro-climatic zones; however, in these high potential areas many other food staples compete with wheat for land (e.g. barley, teff, sorghum, grain legumes, oil crops, potatoes, banana, plantain, cassava, etc.).

In order to emphasize common production constraints, we chose to characterize several wheat producing subenvironments in the region on the basis of agro-ecological similarities. Specifically, five principal groupings have been used (Table 2) and within each, the principal agronomic constraints and wheat pathogens shall be summarized.

Cool, Wet Highlands

The bulk of the wheat crop produced in Africa comes from rainfed production systems in the East African highland areas at altitudes above 1500 masl (i.e., Ethiopia, Kenya, Tanzania). In the East African highlands, yields of up to 3.5 t/ha have been realized, especially at the higher altitudes ranging up to

3000 masl; in this ecosystem, fluctuations in annual rainfall can result in a drought stressed crop in dry seasons, whereas, in years with higher than average rainfall, problem diseases such as stripe rust (*Puccinia striiformis*) leaf and glume blotch (*Septoria tritici* and *S. nodorum*) and spot blotch (*Helminthosporium sativum*) are exacerbated.

Ethiopia

Agronomy--According to recent reports, wheat occupies about 700,000 ha in Ethiopia with durum wheat covering about two thirds of this area and bread wheat one third. Durum wheat, indigenous to Ethiopia, is produced primarily by the peasant farmers; bread wheat is a more recently introduced crop, and the state farms produce about 80,000 ha.

Average wheat yields are reported to be 1.2 t/ha. A major reason for these low yields is the low genetic potential of the local durums grown by many farmers. The traditional durums are tall (125-150 cm) and weak-strawed; they are also vulnerable to diseases and respond poorly to fertilizer.

Agronomic practices impose additional constraints on yield. Under small farmer management, the traditional wooden ox ploughs give poor penetration of the soil and form poor seed beds; plant stands are poor and the date of sowing is often delayed due to poor drainage. The use of fertilizer, herbicides and insecticides is minimal except on state farms. Weed control by handweeding is variable as farmers in many areas experience labour bottlenecks at the optimum time for weeding. Harvesting is done by sickle and threshing by animal trampling. All these practices contribute to low production from varieties with low potential.

A series of crop loss assessment trials are being conducted at the major research stations in Ethiopia with the objective of quantifying crop losses associated with the major constraints in each region (i.e., such as varietal, fertility, seed maggot, foliar disease, drainage and weed competition problems) and to study interactions amongst these factors. This type of multi-factor trial has not been conducted previously.

Other agronomic trials being conducted include: herbicide trials, double cropping trials, reduced tillage trials, and bread wheat varietal performance and fertilizer response in farmer-managed trials.

Pathology--The farmers mainly cultivate land varieties, made up of various biotypes. In the bread wheat crop the major diseases are stripe, stem and leaf rust, depending on the altitude. Stripe rust seems on the increase and broad virulence appears to be present. Kenyan materials have successfully been used as rust resistance sources. *Septoria tritici* can be of local importance. For the durum wheat crop, the major constraint is stem rust. Ethiopia represents one of the most virulent locations in the world for this pathogen.

Race identification work is being carried out and the national wheat program is about to embark on an ambitious integrated disease resistance crop improvement program.

At present, although recorded, *Helminthosporium* spp., bunts and bacterial diseases are of lesser priority.

Kenya

Agronomy--With average yield levels in the order of 2.5 t/ha, much of the emphasis has been on maintenance research for stable, disease resistant varieties. However, the changing structure of the wheat industry, with small farmers increasing in number, demands restructuring of the wheat research programme, particularly in agronomy. Currently, technology is not available to advise small farmers how to sow, control weeds and harvest without the use of large-scale (and foreign exchange expensive) machinery. At present, small wheat growers are serviced by contract machinery provided by large-scale growers who account for more than 90% of total wheat production. With the reduction of large scale commercial wheat growing, these contract services cannot be guaranteed over the longer term. Pilot work on ox and hand management for wheat has been minimal.

As the large wheat farms in traditional high potential areas have been dismantled, some large farmers have moved into lower altitude, marginal areas with less reliable rainfall. Wheat production there will require a high level of management using adapted varieties and new technologies to achieve sustainable economic yields under marginal conditions.

In the traditional high potential areas, the major problems are weeds (i.e., especially where farmers have adopted minimum tillage practices), poor soil and moisture conservation practices and high costs of production (i.e., costs of herbicides and fungicides, in particular).

Pathology--Many different varieties were previously under cultivation, each on a limited scale. Thus, vulnerability to stem and stripe rust was reduced. Resistance breeding for stem rust has been very successful and for leaf rust reasonably so. Recently, however, stripe rust has become the major threat to wheat production. This has resulted in a shift of research emphasis. The multi-location testing approach, so successfully exploited by the Kenyan scientists earlier, remains a pivotal component of the present day resistance screening and breeding program. Stripe rust occurs mainly at the higher altitudes (2400-3000 m).

The Njoro station has played a significant role in the past in developing resistant germplasm, largely because the breeding strategies were founded on thorough rust race and virulence identification analyses. The emanating germplasm has been the basis for many varieties throughout the region.

Helminthosporium spp., *Septoria tritici*, *Gaeumannomyces graminis* (take-all) and Barley Yellow Dwarf Virus have been identified, but do not yet appear to warrant great concern.

Tanzania

Agronomy--In Tanzania, approximately 40,000 ha of wheat are grown under rainfed conditions. Of this, 28,000 ha are grown in the northern highlands which are characterized by marginal and erratic rainfall (i.e., long-term average of 600 mm p.a.) at an elevation range of 1300-2000 masl. The farms on the highlands have long and undulating slopes which are suitable for large scale mechanized wheat production.

The remainder of the wheat crop is grown in the southern highlands where rainfall exceeds 1000 mm per season. Because of the extremely steep slopes in much of this area, the majority of the wheat is produced by small farmers using hand implements.

Wheat yields on the state farms have risen to 1.7 t/ha. Given the mechanized, monocrop characteristics of wheat production in northern Tanzania, agronomic research is essential to maintain yields at their currently profitable levels. Suitable management practices must be developed to address the worsening grass weed situation (especially *Setaria verticillata*) and to minimize the serious problem of soil erosion. As much of the wheat is produced without added fertilizer, monitoring of the soil fertility status over time is also of obvious importance.

Pathology--In southern Tanzania, combined resistance to stripe rust, and *Septoria* spp., is an absolute requirement and, to a lesser extent, tolerance to *Helminthosporium* and *Fusarium* spp. The importance of root rots needs assessment.

Well-chosen testing sites give virtual assurance of high levels of natural infection and, thus, ideal screening conditions. Crosses are directed towards combining exotic resistance and yield potential with local desirable agronomic types.

In northern Tanzania, it has been suggested that new strains have arisen in stripe rust enabling it to produce epidemics at much lower altitudes (i.e., at higher temperatures).

The inherent risk of resistance breakdown when large scale monocultures are grown and the associated dramatic effects on yield, necessitate increased integration of a pathology research and screening component into the crop improvement program.

Indeed, stripe rust is increasingly becoming a problem. Recently, the wheat project embarked on a crossing program as the surest way to develop tailor-made varieties for the region.

Tan spot, *Helminthosporium repens-tritici*, occurs frequently in northern Tanzania, and may become a more serious problem under minimum tillage systems.

Root rots and *Helminthosporium* spp. have also been identified, but have not yet seriously threatened yield.

Burundi

Agronomy--The traditional hand labour production methods used for wheat in Burundi involve low levels of management and result in yields ranging from 500 to 800 kg/ha. The principal constraints are acid soils, foliar diseases and rusts and poor response to fertilizer in broadcast seeded crops.

One interesting observation: farmers in the north of Burundi have adopted line sowing of wheat using a wooden, toothed marker, after observing the ISABU staff planting their trials. Although this had not been recommended, the farmers discovered that by adopting line sowing they saved seed and were able to complete their hand weeding in less time. This innovation also has obvious implications for fertilizer P efficiency, especially on acid soils.

On-farm research is being conducted to enable recommendation of better adapted wheat and triticale cultivars. Other trials address the soil fertility and acidity constraints.

Pathology--Mixtures of generally susceptible varieties are commonly used. Fifty years ago, heavy selection was practiced for low levels of stem rust infection, resulting in resistant germplasm.

Presently, the main disease is stripe rust, followed by leaf rust, while *Septoria tritici* deserves continued attention. Stem rust attacks are rare. Of only local and infrequent importance are powdery mildew and *Helminthosporium* spp.

Rwanda

Agronomy--Similar to Burundi, wheat yields in Rwanda are in the order of 800 kg/ha. This compares with over 5 t/ha for wheat on research station plots. The yield gap between the station and the farm is real and offers a significant potential for improved production. However, fertilizer, pesticides and herbicides are not readily available, and improvements will have to be sought using better adapted germplasm, correct seeding dates, higher plant populations and adequate weed control. Low fertility and soil acidity are major problems on the non-volcanic highland soils, and chemical fertilizers are likely to be necessary in the long run.

In the on-farm variety verification trials, where farmer management is utilized, all the new candidates for release looked very poor relative to the local wheat checks (and local naked barley) in terms of stand establishment and vigor. The farmers' practice is to cover the seed (and cultivate at the same time) with the large African hoe ("jembe"), resulting in fairly deep placement of the seed. It appears that the new lines, all developed under the station practice of line sowing with precise seed placement by hand, are less suited to this deeper seed placement than the farmers' traditional, tall germplasm.

An additional research thrust has arisen from this observation of the on-farm trials and farmers' fields: that of testing line sowing. This simple technology which was adopted by farmers in Burundi's high population density zone may offer a practical means of addressing the agronomic problems in Rwanda's wheat crop; the new cultivars will probably benefit from shallower seeding, lower seed rates will be possible, hand weeding will be facilitated, and fertilizer P should be more effective in the seed row (on acid soils, in particular).

Pathology--The major diseases are stripe rust, stem rust, and *Septoria* spp. *Helminthosporium* spp. have been observed.

Uganda

Agronomy--The principal constraints reported are poor land preparation due to lack of equipment and fuel, resulting in poor stand establishment and poor weed control.

Pathology--Although stem rust occurs, and the other rusts and various foliar diseases have been observed, no major wheat disease has been reported at epidemic levels.

Influx of diseases from wheat growing areas in neighboring countries seems a realistic threat. Constant watchful surveillance and preliminary research into possibly needed resistance sources is advised.

Zaire

Agronomy--The problems of the small-scale wheat cultivators in Zaire are similar to those in Burundi and Rwanda: poor land preparation, thin stands, weed competition and poorly adapted varieties.

Pathology--Stripe rust poses the main threat to wheat production, although stem rust has also been observed.

Common constraints

The principal agronomic constraints vary depending upon the scale of production (i.e., mechanized, ox or human power), but, in general, weed control, land preparation, soil acidity, phosphorus nutrition and drainage limitations represent major areas for research in the region.

The major pathogens in this region appear to be stripe rust and *Septoria tritici* and the potential solutions include:

1. disease surveys,
2. multi-location testing,
3. artificial inoculation,
4. race identification and virulence analyses,
5. an integrated pathology/breeding crop improvement program not just on paper but in practice,
6. geographical deployment of varieties,
7. trap nurseries,
8. mutual visits and germplasm exchange between national programs,
9. back-up sources of resistance.

Irrigated, Cool, Dry Mid Altitude (Winter Season)

In Southern Africa, commercial farms south of 10° S and at an altitude of between 1000 and 1500 masl, produce very high yielding irrigated wheat crops, often in excess of 6 t/ha, as the wheat is grown under optimum moisture and temperature conditions.

Zimbabwe

Agronomy--Sprinkler irrigation is the most common production system for wheat in Zimbabwe. As high capital costs are incurred in wheat production, it is essential that high yields are obtained to break even. Thus, agronomic research is aimed at maximizing the efficiency of input usage on high yielding, semi-dwarf cultivars.

Pathology--The most important diseases are stem and leaf rust. Artificial inoculation is practiced for the rusts. Due to the late occurrence of the natural rust inoculum, resistance breeding based on major genes has proven adequate. This may change when neighboring countries start increasing their wheat production, at which time cooperation with these countries should be promoted and disease management concepts reconsidered. Information on the race constitution of the resident rust inoculum is available. Powdery mildew and maize streak virus may require additional research.

Zambia

Agronomy--Similar to Zimbabwe, irrigated wheat production in Zambia is extremely costly and it has been reported that the break even yield is in the order of 5 t/ha.

Pathology--Resistance to stem and leaf rust are important selection criteria and artificial inoculation is practiced. Due to the use of sprinkler irrigation, which favors infection by powdery mildew, resistance to this pathogen is also required. Powdery mildew is "attracted" and spread by the use of spreader rows.

Malawi

Agronomy--Much of Malawi's irrigated wheat is produced on the tobacco estates under sprinkler irrigation. Again, high cost of inputs is the major production constraint, and research is geared towards production efficiency.

Pathology--To the present, no major disease epidemics have been reported, but leaf and stem rust occur to a limited extent.

Madagascar

Agronomy--Irrigated wheat is grown during the cool winter season in Madagascar's mid altitude rice paddies. Adapted cultivars must be early maturing (i.e., to facilitate the crop rotation), and cold tolerant. Research is required to determine optimum irrigation scheduling on the heavy clay soils. Soil management and land preparation are also important areas for research.

Pathology--Stem rust, leaf rust, *Septoria nodorum*, *Helminthosporium* spp., and *Fusarium* spp. occur, but their incidence is relatively low. Monitoring the potential danger of overlapping crop cycles (winter and summer) as regards disease build-up is essential.

Common constraints

As emphasized, the high cost of production is the major constraint in many of the irrigated production systems, necessitating the use of optimum management practices with high yielding cultivars.

Stem and leaf rust are the major present or potential constraints in this environment, and the solutions may include:

1. disease surveys,
2. use of spreader rows,
3. artificial inoculation,
4. regional disease monitoring,
5. major/minor gene considerations,
6. mutual visits and germplasm exchange between national programs,
7. studying the effect of overlapping crop cycles,
8. preliminary studies of diseases of secondary importance

Wheat for More Tropical Environments

As a result of high wheat importation bills and despite questions of comparative advantage, domestic political pressure in much of Africa is applied in favour of increased domestic wheat production. As illustrated by the cases we shall review in the remaining 3 wheat growing subenvironments, this has sometimes resulted in attempts to produce wheat under extremely challenging conditions; in other cases, wheat has filled or could fill an otherwise underutilized niche in the national production system (i.e., irrigated lowland wheat in Ethiopia, Somalia and Malawi).

Warm, Humid, Mid Altitude (Rainy Season)

Zambia

Agronomy--Pathogens causing leaf spots, head blights and seed infections run rampant in this environment. Delayed planting of wheat is one means of reducing disease pressure on the crop, but this mechanism has two major drawbacks: (1) the intense rainfall in the early rainy season stimulates lush weed growth, which if controlled by tillage incurs high costs and renders the soil vulnerable to erosion; and (2) in vast areas of Zambia, high levels of aluminum in the acid soils restrict rooting, contributing to moisture stress in the late-planted wheat crop in seasons characterized by early cessation of the rains.

A major research effort in Zambia has been directed towards developing cultivars with high levels of disease resistance in combination with tolerance to high aluminum levels in the soil. In order to substitute for imports and to avoid the costs associated with sprinkler irrigated wheat, Zambia would require in excess of 50,000 ha of rainfed wheat. In many of the Zambian soils, however, relatively high input costs are incurred, both for fertilizer and lime amendments, resulting in poor economic returns for rainfed wheat. Yields are often low despite the high levels of inputs, frequently falling below 1 t/ha.

Pathology--The most detrimental pathogens are the *Helminthosporium* and *Fusarium* spp., attacking leaves and heads. *Helminthosporium sativum* is the major obstacle to economical production of rainfed wheat, sometimes entirely destroying the crop.

Stem rust is also important and has been known to decimate introductions. Bacterial infections (*Xanthomonas campestris pv. translucens)* are often components of the rainy season disease complex. Very favorable testing sites are used to screen materials for all pathogens, and artificial inoculation is practiced where required.

Malawi

Agronomy--Small farmers in Malawi have adopted one solution to the problems associated with cropping wheat in a warm, humid environment; wheat is planted by some as a relay intercrop after tasseling of the main crop, maize. Thus, the wheat crop avoids the high disease pressure associated with early planting, and, by utilizing residual fertility and moisture, contributes additional income to the peasant farmer. In some seasons, due to the late planting, the lack of residual moisture may limit yields. Acid soils may also limit rooting depth, as in Zambia.

Pathology--Occurrence of disease is usually limited and serious problems are rare, because most wheat is planted under low humidity conditions towards the end of the main rains. The rusts are thus largely avoided.

The varieties grown by small holders are often susceptible to the rusts and *Septoria* spp. Should the area under cultivation increase during the rainy season in an effort to increase production, then diseases seem bound to become major concerns for the crop breeding program.

Madagascar

Agronomy--Yields of the rainfed wheat crop in Madagascar are largely limited by foliar pathogens and the low fertility and high acidity of the highly leached soils. Boron deficiency has also been reported.

Pathology--Although leaf rust is present, recent virulence changes in stem rust have created an overriding concern, and foreign sources of resistance are being sought. Also, *Septoria nodorum* is important. On occasion, *Helminthosporium* spp., *Fusarium* spp., powdery mildew, bunts and smuts may reduce yields. The importance of soilborne pathogens remains largely unevaluated.

Common constraints

Acid, infertile soils characterize many of the rainfed wheat producing areas in the warm and humid subenvironment.

Besides stem rust, which prefers high temperatures, the foliar blights are the major pathogens in this environment.
Potential solutions include:

1. escaping disease infection by manipulating planting date,
2. local crossing and selection,
3. use of testing sites with reliable disease incidence,
4. artificial inoculation,
5. mutual visits and germplasm exchange between national programs.

Very Hot, Dry, Low Altitude (Irrigated)

Ethiopia

Agronomy--There are two potentially serious threats to the future of wheat production in the irrigated area of Ethiopia. First, grass weeds in particular may be extremely problematic (*Echinochloa colona* and *Sorghum verticilliflorum*, especially) and there has been little relevant weed control research. Second, and perhaps the most ominous, is the high rate of salinization of crop land in the lowland cotton growing areas. Adequate drainage systems have not been installed in this area; as a result, water tables and soil salinity levels have risen dramatically and land is frequently abandoned after several years of cropping. Intensified crop production (i.e., two crops per year--wheat and cotton) will surely exacerbate this problem. Should these problems be adequately dealt with then more than 100,000 ha of projected production area become available.

Pathology--The only recorded disease at present is leaf rust. The two immediate concerns of a pathological nature are, firstly, which other diseases may enter and how they will affect production, and secondly, whether this "off-season" wheat crop harbors leaf rust inoculum which could influence disease development on the main season crop. These issues require careful monitoring.

Malawi

Agronomy--The Government of Malawi has conducted research into the feasibility of producing wheat as a winter season crop in rotation with rice on the state-managed land lease schemes near the southern tip of Lake Malawi (e.g., the Shira Valley with an altitude of 450 masl). With minimum temperatures descending only as low as 13°C, temperature is perceived as being the most limiting factor to wheat production. The flood irrigated wheat in the Shira valley has only reached 3 t/ha, experimentally.

Deep tillage of the heavy clay soils in the rice schemes has been deemed necessary to ensure aerobic conditions suitable for wheat growth. As the small land units are tilled primarily by manual labor, this recommendation has imposed an additional constraint to wheat production in this area. No work has been done to date on sowing of wheat into rice stubble using minimum tillage practices.

Unless a solution can be found to the land preparation constraint mentioned previously and higher yielding cultivars can be developed, wheat is unlikely to gain acceptance by the rice farmers who currently obtain higher economic yields with horticultural crops in the winter season.

Pathology--Preliminary irrigated yield trials have not yet been hindered by any disease.

Very Hot, Humid, Low Altitude

Somalia

Agronomy--In the last 2 years, the Agricultural Research Institute (ARI) has initiated limited trials on irrigated wheat in the highly productive Jenale area, South of Mogadishu. While Somalia has a total potentially irrigable land area of 310,000 ha, ARI scientists estimate that 20 to 30,000 ha would be allocated for wheat production. In Jenale, wheat is envisioned to have potential value as a short season crop (i.e., less than 90 days to maturity), growing between the maize (harvested in mid-July) and the sesame crops (planted in late October during the second rainy season). Obviously, more research will be required to determine the optimum economic cropping pattern and practices.

Trial yields have varied considerably, but in one seeding, the cultivar Belbec yielded over 3 t/ha. A subsequent trial of five cultivars in 1986 produced grain yields from 700 to 1550 kg/ha over a maturity range of 71 to 90 days.

Since irrigated wheat research in Somalia is in a fledgling stage, there are many agronomic and economic issues yet to be tackled. The introduction of new heat tolerant germplasm is an important first step. Additionally, more detailed work on irrigation schedules, fertilizer rates, weed control and cropping systems will have to be undertaken to facilitate the development of an optimum production package.

Pathology--*Helminthosporium sativum* has been observed but does not threaten yields yet. That the "non-tropical" wheat cultivars survive let alone produce seed at this location is quite surprising in itself; Jenale has an altitude close to sea level, a latitude of approximately 2° N and a monthly mean minimum temperature that ranges between 16° and 20°C while the monthly maximum ranges between 30° to 34°C. In addition to the temperatures, one would expect that the high relative humidity (70 to 90% year-round) would encourage the growth of foliar pathogens; however, in the 1986 planting, only a trace infection of spot blotch was present on the leaves, and a 10% level of infection of the seeds (i.e., blackpoint) was observed after harvest, probably due to rains during grain filling. One possible explanation for such an unexpected performance of "non-tropical" wheats under tropical conditions is that the high and constant winds coming off the Indian Ocean cool the plants and minimize leaf wetness periods.

Here the major activity required of a pathologist is careful monitoring of the expected increase of certain pathogens, such as the foliar blights and possibly soilborne diseases.

Conclusion

From om the characterization of the region into five subenvironments, it is very apparent that many national programs face similar constraints and could benefit from similar solutions. Specific details and background issues may, however, vary.

We trust that this review has enhanced your awareness of the major constraints to wheat production in the region, and hope that by sharing our experiences in this scientific forum over the next five days progress shall be made towards finding solutions.

Résumé

Une synthèse et une analyse des contraintes agronomiques et pathologiques majeures dans la région sont présentées. Afin de mettre en évidence les contraintes communes et de dégager des solutions communes ou spécifiques, cinq sous-environnements pour la culture du blé ont été caractérisés comme suit:

I. HAUTE ALTITUDE, CLIMAT FRAIS ET PLUVIEUX: ce sous-environnement comporte la majorité des régions à blé; les contraintes sont les adventices, l'acidité du sol, les limitations dues au drainage, la rouille jaune et la septoriose (Septoria tritici).

II. MOYENNE ALTITUDE, CLIMAT FRAIS ET SEC (saison hivernale), CULTURE IRRIGUEE: sous-environnement situé en seconde place pour son étendue; les contraintes sont les coûts élevés de production, les rouilles noires et brunes.

III. MOYENNE ALTITUDE, CLIMAT CHAUD ET HUMIDE (saison pluviale): environnement pour le "blé tropical"; les contraintes sont l'acidité et la faible fertilité des sols, les brûlures foliaires et la rouille noire.

IV. BASSE ALTITUDE, CLIMAT TRES CHAUD ET SEC (culture irriguée): environnement pour le "blé tropical"; possibilité d'intensification de la culture; les contraintes sont les hautes températures, la maîtrise de l'utilisation du sol et de l'eau; les maladies sont, par contre, virtuellement absentes.

V. BASSE ALTITUDE, CLIMAT TRES CHAUD ET HUMIDE: environnement pour le "blé tropical", cycle cultural de courte saison; les contraintes sont l'absence de familiarité avec la production du blé et probablement les brûlures foliaires.

La similarité des contraintes entre pays caracterisés par un même sous-environnement est discutée afin d'encourager la mise en commun des expériences des divers chercheurs de la région.

Table 1. Wheat production and importation in East, Central and Southern Africa, 1981-1986

	Area ('000 ha)	Imports ('000 t)
I. East Africa		
Ethiopia	700	300+
Kenya	110	135
Tanzania	40	49
Rwanda	4	11
Burundi	14	11
Somalia	4	180
Uganda	5	N/A
II. Central & Southern Africa		
Zaire	9	189
Malawi	1	12
Zambia	4	100
Zimbabwe	17-41	40
Mozambique	4	117
Madagascar	1	56
Total	913-937	1,200+

Sources: a) 1985 World Wheat Facts and Trends; b) Proceedings of Regional Wheat Workshop for Eastern, Central and Southern Africa and Indian Ocean. September, 1985; c)Sundry personal communications.

Table 2. Characterization of Wheat Subenvironments in East, Central and Southern Africa

Subenvironment	Location	Latitude (o)	Alt. (masl)	Minimum temperature (oC)[a]	R.H. %	mm of precip. Total	mm of precip. crop cycle
I. Highlands, cool, wet	Adet, Ethiopia	11 N	2400	10-12	--	1100	900
II. Mid altitude, irrigated, cool, dry (winter season)	Harare, Zimbabwe	18 S	1470	7-10	--	868	9
III. Mid altitude, warm, humid (rainy season)	Chilanga, Zambia	16 S	1210	17	85	1110	690
IV. Low altitude, very hot, dry (irrigated)	Melka Werrer, Ethiopia	9 N	740	14	45-65	470	<100
V. Low altitude, very hot, humid	Jenale, Somalia	2 N	50	16-20	75-92	580	<100

[a] Mean minimum temperature during months in which wheat is grown.

DURUM WHEAT BREEDING IN ETHIOPIA

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Abstract

Durum wheat is indigenous to Ethiopia and has an amazing wealth of genetic diversity. It occupies 60-70% of the total area under wheat in the country. The bulk of the durum wheat grown by the farmers are unimproved cultivars. Improved varieties constitute less than 10% of the wheat area.

The objectives of the durum wheat breeding program in the country are examined and the breeding methods discussed. The steps followed in variety testing and release are also reviewed.

Due to the difficulty in selecting a high-yielding, widely adapted variety of durum wheat under Ethiopian conditions, future programs will concentrate on the development of varieties for specific areas or conditions. More emphasis will also be given to the utilization of indigenous germplasm.

Introduction

Durum or macaroni wheat (*Triticum durum*) occupies a significant portion of the total wheat area in Ethiopia. Out of the 700,000 hectares of land presently under cultivation (1), 60-70% is estimated to be under durum wheat while the rest is devoted to bread wheat (*Triticum aestivum*). All of the durum wheat in the country is produced under rainfed conditions by the peasant sector.

Although the primary use of durum wheat is in the manufacture of pasta products (macaroni, spaghetti and noodles), in Ethiopia it is also used in making bread, "Injera" and other indigenous food preparations. Due to its vitreous grain, and amber, large and golden-yellow grain color, durum wheat commands a higher price in the local market than bread wheat.

Durum wheat is indigenous to Ethiopia and has an amazing wealth of genetic diversity. It is traditionally planted on heavy black clay soils (vertisols) of the high land at altitudes between 1800-2700 meters under rainfed conditions. These soils crack badly on drying and quickly become water-logged during the rains. Most of the rain falls between June and September with the peak fall coming in July and August. Durum wheat is generally sown in August when the rains start tapering off. In many areas the planting is extended into September. As a result, plant stands are usually poor and yields are reduced by moisture stresses and cracking soils late in the season. The crop matures in November and December but often times desiccating winds in October cause premature drying of ears.

The durum wheat in Ethiopia is subject to frequent damage by a number of fungal diseases. Of these, leaf rust (*P. recondita*), stem rust (*P. graminis tritici*), and stripe rust (*P. striiformis*) are the most important. Other diseases that cause considerable damage in some areas include leaf blotch (*Septoria tritici*), glume blotch (*S. nodorum*), bunt or stinking smut (*Tilletia fortide* or *T. caries*), *Helminthosporium* spp., root rot (*Fusarium spp.*) powdery mildew (*Erisiphe graminis*) and recently bacterial stripe (*Xanthomonas translucens*). The extent of damage due to the above disease depends on weather conditions (3). However, because the cultivars grown are land race varieties consisting of genotypes which differ in reaction to diseases and pests, some lines may still be resistant or tolerant to certain races of pathogen and still some to other races. Consequently, the wheat diseases rarely reach epidemic proportions due to the mixture of resistant and susceptible genotypes in the population which provide a buffer against rapid disease development and help extend the life of the resistance genes (2).

Among the insects that commonly attack wheat is the wheat aphid (Diurphis noxia) which sucks on the leaves. Occasionally, lady bird beetle larvae (*Chneotriba similis*) feeds on the leaves, leaving only the fiber while stem borer (*Sesamia epunotifera*) kills the plants after heading in scattered spots in wheat fields.

Although, in general, the yield of wheat in Ethiopia has been increased with the wheat improvement work that has been in progress during the last 20 years, the fact remains that the average yield of wheat, specifically durum wheat, is very low (less than 10 q/ha) as compared to that obtained in other durum wheat producing countries. The reasons are many; however, one of the major reasons for the low yield of durum wheat in Ethiopia is the wide use of unimproved local cultivars by the farmers. These cultivars, despite their good adaptability, drought tolerance and good quality characteristics generally have weak straw and lack satisfactory resistance to lodging and prevalent diseases. Traditionally they are adapted to survive unfavorable crop growing conditions and as a result they have low productivity. Although, some high yielding improved varieties of durum wheat have been released and distributed to farmers, the area under improved varieties is less than 10%.

Past and Present Breeding Programs

Durum wheat breeding in Ethiopia dates back to 1949 when work was started at the Paradiso Experiment Station near Asmara, Eritrea Administrative Region. Early attempts were focussed on isolation of superior varieties from introductions and indigenous material. In 1952, four local selections, namely A 10, R 18, P 20 and H 23 were released to farmers in Eritrea (3). However, for various reasons, activities at the Paradiso Experiment Station slowed down later on, during which time other experiment stations were established in the central part of the country.

At present, the National Durum Wheat Program is centered at the Debre Zeit Agricultural Research Centre located in one of the major durum wheat growing areas of the country. Although the Research Center was established in 1953 regular durum wheat breeding activities were not started until the bread wheat program moved to Holetta with the establishment of the Institute of Agricultural Research in 1966.

The main objective of the breeding program has been to search for widely adapted high yielding and disease resistant varieties through selections from indigenous germplasm, introductions and hybridization. Initially, the program partly consisted of mass selection from local cultivars and introductions from abroad through FAO, USDA, ALAD and CIMMYT. As a result of this concerted effort, prior to 1966, two local selections, namely Arendeto (DZ04-118) and Marou (DZ04-688) which were developed from land races by mass selection were released to farmers. From 1967 to 1982, four improved high yielding varieties of durum wheat namely Cocorit 71, Gerardo VZ 466.61/130//G11"s", Ld 357 and Boohai were released for general cultivation. It is worth nothing that except Ld 357 the other three high yielding improved varieties are introductions from CIMMYT. Under very good management conditions in the farmers' fields, these varieties produce yields ranging from 2.5 to 4.0 t/ha as compared to the local cultivars which give 1.5 to 2.5 t/ha under similar conditions (4).

Durum wheat hybridization at Debre Zeit Research Center use initiated in 1974. Here a conventional breeding program is undertaken, using artificial hybridization followed by severe selection for disease associated with yield testing. In general, the pedigree method with individual plant selection is applied in the breeding program. Homozygous lines obtained in the F_4-F_6 generations are subjected to Preliminary, Pre-National and National Yield Trials at Multi-locations in an attempt to select the most promising genotypes for eventual release to farmers. Although two-way crosses were common in the early stages of the program it has, in recent years, been found more useful to back cross the F_1 to one of the parents or topcross with another adapted variety. Since 1974, quite a large number of crosses have been made between locally adapted and high yielding lines, suited for cultivation under rainfed conditions. Some of the material from this program is in the final stage of yield testing.

Introductions make up the bulk of the wheat material used in the breeding program. Every year, quite a large quantity of genotypes are received from CIMMYT, ICARDA and elsewhere in the form of segregating populations, observation, disease and yield nurseries. Since Debre Zeit is a "hot spot" for leaf and stem rusts, the wheat materials are screened under naturally occurring severe rust disease pressure during the dry period using water from a well for irrigation. It has been found that more rust inoculum prevails during the off-season than in the regular rainy season. In addition, the "off-season nursery system" allows the breeding material to be advanced for the second time during the year.

Some screening work is also carried out at Cheffe Donsa, Akaki and Koka sub-stations. The Cheffe Donsa site (2500 m) represents the highland areas of Ethiopia where water logged soil conditions and stripe rust are problems. The Koka site (1600 meters) serves as a testing site for identifying varieties suitable to low rainfall or moisture stress conditions while Akaki (2200 m) represents the vast areas of the Ethiopian highlands where the soils are well drained and the yield of durum is relatively higher.

In all cases the most promising lines are advanced to Preliminary Yield Trials and later to Pre-National and National Yield Trials where they are tested at multilocations through out the major durum wheat growing regions of the country. As soon as the new variety has proved to be superior in performance in the National Yield Trial for at least three years, it will be placed in a Farm Verification Trial in the farmers' fields along with the commercial wheat varieties of the locality in which it is intended to be used. Finally, the information so acquired together with previous test results are submitted to the Variety Release Committee for consideration. After the approval for release, the unrestricted seed multiplication activity will be taken up by the Ethiopian Seed Enterprise.

Future Programs

The objective of the durum wheat breeding program will continue to be the development of new varieties which are superior to the ones grown by the farmers in the various durum wheat growing regions of the country. Emphasis will be laid on identification of stable, high yielding disease resistant varieties. Diseases such as leaf rust, stem, rust, stripe rust, root rot and bunt will receive due attention. Selection for resistance to wheat aphid and leaf beetle will also be considered.

In Ethiopia, durum wheat is cultivated under a wide range of Agro-ecological conditions where the crop requirement and disease development vary to a high degree. Consequently, the cultivars grown by the farmers are area specific and when taken out of their original environment they perform very poorly. Multilocation yield tests of improved varieties of durum wheat in the country over the years also have clearly indicated that under Ethiopian conditions it is difficult to select a high yielding variety with wide adaptation. This means that specific varieties must be developed for specific conditions or areas.

Since Ethiopia is the center of genetic diversity for durum wheat, there is a tremendous genetic variability in the indigenous material. Unfortunately, very little effort has been made to improve or utilize the local germplasm. Therefore, in cooperation with the Plant Genetic Resources Center/Ethiopia, the improvement of the indigenous landraces and their utilization in breeding programs will receive greater emphasis.

The introduction and selection of varieties of durum wheat from CIMMYT, ICARDA and other foreign sources will continue since it provides a possibility to identify genotypes suitable for direct use as commercial varieties by farmers and or as parents in crossing programs.

Hybridization work involving outstanding local germplasm and adapted introduced varieties will be intensified since this has been found to show more promising results. In this regard, the shuttle breeding program which has been recently initiated by CIMMYT and the Ethiopian durum wheat program in an attempt to select superior genotypes which combine the best features of CIMMYT and Ethiopian durums should be strengthened.

Soils in the durum wheat growing regions of the country are deficient in one or more of the major elements. As a result, generally yields are low and continue to be low unless proper management practices are followed by the farmers. Fertilizer studies on these soils have shown the best responses from a combination of nitrogen and phosphorus fertilizer applications. Unfortunately, the use of fertilizer on durum wheat is not traditional in Ethiopia. All of the fertilizers in the country are imported. Besides being expensive they are not available in adequate quantities. Under no fertilizer conditions the local cultivars are generally superior to the high input demanding, improved varieties. Therefore, attempt will be made to develop varieties with high response to small inputs of fertilizers.

The Ethiopian durum wheat program has enjoyed the good relationships it has established with CIMMYT and ICARDA in the areas of interchange of germplasm, training of technical personnel, interchange of publications, exchange of visits and support to attend international conferences. Recently, the National Program received a Toyota Land Cruiser, a large plot thresher and other indispensable items, as donations from CIMMYT. At this opportune time, I would like to express my sincere appreciation to CIMMYT for its keen and genuine interest in strengthening the Ethiopian Program. I hope this cooperation will continue in our efforts to increase wheat production.

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Résumé

Le blé dur est originaire d'Ethiopie et y possède une diversité génétique exceptionnelle. Il occupe 60 à 70% des terres emblavées dans le pays. Les mélanges de blé dur cultivés par les agriculteurs sont constitués de cultivars non ameliorés. Les variétés ameliorées occupent moins de 10% de la surface en blé.

L'historique de la sélection du blé dur en Ethiopie est passée brièvement en revue en mettant l'accent sur les variétés diffusées à ce jour.

Les objectifs du programme de sélection du blé dur dans le pays sont décrits et les méthodes utilisées sont examinées. Les différentes étapes suivies dans les essais et la distribution des variétés sont également passées en revue.

Vu la difficulté d'obtenir une variété à haut rendement adaptée aux différents environnements de l'Ethiopie, les programmes seront axés à l'avenir sur le développement de variétés pour des régions ou conditions spécifiques. Une plus grande attention sera également accordée à l'utilisation de germplasm indigène.

ADAPTATION, PRODUCTION AND USES OF TRITICALE IN SOUTHERN TANZANIA

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Abstract

Work in many parts of the world has confirmed that in cool, wet growing conditions, triticale varieties substantially outyield the best wheat varieties. These growing conditions are typical of much of southern Tanzania. Field trials conducted at Tanwat in 1975-1986 have so far confirmed this.

Utilization of the crop is unlikely to present a major problem to its adoption.

Introduction

Triticale (*X Triticosecale* Wittmack) is grown in the Southern Highlands of Tanzania mainly as a monoculture crop in rotation with maize. A genuine and increasing desire from the population to enhance small scale triticale production is evident in the region. As an initial step towards identifying important agronomic problems of triticale production in Southern Tanzania, the Tanganyika Wattle Company Limited (TANWAT), a subsidiary of the British Commonwealth Development Corporation, has picneered triticale research and production in the region since 1975. Results of agronomic studies into environmental adaptation of triticale at Njombe, in the heart of the Southern Highlands of Tanzania, show that triticale has a wider range of adaptation and performs better than wheat both in extremes of soil conditions and disease regimes.

It is the subject of this paper to combine results of past and present work, and discuss information derived from these. The paper is not intended to give detailed accounts of experimental procedures, but it is hoped that it might be of use to people directly concerned with production of triticale. Therefore, only a broad outline of factors affecting triticale production in this region and major trends which have emerged will be discussed.

Climatic, Soil and Social Environment

The Southern Highlands of Tanzania lie between 5°S and 10°S and between longitudes 31°E and 37°E, and fall within the Eastern African monsoon zone with distinct wet and dry seasons generally considered suitable for production of annual grain crops. Rainfall in the region is unimodal. Average rainfall varies from 1000 mm to 1500 mm with increased reliability at altitudes above 2000 m. Rainfall extends from November to May, with practically no rainfall from June to October.

Much of the Southern Highlands of Tanzania are covered with volcanic ash. Commonly occurring erosion leaves outcrops of ferrugineous sandstone (1). Soils may be divided into those derived from volcanic ash which are generally found on ridges, and those derived from bedrock material which are generally found on valley slopes (2). Chemical characteristics of Njombe soils are listed in Table 1.

Food crops in the region are maize, potatoes, peas and beans. Main sources of cash are tea, coffee and wattle, in addition to selling surplus food crops. Following the recent introduction of high yielding hybrid maize and the development of a hybrid seed maize industry by the Commonwealth Development Corporation, maize has become the most important cash crop (3, 4).

Evaluation of Triticale Varieties

At present, triticale lines are evaluated following similar procedures as for testing bread wheat cultivars. Screening and yield nurseries are obtained directly from CIMMYT Mexico and CIMMYT East Africa. Selected lines from these nurseries are advanced to the triticale screening trial, to be compared against the most established wheat and triticale varieties. Selections made out of these trials, which normally continue for at least three seasons, are subjected to a large scale commercial production test at TANWAT to assess their adaptation under commercial conditions. Likely candidates for release are increased in Foundation Seed production blocks and tested in cooperation with progressive farmers, international aid organizations, Evangelical Missions and other research institutions within the region to gain reactions as to the adaptability in the region.

The main selection criteria in order of priority, have been:

1. High yield potential,
2. Fusarium, Septoria and rust resistance,
3. Plumpness of kernels,
4. Lodging, shattering and pre-harvest sprouting resistance.

Table 2 shows a summary of mean yields of the best triticale varieties compared to the best wheat varieties since 1975. Yields are expressed as percentage of the best wheat check varieties.

Diseases

Among numerous pathogens affecting triticale in Southern Tanzania, fungal diseases are known to infect triticales either at one stage, or throughout the life of the plant. Major triticale diseases that are prevalent in this region are stripe rust, *Pucinia striiformis*, leaf blotches caused by *Septoria* spp. and head blights and seedling foot rots caused by *Fusarium* spp. The extent of septoria and fusarium decreases with later planting (Table 3). Fusarium had not been noted as an important disease of triticale in the region, but it may prove damaging only in seasons with abnormally wet conditions occurring during the establishment stages of the crop. The effect of stripe rust can be devastating and it is the single major constraint to large scale production in Southern Tanzania. Yield of the best triticale lines were reduced to only 47% of wheat in 1985 due to infection at epidemic levels. Relatively high levels of resistance have been recorded with direct introductions from Kenya while Mexican introductions showed very severe infections in 1985.

Time of Planting and Phosphate and Nitrogen Applications

Phosphate deficiency is widespread in Southern Tanzania. At TANWAT consistent economic linear responses to applications of phosphatic fertilizer have been recorded up to 50 kg P/ha. This application level has been adopted with triticale. Further trials have been conducted at TANWAT to examine the effect of time of planting.

Nitrogen application rates were also evaluated because work elsewhere has suggested that triticale is more responsive than bread wheats (8, 9, 10). Results of trials indicated that disease incidence decreased with late planting and thus improved yields. Application of nitrogen resulted in a significant quadratic response over the range of treatments, with optimum application achieved at about 30 kg N/ha (Table 4). However, examination of the crop did not suggest that there was any correlation between the extent of disease incidence and level of nitrogen application.

Due to the variation in days to maturity of different triticale varieties, the optimum planting date of triticale in Southern Tanzania must be considered relative to the moisture requirement of the particular variety. It must also be noted that sterility in triticales may be caused by frost at ear emergence and flowering stages. Since frost may occur in Southern Tanzania any time in June, planting must be done early enough to allow anthesis before this time, especially with late varieties.

Seeding Rate and Method

Results from trials conducted at TANWAT since 1975 with triticale to compare broadcasting and drilling on a plot and field scale indicated no grain yield differences. Although broadcasting seed and fertilizer proved to be a cheaper operation, it required more supervision and preparation. The optimum seeding rate has been recommended at 120 kg/ha.

Weeds

Severe weed infestation is probably the most serious limiting factor to good triticale yield in Southern Tanzania. The species most difficult to control are *Cyperus rotundus* and *Cyperus esculentus* since they are able to propagate from underground tubers and can only be effectively controlled by translocated herbicides which are currently prohibitively expensive. Other grass weeds which are difficult to control are East African couch grass *Digitaria scalarum*, *Eleusine indica* and *Cynodon dactylon*. Broad-leaved weeds can be controlled by cultivations during seed-bed preparation followed by 2,4-D, or MCPA post- emergence. General field observations show that triticales can withstand weed infestation better than wheat.

Future Production Trends

At present, the Tanganyika Wattle Company is the only commercial producer in the country. Production figures stand at about 550 tons annually. This figure is likely to double as area under production is expanding in recognition of the high yield potential of triticale. Local farmers and institutions are also following the expansion trend. It is likely that triticale will become a major crop in this part of Tanzania.

Current and Future Uses

Triticale is one of the main ingredients in feed formulae and it is probably second only to maize. Farmers who have tried to make the staple dish "ugali" from triticale flour have preference to it rather than wheat, claiming that "ugali" made from wheat flour is too elastic and that triticale "ugali" is stiff and palatable. In the absence of rye bread in the country European residents in the region either bake straight triticale bread or in 1:1 mixture with wheat flour. It is likely that this trend will be adapted by natives.

Conclusion

Work in many parts of the world has confirmed that in cool, wet growing conditions, on acid soils, triticale varieties substantially outyield the best wheat varieties. These growing conditions are typical of TANWAT and much of the Southern Highlands of Tanzania. Trials have so far confirmed this. Utilization of the crop is unlikely to present a major problem to its adoption.

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Résumé

Des travaux dans de nombreuses régions du monde ont confirmé que les rendements du triticale produits dans des conditions climatiques fraîches et humides surpassaient de beaucoup ceux des meilleures variétés du blé. Ces condtions sont typiques de la plus grande partie du sud de la Tanzanie. Des essais conduits en champs à Tanwat de 1975 à 1986 ont confirmé ces résultats.

Le type d'utilisation du triticale ne doit pas empêcher son adoption.

Table 1. Chemical characteristics of Njombe soils (after Van Barneveld and Harop)

Horizon Depth (cm)	0-10	10-25
pH water 1:2,5	4.5	4.2
pH KCl 1:2,5	3.7	3.5
EC mmho 1:2,5	0.02	0.02
Organic C %	1.9	1.5
Total N %	0.13	0.09
Available P Bray II ppm	23.4	3.6
CEC NH_4 OAc me/100 g	7.3	8.3
Exch. Ca "	1.5	0.8
Exch. Mg "	1.1	0.4
Exch. K "	0.1	0.2
Exch. Na "	0.1	0.2
Exch. H (KCl) "	0.3	0.3
Exch. Al (KCl)"	1.4	0.6
Base saturation %	39.0	19.0
Effective CEC	29.8	45.7

Table 2. Summary of triticale yields as percentage of best wheat check varieties

Name and Cross	Year of Production												Grain density
	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	kg/hl
Cinnamon, M2A	117												64
Beagle"S", UM"S"/3/BGL//ITA/LEO		163											64
Beagle"S", UM"S"/3/BGL//ITA/LEO			149										65
Beagle"S", UM"S"/3/BGL//ITA/LEO				125									65
Bacum"S", M2A					207								66
Beagle"S", UM"S"/3/BGL//ITA/LEO						88							61
Ram"S" IA/IRA/BUITRE							123						67
Ram"S" IA/IRA/BUITRE								110					67
Delfin 205, M2A/BGL"S"									225				77
Delfin 205, M2A/BGL"S"										137			77
Delfin 75, M2A/BGL"S"											47		67
Delfin 99, M2A/BGL"S"												121	76

Best wheat check varieties with yields (kg/ha) in brackets: 1975 Kenya Leopard (1825); 1976 K4500-2 (2961); 1977 K6290-17 (3348); 1978 196-74 (2523); 1979 Tanzania Trophy (2373); 1980 Tanzania Kororo (2735); 1981 IAS 54 (2743); 1982 CM 36681 (3119); 1983 K4500-2 (1903); 1984 IAS 54 (3424); 1985 CMH 76.480 (2620); 1986 CMH 76.480 (1923).

Table 3. Triticale time of planting x nitrogen trial (variety: Beagle"S")

Planting date	kg N/ha topdressed	Height of crop (cm)	Septoria scores (19/5)	Grain Density (kg/hl)	Yield kg/ha
19 Jan.	0	114	9/5	52	1112
19 Jan.	30	119	9/5	55	1551
19 Jan.	60	119	8/5	54	1578
30 Jan.	0	117	8/5	56	1549
30 Jan.	30	120	8/5	55	1742
30 Jan.	60	121	8/5	56	1866
10 Feb.	0	116	8/tr	59	1765
10 Feb.	30	119	7/0	59	2368
10 Feb.	60	119	7/0	58	2137
21 Feb.	0	117	7/0	58	1920
21 Feb.	30	119	6/0	59	2393
21 Feb.	60	119	6/0	57	2406
		Mean yield			1866
		SE Mean			+120
		Coefficient of Variation			9.9%

Table 4. Yield summary of triticale time of planting x nitrogen trial. Yields in kgs/ha

	N0 No nitrogen	N1 30 Kg N/ha	N2 60 Kg N/ha	Mean
T1 19 Jan.	1112	1551	1578	1414
T2 30 Jan.	1549	1742	1866	1719
T3 10 Feb.	1765	2368	2137	2090
T4 21 Feb.	1920	2393	2406	2240
Mean	1586	2013	1997	1866

PROGRESS ON SCREENING AND EVALUATION OF WHEAT, BARLEY AND TRITICALE VARIETIES IN THE SOUTHWESTERN HIGHLANDS OF UGANDA

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Abstract

In the southwestern highlands of Uganda, wheat has of recent become an important cash and food crop. However, its production has been largely hampered by lack of high-yielding varieties that are resistant to foliar diseases, and possess general agronomical adaptability.

Introduction of germplasm from CIMMYT, especially ACWYT, SNACWYT and IDTN nurseries has been made to evaluate for resistance to diseases (rusts), yield, earliness and overall agronomic desirability.

Selections have been made and, over a short period of time, promising lines have been identified.

From the 7th ACWYT nursery (1983), four lines were screened and two of these are undergoing further multiplication and will soon be released to farmers as commercial varieties.

On-farm research is to be undertaken and multilocation regional trials are being conducted.

Triticale and barley elite lines have been screened, but the former is not yet utilized in peoples' food systems and the farmer has a marketing constraint.

Introduction

Wheat in Uganda is gaining popularity as a food crop for especially the urban population where it is consumed mainly as bread. Elsewhere in the country, it is consumed as porridge, cakes and local bread.

The South Western Highlands of Uganda generally at an altitude of 5000 to 8000 fasl represent the region with the highest potential for wheat cultivation.

Soil types are fertile and rich in organic matter and suitable for cereal production. The rainfall pattern is bimodal with two rainfall seasons, the first extending from February to May and the second from September to December with dry seasons in between when farmers harvest.

Average annual rainfall is 800-1500 mm being higher and more reliable at altitudes above 6000 fasl. About 4000 to 5000 ha of wheat is grown in

Uganda with an annual production of 10,000 to 20,000 tons, all of it under rainfed conditions.

Constraints to Wheat Production

There are a wide range of constraints that limit wheat production in Uganda, ranging from social, economic and environmental to scientific.

Improved varieties--Most of the wheat grown in the country is of local varieties. Release of new improved varieties has slowed down much due to inadequate research facilities.

Diseases--Leaf rust (*Puccinia recondita*), stripe rust (*Puccinia striiformis*), and blotch diseases (*Helminthosporium* spp.) are the major wheat diseases in the highland areas of Western Uganda. In a disease season, as much as a 50-70% yield reduction can be experienced with the small-scale farmer due to diseases.

Pests--Pests are not of serious concern. However birds, rodents, aphids, primates (monkeys) and domestic animals feed on the wheat at one stage or another during growth. Mechanisms for their control have been developed by small scale farmers.

Cultivation--Small-scale farmers still cultivate wheat using the hand hoe, throughout the S.W. Highlands. Ploughing is done first followed by seed broadcasting and the field harrowed by the hoe to make the seed bed. Low seed rates, harrowing the seeds too deep or seeds remaining on the surface lead to poor yields for most small scale farmers.

Soil fertility--There is a general decline in soil fertility in S.W. Uganda due to intensive cultivation and poor soil conservation that has led to soil erosion. This leads to poor crops stands and consequently low yields.

Water--Sometimes when droughts set in early water stress leads to low yields.

Weeds--Weeds may reduce yields.

Harvesting and post harvest handling and storage--This is done by hand throughout the region. Shattering and sprouting may lead to losses in yield. Threshing is done by hand and there is a lot of loss in this operation.

Materials and Methods

From 1977 through 1985, 253 varieties (lines) of wheat, 12 barley, 20 oats, 94 triticale and 2 durum wheat were received from International Maize and Wheat Improvement Center (CIMMYT, Nairobi/Kenya). They were planted out at the Kalengyere Highland Crops Research Center (KHCRC) in the first and second rainy season and certain lines were selected for further study (Table 1).

Planting was done in observation plots 2.5mm long by 1.8 wide in 6 rows. Data were taken on yield (4 center rows: $3m^2$), disease, height (cm) and days to heading and maturity, lodging (%) and pest damage.

The variety testing flow chart presented in Table 2, summarizes the procedures used in selecting outstanding lines.

Results

Seven selections of bread wheat, three of barley, one of triticale and one of oats have been released from KHCRC (Tables 3 and 4). Further evaluations is to be made at other locations in the South Western highlands of Uganda and bulking the seed for distribution to farmers.

Barley--Barley (*Hordeum vulgare*) is of great importance for the national breweries industries. To date, all the barley for malting is imported. Efforts to initiate a barley production programme has already started.

Three varieties have been screened from the 6th SNACWYT and one of them, entry No.2 (Tables 4 and 5) from the 6th SNACWYT, is undergoing multiplication at KHCRC.

Acceptance of barley by farmers into their cropping system is still questionable as farmers prefer crops with the potential for domestic consumption besides cash income.

Triticale--Triticale is not yet included in the average diet of Uganda's population, and hence farmers have not yet shown interest in it as a crop. However families neighboring Kalengyere H.C.R.C. have found it to produce sweet porridge.

Its importance in blending with wheat or other cereals has not yet been exploited by bread making companies. One variety have been selected for its high yield and resistance to diseases from the 7th SNACWYT (Table 1).

Future Research Efforts

Wheat, barley, and triticale by virtue of their great potential as food and cash crops are receiving great attention from the government. The major research efforts will be to improve their performance as much as possible. Research efforts are as outlined below:

1. Introduction, and selection of high yielding varieties.

2. Screening for resistance to foliar diseases especially rusts and leaf blotches.

3. Screening for eariiness. This will help in fitting them into rotational systems and encouraging production in regions with short or unreliable rainfall regimes.

4. Other agronomic characteristics like lodging fertilizer response, quality, seed rate, tolerance to weeds, etc.

5. Vigorous seed multiplication programme.

6. Post harvest handling and storage.

7. Pest management.

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Résumé

Dans les régions de haute altitude du sud-ouest de l'Ouganda le blé est depuis peu une importante culture vivrier et de rapport. Cependant, sa production a été largement limitée par l'absence de variétés hautement productives, résistantes aux maladies et douées d'une bonne adaptabilité aux diverses conditions de culture.

L'introduction de germplasm du CIMMYT, spécialement dans le cadre des ACWYT, SNACWYT et IDTN, a été effectuée afin d'en évaluer la résistance aux maladies (rouilles), la productivité, la précocité et l'acceptabilité agronomique en général.

Des sélections ont été effectuées et, en court un laps de temps, des lignées prometteuses ont été identifiées.

Quatre lignées ont été retenues dans le 7th ACWYT 83. Deux d'entre elles font l'objet d'une multiplication et seront dans peu de temps diffusées aupres de paysans en tant que variétés commerciales.

Des essais régionaux multilocaux sont conduits et l'expérimentation en milieu rural sera réalisée.

Des lignées élites de triticale et d'orge ont été sélectionnées, mais l'agriculteur ne les utilise pas encore dans l'alimentation traditionnelle et l'absence de marche constitue une contrainte.

Table 1. Introductions (1977-1985)

ACWYT[a]:

Year	No. of entries	Entry(s) selected
1977	16 (1st ACWYT)	Fury X CNO"S" - No. 66
1978	16 (2nd ")	Kenya Fahari
1982	16 (6th ")	Chova
1983	25 (7th ")	Bb-Gallo X Cj 71/T Aest X Kal - Bb
		Neelkant
		Kenya Paa
		Veery SR-253

SNACWYT[a]:

Year	No. of entries					No. of entries selected				
	Bread Wheat	Barley	Oats	Triti -cale	Durum Wheat	Bread Wheat	Barley	Oats	Triti -cale	Durum Wheat
1983(6th SNACWYT)	120	12	20	80	0	0	3	1	0	0
1984(7th ")	34	0	0	8	2	0	0	0	1	0
1985(8th ")	26	0	0	6	0	Screening continuing				

[a] ACWYT : African Co-operative Wheat Yield Trial
SNACWYT : Screening Nursery for African Co-operative Wheat Yield Trial.

Table 2. Variety testing flow chart

Introduction

ACWYT, SNACWYT (CIMMYT)
LOCAL
OTHERS

↓

Selections at KHCRC (1st Season)

- Observation plots
- Yield
- Days to heading
- Days to maturity
- Diseases eg. rusts
- Bird damage

↓

Screening Trial (KHCRC) (2nd/3rd Season)

- Yield
- Diseases
- General adaptability
- Seed multiplication in breeders plots for superior lines

↓

Foundation Variety Trial (4th Season)

- Seed multiplication
- On-farm research
- Quality testing eg. bread, porridge
- Fertilizer response

↓

Commercial Variety Trial (5th, 6th Season)

- Bulking of seed
- Initial distribution of seed
- To outstanding farmers
- Initial commercial varieties included

Table 3. Selected wheat and triticale lines at Kalengyere (S.W. Uganda) 1977-1985

Selection	Yield t/ha	Average height (cm)	Days to Flowering	Days to maturity	Lodging	Diseases P. rec.	P. strii.	P. gram.	Helm.
Fury X CNO"S"-No.66	1.55	105	75	142	20%	MR	R	MR	MR
Kenya Kigaru	2.10	100	76	138	20%	MR	R	MR	MR
Chova	1.60	100	70	145	10%	R	R	R	--
Bb-Gallo x Cj71/T. Aest X Kal-Bb	1.80	90	77	145	10%	R	R	MR	R
Neelkant	2.25	110	78	140	10%	R	R	R	MR
Kenya Paa	2.50	120	69	149	50%	R	R	R	MR
Veery 5 R-253	2.30	115	75	148	60%	R	R	R	MR
Ptr"S"-Gzl"S" X34819-11M-1Y-1M-0Y(TU)	2.65	145	70	155	30%	R	R	R	MR

Table 4. Selected Barley Lines from 6th SNACWYT

Entry No.	Kalengyere Code No.	Variety on cross & Pedigree	Remarks
2	KH-2	Jha 33/M66 85 CMB74A-721-73-95-3AP-2AP-2ke	six row
9	KH-3	CR115/Por116-M-103C/3/Avt/Aths ICB77-55-4AP-0AP-3ke	two row
4	KH-4	Avt/11012.2//Gaines CMB76A-363-2AP-0AP-2ke	six row

Table 5. Agronomic and disease notes from selected barley lines

Kalengyere Code No.	Yield (t/ha)	Average height (cm)	Days to Flowering	Days to maturity	Lodging	Diseases P. rec.	P. strii.	P. gram.	Helm.	Remarks
KH-2	2.20	95	60	120	15%	R	R	MR	MR	six row early
KH-3	[illegible]	120	75	155	30%	R	R	R	MR	two row late
KH-4	[illegible]	90	60	[illegible]	0%	R	R	R	R	six row medium

BREEDING WHEAT AND TRITICALE FOR STEM RUST RESISTANCE AND ADAPTATION TO ACID SOILS

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Abstract

In the highlands of Madagascar, wheat and triticale production requires aluminum-tolerant varieties and high levels of stem rust resistance. After the outbreak of stem rust in 1986, caused by a physiologic race identified as QTC, all collections and introductions have been evaluated at the Mimosa station under high disease pressure through artificial inoculation. Many varieties/lines proved resistant to the local race of Puccinia graminis f.sp. tritici; among the nurseries, it was the SNACWYTs which have been already evaluated in East Africa for stem rust that show the highest number of resistant lines both in wheat and triticale. A selection technique was developed to detect in one season lines possibly combining aluminum tolerance and stem rust resistance. It was found with this technique that the nursery "Elite Aluminum" from CIMMYT (Mexico) contains the highest number of lines combining aluminum tolerance and stem rust resistance. A local trap disease nursery has been assembled with varieties, advanced lines and recently developed varieties. Rust development was studied on recently developed varieties. A map of the soil pH of the area and another one for the 1987 rust survey were drawn.

Introduction

The wheat crop was introduced in the Vakinankaratra area in the beginning of this century but production has always been hampered by rust outbreaks. In 1912 a production of 500 t was achieved, but this did not increase further due to stem rust attacks (12).

Research on wheat was conducted by IRAM until 1970 and the FIFAMANOR project took over the activities from 1972 onwards. Stem rust pressure was very high between 1970 and 1975 but then became very low between 1975 and 1985; during this period only the old susceptible varieties (e.g., Florence Aurore, Ariana) were attacked but recommended varieties were clean of stem rust. During the rainy season of 1986 all the released varieties became susceptible: e.g., BW 19, CNT 7, IBWSN 108. The triticale Puppy/Beagle remained resistant but the substituted triticale Tcl Bulk 50 MA showed a low level of susceptibility in 1986 and completely lost its resistance in 1987.

In experiments conducted at FIFAMANOR, triticale always outyielded wheat, especially on acid soils (6, 7). For this reason the triticale acreage expanded rapidly although it was introduced to the farmers after wheat

(1982). To ensure an equilibrium between wheat and triticale development two solutions were adopted:

1. Wheat was mainly introduced in the best soils and triticale in medium fertility soils.

2. The buying price of triticale was set lower than that of wheat (roughly 80%). Furthermore triticale was mainly directed to rainfed areas and wheat to the paddy fields after rice under irrigation.

Wheat Growing Environment in the Vakinankaratra Area

Two growing seasons are used: 1) the rainfed crop from January/February to May/June on the hillsides and 2) the irrigated crop on the paddy fields from May/June to October/November. Whereas the rainfed crop is limited to volcanic soils, the potential for the paddy field crop which is grown during the cool season is much higher.

Wheat and triticale are grown at altitudes ranging from 1400 to 2000 m.

Rainfall and temperatures--The prevailing climate is of a tropical type effected by altitude and a rainfall of 1300 mm per annum distributed from October to April with a peak in January/February (Table 1). The dry season goes from May to September with a high frequency of frost in July. Nevertheless temperatures were as low as -5°C in October 1985 (3) and -8°C for 4 days in September 1986 (4) but these are assumed to be exceptional as they did not appear in previous records. Hail may damage the paddy field crop in October in the high altitude plains (9).

Soils--Two main groups of soils are found.

1. The oxisols derived from granite and genesis with a low pH and a low phosphorus content,

2. The volcanic soils with a higher fertility and pH.

The pH of the soils in the area appear in Figure 1. These pH values were analyzed at FIFAMANOR for the sites of the multilocation trials from 1984 to 1986, before planting. Many soils, i.e. 45%, have pH values between 4.6 and 5.0 (Figure 2). Only some soils from the volcanic regions (Betafo area and the vicinity of Antsirabe) have pH values higher than 5.5 which is the lowest limit where liming is not generally recommended. From previous trials a significant correlation was found between yield and soil pH. This is in accordance with the relation between these two factors in Figure 3. The best correlation with yield was obtained with the pH (H_2O) (6), which is also the case in Figure 3.

It has been found in many trials that triticale gives higher yields than wheat (6, 7) and the lower the pH the higher the difference between the yields of the two crops (6). In Figure 4 the mean yield of the sites of the multilocation trials from 1984 to 1986 are presented. In these trials triticale Puppy/Beagle was always included with 4-5 wheat varieties. It appears that the mean yield of the sites is between **1500** and 2500 kg/ha whereas that of Puppy/Beagle is around 3500 kg/ha (Figure 4).

Stem Rust

Background--At the early stage of the project (1970-1975), stem rust was a big concern. Infected samples were sent to Elvas in Portugal for physiologic race identification. The race identified at that time was 34 (1). This race occurs also in Mozambique, besides race 222 (1).

In 1986 and 1987, infected samples were collected in the area and sent for identification to the Cereal Rust Laboratory, University of Minnesota, St. Paul. The first result from 1986 samples was race QTC. According to E. Torres, race 34 has virulence for the genes *Sr5, 6, 7b, 8, 9a, 9b, 10* and *11*. QTC is very similar to race 34 but it lacks virulence for *Sr7b*. The appropriate evaluation of the presence or the absence of *Sr7b* depends on the environment, therefore the difference between the old race 34 and QTC is less important (Torres, pers. comm.).

Evaluation of available materials and introductions--During the rainy season 1987, all the germplasm collections stored at below zero temperatures at Mimosa since 1983 and the introductions were planted for evaluation to stem rust.

Materials and Methods

In 1983 all the materials of wheat, triticale and oats were stored at -17ºC. The seeds were dried to 8% humidity before storage. This collection includes all the nurseries received from CIMMYT Mexico and East Africa after discarding the poorest lines. After the outbreak of stem rust (*Puccinia graminis* f.sp. *tritici*) in 1986, this entire collection was planted for re-evaluation. The introductions of 1986 were included as well. These introductions are special nurseries meant for aluminium tolerance and stem rust resistance. The lines were planted at Mimosa on two rows of 1m with the susceptible variety PAR as infection rows.

All the lines were sprayed with a spore solution collected in the area. Infected haulms were cut and spread between the rows of PAT; furthermore, one plant out of three was needled at booting stage on the variety PAT.

Two special nurseries were received from CIMMYT on our request; the RRM (Rust Resistant Materials) and the ALDRM (Aluminium and Disease Resistant Materials). The seeds were divided in two parts: 1) the first part was planted at Mimosa in the same plot as the collection for stem rust resistance evaluation 2) the second part was planted on virgin oxisol (pH 4.4) without liming to test the tolerance to acid soils. By analyzing the results from these two sites, it is possible to detect the lines combining stem rust resistance and tolerance to aluminium toxicity. These two nurseries were also artificially inoculated in the same way as the collection.

A group of 26 wheat, 10 triticale and 3 oat varieties was assembled in 1987 based on their reaction to stem rust in 1986 to form the Trap Disease Nursery. This trap disease nursery was composed of:

Group A: Varieties of known susceptibility (Romany, Ariana, etc.),

Group B: Commercial varieties which had been abandoned (PAT, IBWSN 108.3, CNT 7),

Group C: Varieties/advanced lines recently developed and under multiplication,

Group D: International differentials,

Group E: Foreign varieties.

The groups A and E were not yet included in 1987 but will be included in 1988.

The trap disease nursery was inoculated in the same way as the collection but to increase the pressure, each plant was needled at the booting stage. Six notes were taken on stem rust during the season. The trap disease nursery was planted at two sites e.g., at Mimosa and at Betafo (40 km from Mimosa). No artificial inoculation was done at the latter site. At the Mimosa station the infected rows (PAT) and the susceptible varieties were cut and burnt when they reached the rating 100S to avoid creating an important focus of rust which may threaten the commercial crop on the paddy fields. This was after all the notes on the varieties were taken. The modified Cobb scale on rust was converted into numeric values using the coefficient of infection as adopted by CIMMYT (2) to allow the processing of data on the computer.

A rust survey was done on farmers' fields during the rainy season 1987.

Results

Evaluation of wheat nurseries to stem rust--The artificial inoculation along with the natural rust attack created a high pressure of rust on the check PAT and the susceptible varieties.

The varieties/advanced lines included in the different nurseries were classified in five groups according to their percentage of infection to stem rust:

1. CI = 0.0
2. CI = 0.1-1
3. CI = 1.1-10
4. CI = 10.1-50
5. CI > 50

The distribution of the varieties/advanced lines in each nursery according to the above classes appears in Figure 5:

The IBWSN 13, IBWSN 14, ISWYN 17, CB 79, CB SPRING are nurseries from Mexico. As a whole, they present a low percentage of resistant to moderately resistant lines e.g. less than 10% (Figures 5a, 5c, 5d, 5e, 5i).

The SNACWYT and ACWYT (Figures 5b, 5h, 5k) include varieties/advanced lines assembled CIMMYT in East Africa; they have undergone selections in other countries (Kenya, Zambia, Tanzania etc.). It was noticed that they include a high proportion of resistant to moderately resistant varieties. This is in accordance with the statement by E. Torres that the varieties from the above countries have been selected under high disease pressure (pers. comm.).

The F_2 Al+++ MASA 79 and F_2 Al+++ MASA 80 are F_2 populations introduced from Mexico and selected at FIFAMANOR. These advanced lines which have good adaptation to acid soils and contain a reasonable proportion of resistant to moderately resistant varieties in spite of the low pressure of stem rust during their selection at FIFAMANOR, e.g., between 1980 and 1985.

The RRM, ELITE Al, and Al+++ DRM are special nurseries for stem rust (RRM), for tolerance to acid soils (ELITE Al) and for resistance to diseases and tolerance to acid soils (Al+++ DRM). They were received from Mexico and represent the most recently developed lines in CIMMYT within this group. The RRM includes a high proportion of resistant varieties but most of them did not grow on acid soils. The group ELITE Al is the most promising both in resistance to stem rust and in tolerance to acid soils.

The varieties included in the group "Miscellaneous" have different origins.

The best varieties/advanced lines from all the above nurseries appear in Table 2. The number of sister lines appearing in each nursery and those appearing in the three lowest classes of infection to stem rust are presented.

VEE, BOW and KVZ are sources of resistance to the present stem rust race.

The crosses which have the highest number of resistant sister lines are as follows:

IAS 58/4/KAL/BB//CJ/3/ALD/5/BOW
PF70354/ALD//BOW
CMT/MO//TRM
KVZ/TRM//PTM/ANA
MURI/AMS//TUZA/3/ALD
PF70100/ALDAN

It is worth noting that most of these crosses are crosses between Mexican and Brazilian lines.

Evaluation of triticale nurseries to stem rust--The results on triticales appear in Figure 6. The most resistant group is "Forage triticale" (Figure 6e) but these are varieties with low breadmaking quality, therefore their usefulness might be as sources of resistance in further crossings. Apart from the forage triticales, again the SNACWYT's (Figures 6a and 6b) contain the highest proportion of resistant lines. The ITSN 11 and 12 and the Y 84-85 (more recent) are less resistant compared to the SNACWYT's.

MERINO, RAM, STIER, BGL, PANTHER are highly resistant to the present race of rust. Nevertheless it is not yet determined if it is a biotype specialized to triticale or the same race as that on wheat. In the fields it was noticed that substituted triticales as a whole were more susceptible than the complete ones.

Sixteen varieties of wheat and seven of triticale were multiplied based on their resistance to stem rust in 1986 and 1987, previous yield data and other criteria (Table 3). This choice takes into account also the variation of the genetic base of the materials put under multiplication. This is very important because the varieties released in the past had a narrow germplasm base (Table 4). Some of these varieties may discarded during further multiplications.

There will be enough seed for contract growers by the end of 1987 of the wheat varieties Daniel 87, Bozy 87, FIFA 74 and the triticale varieties Merino Bulk 87 and PBR 87.

Selection of lines combining stem rust resistance and tolerance to aluminium toxicity--This selection method has been used for two nurseries recently received, e.g. Elite Aluminium and Diseases resistant materials. At planting time the seeds were divided in two parts: 1) the first part was planted at Mimosa under high pressure of stem rust and 2) the second part was planted on virgin oxisol at pH 4.4 without liming.

During data processing, the lines were sorted on the computer using three sorting keys:

1) The yield at Mimosa (good fertility soil)
2) The stand on virgin low pH soil (0 = no plant, 1 = at least one plant has grown)
3) The percentage of infection to stem rust at Mimosa after transformation of the modified Cobb scale data into numeric values.

All the varieties which did not grow on virgin oxisol were discarded. The lines kept for further selections appear in Tables 5 and 6. They may already be considered as combiners of stem rust resistance and aluminum tolerance. It was the Elite Aluminium Nursery which gave the highest number of combiners (16) whereas the Al+++ and Disease Resistant Materials was rather poor (6%). These lines which represent the most recent crosses in CIMMYT within this group should be looked at closely. Table 7 lists advanced lines that combine high yield potential with tolerance to soil acidity and resistance to stem rust.

The Trap Disease Nursery--After transformation of the modified Cobb scale data into numeric values, the varieties/advanced lines of wheat, triticale and oats were classified according to their resistance to stem rust in the two sites (Table 8). On average stem rust pressure was lower in Betafo than at Mimosa, despite the fact that temperatures are higher in Betafo; this difference might be due to the absence of artificial inoculation in Betafo. There is a concordance between the ratings of rust in the two sites except for the oat variety n° 24 which was completely free at Mimosa whereas at Betafo it was 70% infected. This race of stem rust on oats at Betafo is a specialized biotype on oats which may not be present at Mimosa.

The development of rust on the varieties with similar reactions (R-TR, MR-MS, MS, MS-S) is presented in Figure 7. There is a big difference between the S type (PAT and IBWSN 108.3) and the other types of reaction; even the difference between MR-MS and MS or MS-S is very significant, therefore varieties with the reactions R, TR, MR should be looked at closely.

The development of stem rust on some of the varieties under multiplication included in the trap is presented in Figure 8. The scores on rust at the end of the cycle were TR, 10MR-MS, 40MS, 5MR-MS, 40MS-S and 100S, respectively for Andry 87, Honore 87, Tif 7255/IMU, Daniel 87, Jules 87, Gaston 87 and PAT. The kernel qualities at harvest were much better compared to that of the check PAT.

If the race does not change, one would expect that the pressure of rust will be lower under natural condition compared to the pressure being used at Mimosa. Indeed, the scores on the same varieties on multiplication plots nearby without needle inoculation were much lower (Table 3).

Rust survey on farmers' fields, rainy season 1987--During the rainy season of 1987 it was decided with the other institutions to provide the farmers with seeds of the triticale Puppy/Beagle only. The triticale Tcl Bulk 50 MA was also multiplied with a few seed growers as was the wheat variety PF70354 with fungicide application (Tilt). Besides these three varieties, some farmers have still used their own seed of PAT and Romany.

Most of the fields were visited twice during the cycle. The last scores on rust in each main area appear in Figure 9; on average one may say that the rust attack of 1987 was low compared to 1986 for two main reasons:

1) The substantial decrease in area planted with susceptible varieties

2) The use of recommended planting date.

One of the reasons for the rapid expansion of stem rust in 1986 was the planting date (11). The farmers were planting at any time of year. Therefore wheat fields were present everywhere all year around. The intermediate hosts of *Puccinia graminis* f.sp. *tritici*: e.g., *Berberis* sp. and *Mahonia* sp are not recorded in the flora of Madagascar, therefore the cycle of the parasite is perpetuated on vegetative wheat and on regrowth. Survey of wheat, triticale and oats regrowth in the area during January/February 1987 indicated that they are present everywhere and heavily rusted (5).

Discussion and Conclusions

Wheat and triticale are already accepted in the farming system in the area. Despite the problems related to prices and marketing (8) production has increased significantly in 1985 and 1986, also due to a slight improvement of the price but mainly because of the action of the nutrition section of FIFAMANOR which teaches the rural women to use wheat and triticale as complementary food (8).

The experiments' results show clearly that most of the soils are acid and need liming. Therefore selection of aluminium tolerant varieties should be done continuously.

The selection for stem rust must be one of the most important priorities because of the eventual changes of races. Also some races may appear and disappear without changing (13) as was the case in North America and in other parts of the world. Consequently, even in the periods of absence of rust, it is necessary to create a high pressure at the station to allow a good selection of the varieties.

A local crossing block has been established for resistance to stem rust, tolerance to acid soils or both. Therefore limited and well selected crosses can be made in the future.

The exchange of materials between the countries of East Africa is highly recommended due to the similarity of conditions and to avoid the duplication of research; this is apparent from the evaluation of different nurseries where the SNACWYT's and ACWYT's contained the best performers. It is recommended that CIMMYT continue to distribute the SNACWYT's.

The selection method to detect combiners of stem rust resistance and aluminium tolerance is promising, especially in regard to the time required to discard many lines. However, the question arises whether a line which did not grow at pH 4.4 but has given good yields on good fertility soils and has shown a high level of resistance should be discarded or should undergo further selections?

All the actual wheat varieties put under multiplication may not have a high level of resistance. Some of them are probably at the limit of tolerance. It is our intention in the future to increase seeds for at least four varieties in order to have seeds available in case one of them looses its resistance.

The trap disease nursery is a first step to characterize the varieties known locally with regard to the prevailing rust races. The identification of all infected samples collected in 1986 and 1987 have not been completely received. The races known to date are 34 and QTC which are very similar.

According to E. Torres, race 34 has many virulent biotypes and the resistance to these biotypes may be associated with genes from *Triticum timopheevi* or the single resistance genes *Sr13* and *Sr17*. Therefore crosses having one or more of these genes should be looked at closely (11).

Besides the identification of races in a specialized laboratory, the addition of the international differentials in 1988 will help in the identification of resistant genes in the varieties.

Glossary of Terms

ACWYT: African Cooperative Wheat Yield Trial
ALDRM: Aluminium and Diseases Resistant Materials
C-B: Crossing-Block
CIMMYT: International Maize & Wheat Improvement Center
IBWSN: International Bread Wheat Screening Nursery
IRAM: Institut de Recherches Agronomiques de Madagascar
ISWYN: International Screening Wheat Yield Nursery
ITSN: International Triticale Screening Nursery
R R M: Rust Resistant Materials
SNACWYT: Screening Nursery for African Cooperative Wheat Yield Trial

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Résumé

La culture du blé et du triticale sur les hauts-plateaux de Madagascar demande des variétés tolérantes à la toxicité aluminique et ayant un niveau de résistance élevé à la rouille noire. Après l'attaque de la rouille noire en 1986 dont la race a été identifiée à QTC, toute la collection et les introductions ont été évaluées à la station Mimosa sous forte pression de maladie induite par inoculation artificielle. Plusieurs variétés/lignées ont été résistantes à la race de Puccinia graminis f.sp. tritici, mais ce sont les SNACWYT qui ont déjà subi des sélections en Afrique de l'Est qui contiennent la plus forte proportion de lignées résistantes, aussi bien pour le blé que le triticale. Une technique de sélection combinant la toxicité aluminique à la résistance a la rouille noire a été utilisée pour détecter en une saison les lignées pouvant associer ces deux caractères. A partir de cette technique, il s'est avéré que c'est le groupe "Elite Aluminium" en provenance du CIMMYT (Mexico) qui contient le plus de lignées combinant la toxicité aluminique à la résistance à la rouille noire. Une "Trap Disease Nursery" locale a été assemblée à partir des variétés et lignées connues et des variétés récemment développées. Le développement de la rouille noire sur les nouvelles variétés développées a été etudié. Une carte des pH des sols de la région et une autre sur les attaques de rouilles de 1987 ont été établies.

Table 1. Average daily minimum, maximum temperatures, rainfall, relative humidity and evapotranspiration, FIFAMANOR, Antsirabe (10 years avg)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Max. Temp °C	28.6	28.5	27.9	26.8	24.9	22.9	21.9	24.1	27.2	28.6	28.4	28.1
Min. Temp °C	11.7	11.5	11.2	8.7	5.6	3.3	3.2	3.8	4.5	7.3	9.6	10.2
Rainfall (mm)	283.8	235.0	189.6	73.9	29.0	7.6	15.7	9.1	26.4	77.0	185.6	217.7
Relative Humidity (%)	82	80	81	78	76	80	76	74	72	69	71	77
Evapotranspiration (mm)	75	75	72	86	75	80	68	70	80	105	100	80

Table 2. Bread wheat varieties/crosses having more than two sister lines with stem rust infection less than 10%

Nursery/variety/crosses	Total number of sister lines	Range of the coefficient of infection to stem rust		
IBWSN 14		0	0.1 - 1	1.1 - 10
1. VEE	30	13	11	6
2. CHAT	9	9	--	--
3. BOBWHITE	18	8	3	7
4. CNT/MO//TRM	12	8	4	--
5. RSK/MO/EMU	6	--	6	--
6. JUP/MUS/4/CNO/7C//CNO/3/TOB	5	--	5	--
7. KVZ/TRM/PTM/ANA	11	--	11	--
8. CNO/8156//TOB/CNO(NO)/3/12300/LR 64	3	--	--	3
9. TANAGER	4	2	--	2
10. K 4500.2/PJY	4	2	2	--
11. HAHN	7	--	--	7
12. SUNBIRD	3	1	--	2
13. TI TOB/ALD	4	--	--	4
14. DOVE	4	--	--	4
15. MN 7213/PVN	3	--	--	3
6th SNACWYT				
16. VEE	4	2	--	2
17. BB/GLLO//CJ 71/3/T. AEST.//KAL/BB	3	2	--	1
	4	--	--	4
ISWYN 17				
18. VEE	4	3	1	--
19. 70 402/ALD/PAT 72 160/ALD				
F2 A1 79				
20. PF 71.131/3/KAL/BB//ALD	3	2	1	--
21. CZHO/RON//ALDAN	3	3	--	--
22. PF 7330/FEW	3	3	--	--
23. CHR MUTANT/WS 1809/4/MN 7083/MN	4	3	1	0
24. KVZ/K 4500 LA4//ALD	3	2	1	--
25. PF 70354/ALDAN	3	--	1	2
26. PF 7339/ALDAN	3	3	--	--
F2 A1 80				
27. BH 1146/ALDAN	5	2	--	5
28. PEL 73380/ATR 71//ALDAN	4	3	--	1
29. PF 71 131/3/TI/PCI//KVZ/TI	5	2	--	3
30. PF 70 100/ALD	8	3	--	5
31. MURI/AMS//TUZA/3/ALD	9	5	--	4
32. PEL 73 380/ATR 71//VEE	5	2	2	1

Table 2. (continued)

Nursery/variety/crosses	Total number of sister lines	Range of the coefficient of infection to stem rust		
F2 A1 80				
33. CNT B/CHAT	5	4	1	--
34. JAC/PSN	4	2	1	1
35. RON/TOB//ALD	4	1	--	3
36. JAC/3/TI/PCI//KVZ/TI	3	--	--	3
37. M,A/WW 15/3/KAL/BB//ALD	3	--	--	3
38. ALD//7C//ALD	3	--	--	3
39. MRNG//7C/ALD	3	--	--	3
40. PF 7339/4/BB/GLL//CNO/7C/3/KVZ/TI	5	5	--	--
41. PF 7339/VEE	4	4	--	--
7th ACWYT				
42. VEE	6	4	2	--
AUTRES				
43. PF 7339/ALDAN	7	6	1	--
9th SNACWYT				
44. VEE	3	3	--	--
C B SPRING				
45. PAT 10/ALD//PAT 72 300/3/PVN	3	1	2	--
EL. A1.				
46. CEP 11/BOBWHITE	3	3	--	--
47. IAS 58/4/KAL/BB//CJ/3/ALD/5/BOW	33	17	11	5
48. PF 70 354/ALD//BOW	3	3	--	--
49. IAS 58/4/KAL/BB//CJ/3/ALD/5/CHR	4	--	--	4
50. PHQ/IMP/3/PF.72 640/PF 7326/PF 7065/	4	--	--	4
51. LD 6/KVZ//LD 6/AGE/3/LD 6/KVZ//...	4	--	--	4
52. PF 70 354/MUS//GEN	3	--	--	3
53. THB/KEA	3	--	--	3
54. PF 74 354//LD/ALD	3	--	--	3
R R M				
55. AGA/3/YR 70//ERA	3	3	--	--
56. ERA/SON 64//5 ERA	4	--	4	--
A1 DRM				
57. M_2A/CML//CMH 78 390	3	3	--	--
58. M_2A/CML/3/H 569.71/P.AR//3 TRA	3	3	--	--
59. M_2A/CML//NYUBAY/3/CMH 72A 576/MRNG	3	3	--	--
60. CMH 72A.576/3 NAC 76	4	--	1	3

Table 3. Varieties of bread wheat and triticale in multiplication 1987

No.	Variety Name	Pedigree	Origin 1987	Stem rust	Maturity	Yield Level	Hoight
	Bread Wheat						
1	Andry 87	PF7339/Aldan (1)	7	t R	P+MT	B= Good	110
2	Bozy 87	CZHO/RON//Aldan	28	10 MR-MS	Medium	B	105
3	Corinne 87	PF7339/VEE	23	0	M	TB= Veery Good	110
4	Daniel 87	PF70.354/VEE 2221	6	20 MR-MS	P = Early	TB	120
5	Egil 87	PF70.354/3/KAL/BB// ALD (1)	18	30 MR-MS	MT= Medium late	TB	125
6	FIFA 74	PC 292/764	14	t R	MP= Medium Early	B	105
7	Gaston 87	Haue-TJB 788.1038	1	30 MS	MP	B	105
8	Honore 87	Veery 1		5 MR-MS	MP	B	80
9	IKBAL 87	IAS58/3/KAL/BB/ALD	16	20 MR	P	AB Fairly Good	100
10	PALDA 87	PF70 354/Aldan		5 MR	MP	B	195
11	Marie 87	IAS 63/Aldan	11	t MR	T Late	AB	80
12	Mimosa 87	PAT 7219//Carpintero	10	0	MP	AB	120
13	Tif 7255/Imu		12	10 MR	MP	AB	75
14	Bon/Yr//T.Aest./3/Kal/Bb		37	0	P	AB	80
15	Jules 87	Parula/Alondra		5 MR-MS	T	AB	100
16	Tsara 87	KVZ/K4500//ALondra		50 MS	T	B	90
	Triticale						
17	KLAP 87	IA/KAL//PI62/3/BGL		0	MT	B	120
18	Lemming 87			0	P	AB	80
19	Merino 87	Merino G		0	MT	TB	130
20	Merino Bulk 87			0	MT	TB	130
21	Noro 87	PFT 77.717//M2A/BN/ 3/BOK/LMG		0	T	B	110
22	PBR 87	Puppy/Beagle,resel.		0	MP	TB	120
23	RAM Bulk 87'			0	MP	TB	110

Table 4. Commercial varieties abandoned for susceptibility to stem rust

Name	Area of release	Pedigree/Origin
BW19	Vakinankaratra	KAL/BB
CNT7	"	Brazilian cross
IBWSN108.3	"	WE/GTO//KAL/BB
IBWSN112	Lac Alaotra	WE/GTO//KAL/BB
PAT	Vakinankaratra	PAT7219//KAL/BB
PF70354	"	Brazilian cross

Table 5. Varieties/crosses having two or more sister lines showing less than 10% infection with stem rust

Nursery/variety/crosses	Total number of sister lines	Range of the coefficient of infection to stem rust		
		0	0.1-1	1.1-10
6th SNACWYT				
1. RAM	8	7	1	--
2. MERINO	10	9	--	1
3. IRA/BGL/4/IA/KLA//CAL/3/BGL	2	2	--	--
4. IRA/BGL//JUANILO	2	--	2	--
5. IR/BGL/3/M_2A/ARM//BGL	2	--	--	2
6. MASA MEX/KEN ACC 3833-59-4-10 KE	2	--	--	2
ITSN 12				
7. TEJON/BGL	4	4	--	--
8. M4/FS 1795//BGL	2	2	--	--
9. PANTHER//OCTO BULK/BUSH	8	3	--	5
10. M_2A/RM/4/ADDAX/3/BGL/M_2//IRA	2	2	--	--
11. W 74.103/4/ADDAX/3/BGL/M_2A//IRA	4	4	--	--
12. MERINO	5	3	1	1
13. IRA/DRIRA	2	--	1	1
14. BEAGLE	3	--	1	2
15. PANDA R/ADDAX	2	--	--	2
16. MUSKOX	2	1	--	1
17. PANTHER/M_1A	2	--	--	2
ITSN 11				
18. BEAGLE	4	1	1	2
19. IRA/BGL	2	2	--	--
20. ABN/CHA #2	2	2	--	--
21. BGL DER.SEL.BULK	2	--	--	2
TCL FOURRAGER				
22. M_2A/BGL	5	5	--	--
23. IRA/KLA	11	11	--	--
24. PANTHER	5	5	--	--
25. UM 940/ARM//IRA/BGL	5	2	1	2
26. CIN/PI 251.923//PATO/3/BGL	2	2	--	--
27. OCTO BULK/CIN	4	4	--	--
TCL FOURRAGER				
28. R4 E-COMPOSITE	3	3	--	--
29. TETRA PRELUDE//QD 289/3/DRIRA	2	2	--	--
30. H. 277.69/UM//2 2	4	4	--	--
31. TCC X 11	2	2	--	--
32. H ROJO/HUARANI	2	--	2	--
Y 84-85				
33. LMG/4/GT/SP Y//2*M_2A/3/RM/CASTOR	2	2	--	--
34. GNU	3	2	--	1
35. STIER	5	5	--	1
36. OCTO NV/4/CIN/CNO//BGL/3/MERINO/5/BCH	2	1	--	1

Table 6. Advanced lines combining tolerance to soil acidity, resistance to stem rust and yield; origin: Elite Aluminium

No. entry	Pedigree or Crosses	Stem rust	Yield, plot (1.20 m^2)
45	IAS58/4/KAL/BB//CJ/3/ALD/5/BOW	0	399
31	" "	0	315
49	" "	0	308
91	PF70.354/ALD//BOW	0	244
58	IAS 58/4/KAL/BB//CJ/3/ALD/5/BOW	TR	378
130	THB/5/IAS 55//ALD/3/MRNG/4/ALD/ IAS58.103A/ALD	TMR	351
63	IAS58/4/KAL/BB/CJ/3/ALD/5/CNR	TMR	346
51	IAS58/4/KAL/BB//CJ/3/ALD/5/BOW	5MR	477
84	LD 6/KVZ//LD 6/AGE/3/LD 6/KVZ//LD 6/WIP	5MR	393
23	CNT10 4/ LV 5/AGA/3/LD 4/AGE/ LD 3/N.BAY	5MR	317
111	PHO/IMP/3//PF72640/PF7326//PF7065/ALD	5MR	284
88	MRNG/ALDAN//CNR	5MR	255
22	CNT8 4//IAS55 4/AGE	5MR	230
86	LD 6/KVZ//LD 6/AGE/3/LD 6 KVZ/ LD 6/WIP	5MR-MS	447
95	PF70354/ALD//YACO	5MR-MS	429
80	KVZ//EN/BB/3 CEP7596/4 CEP8064	5MR-MS	290
110	PF85487	5MS	447
78	IAS58//IAS55//ALD/3/MRNG/4/ALD/ IAS58.103A...	5MS	222
87	MOR/MON	5MS-S	248
82	KVZ/3/TOB/CTFN//BB/4/BLO/5/TAN	5S	408
106	PF74354/ LD/ALD	10MR-MS	300
108	PF74354/LD/ALD	15MR-MS	362

N.B. All these lines were grown on virgin oxisol pH 4.4

Table 7. Advanced lines combining yield, tolerance to soil acidity and resistance to stem rust

No. entry	Pedigree or Crosses	stem rust	Yield g/plot (0.6 m^2)
125	M2A/CML/3/H 569.71/P.AR//3 TRA	0	195
88	CMH79A.307//RL 6010/4 INIA66/3/ALD/ CMH79A.307	15MR-MS	152
68	MRNG/ALDAN/3/S20/3/CNO79	0	145
60	CMH79A.307//MRNG/ALDAN	5MR-MS	112
131	GEN81	0	107
83	H569.71/5 JACUI	5S	80
124	M2A/CML//NYUBAY/3/CMH72.A.576/MRNG	0	72
132	PVN76	5MS	69

Table 8. Classification of the Malagasy Trap Disease Nursery according to the percentage of infection of stem rust (rainy season 1987)

No.	Varieties/advanced lines	Site:	Percent infection stem rust: MIMOSA (at 129 days)	Percent infection stem rust: BETAFO (at 115 days)
39	AVOINE No.145		0	0
35	IRA/BGL/4/IA/KLA//CAL/3/BGL		0	0
31	RAM		0	0
30	PUPPY/BGL		0	0
33	MERINO (NO. 39)		0	0
34	ABN/M_5A//IRA/3/PND		0	0
4	HONORINE		0	0
3	FIFA74		0	0, 5
27	TCL10		0	1
37	AVOINE NO.24		0	70
15	ANDRY87		0 2	0
22	VARIETE X		0 9	0, 2
36	JUANILLO317		1	0, 4
11	JULES87		3	18
6	HONORE87		6	9
32	IRA/DRIRA		12	0
18	T'F7255/IMU		18	0, 3
38	BEVOA		18	16
13	EGIL87		24	3
16	BO/TR/ T AEST.		24	8
8	BLUETIT"S"		24	30
23	SPARROW/PVN		27	
19	RON/TOB ALDAN		32	4
12	DANIEL87		32	27
14	PEL73380/ATR71//TI		35	12
20	GASTON87		36	4
7	PICHUILA"S" = BW 8		36	50
17	TSARA87		40	3
21	PAVON76		40	9
25	SEMENCES TRITRIVA		40	9
26	COLL. SOLOMON = ARIANA ?		40	40
1	ROMANY		45	40
28	TCL65		50	4
9	IBWSN81		50	30
24	ROMANY		54	30
29	TCL BULK 50 MA		60	3
5	CNT7.1		90	70
10	PAT7219//KAL/BB		100	70
2	IBWSN 108.3 (=MONCHO)		100	90

Figure 1. pH of soils in the Vakinankaratra Area of Madagascar

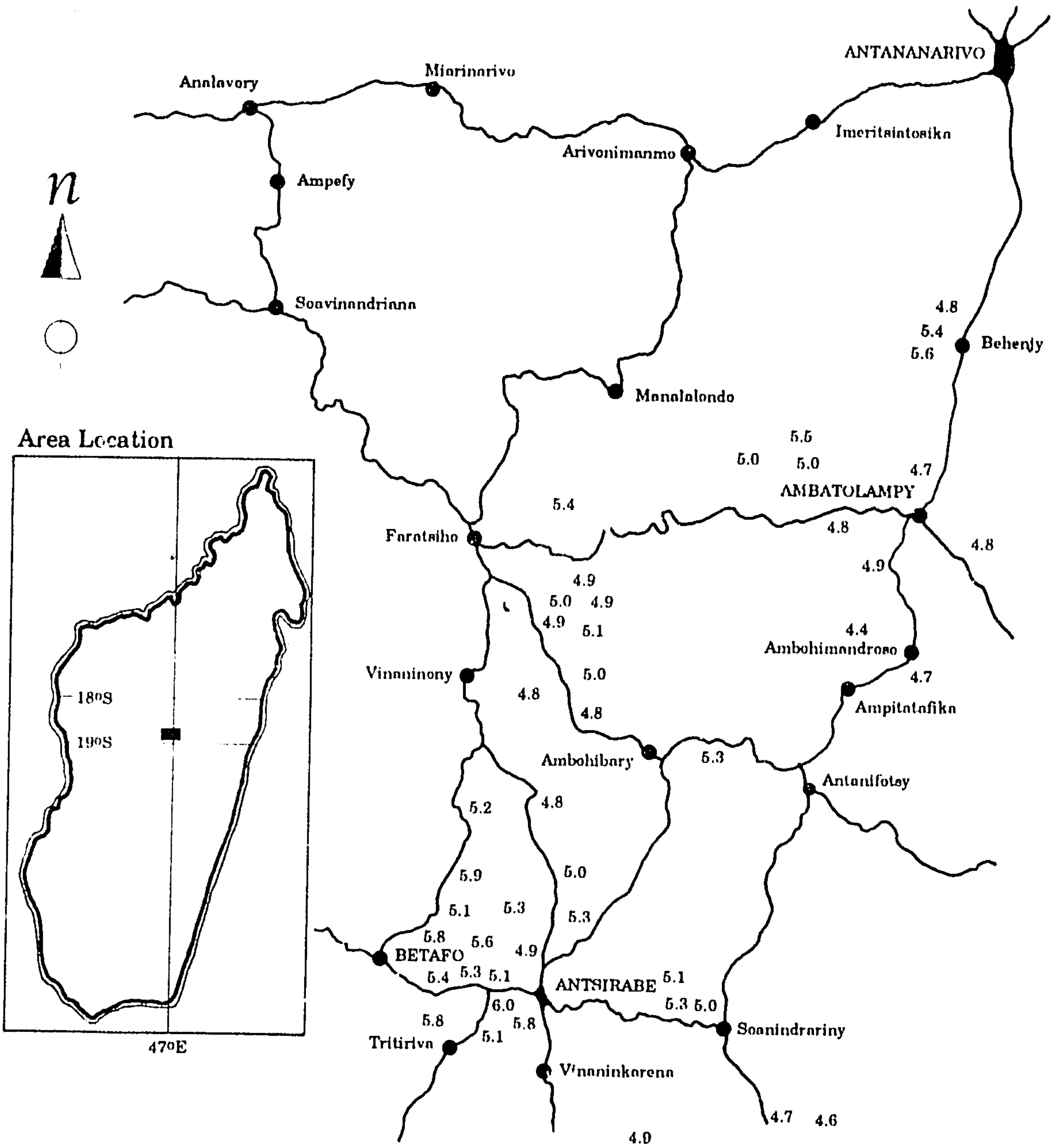


Figure 2. Distribution of the pH o ne soils in the Vakinankaratra Area. Multilocation trials, rainy season 1.34, 1985, 1986 at 61 sites.

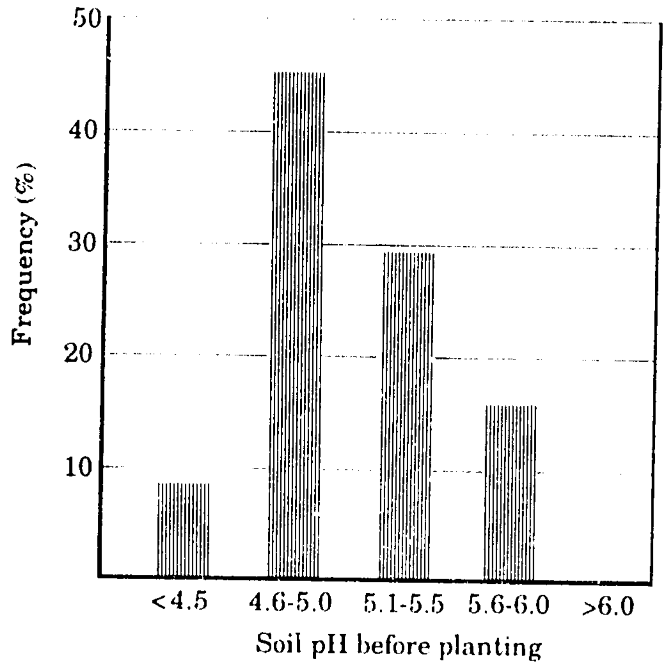


Figure 3. Relation Between Yield and Soil pH, Multilocation Trials 1984, 1985 and 1986.

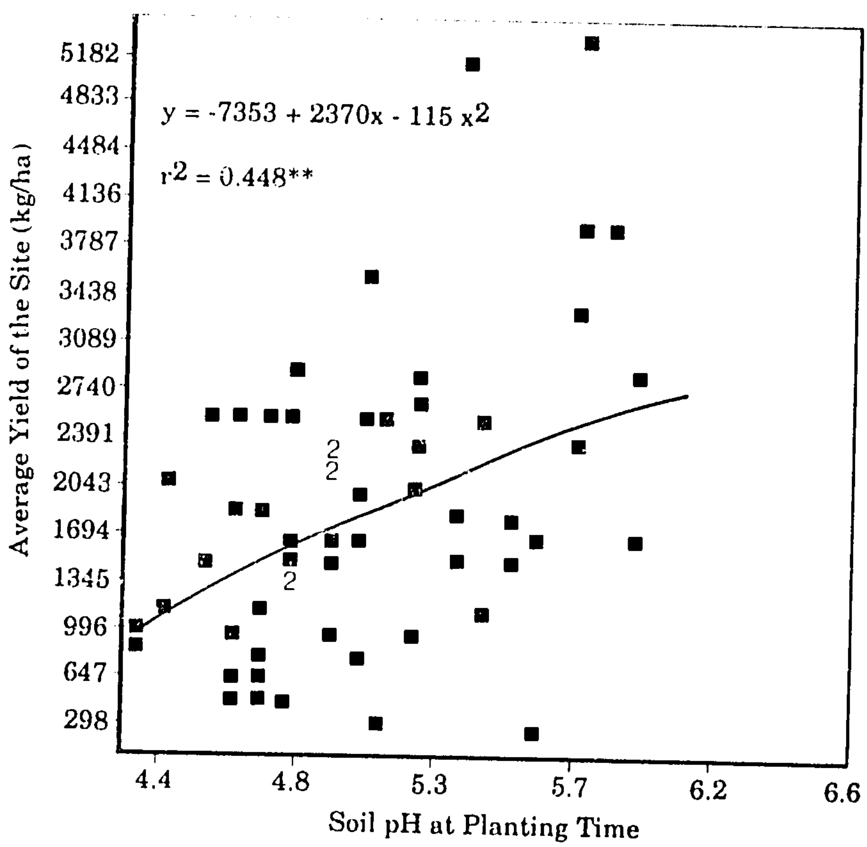


Figure 4. Distribution of the average yield of the site and the yield of the triticale Puppy/Bgl. Multilocation trials 1984, 1985 and 1986.

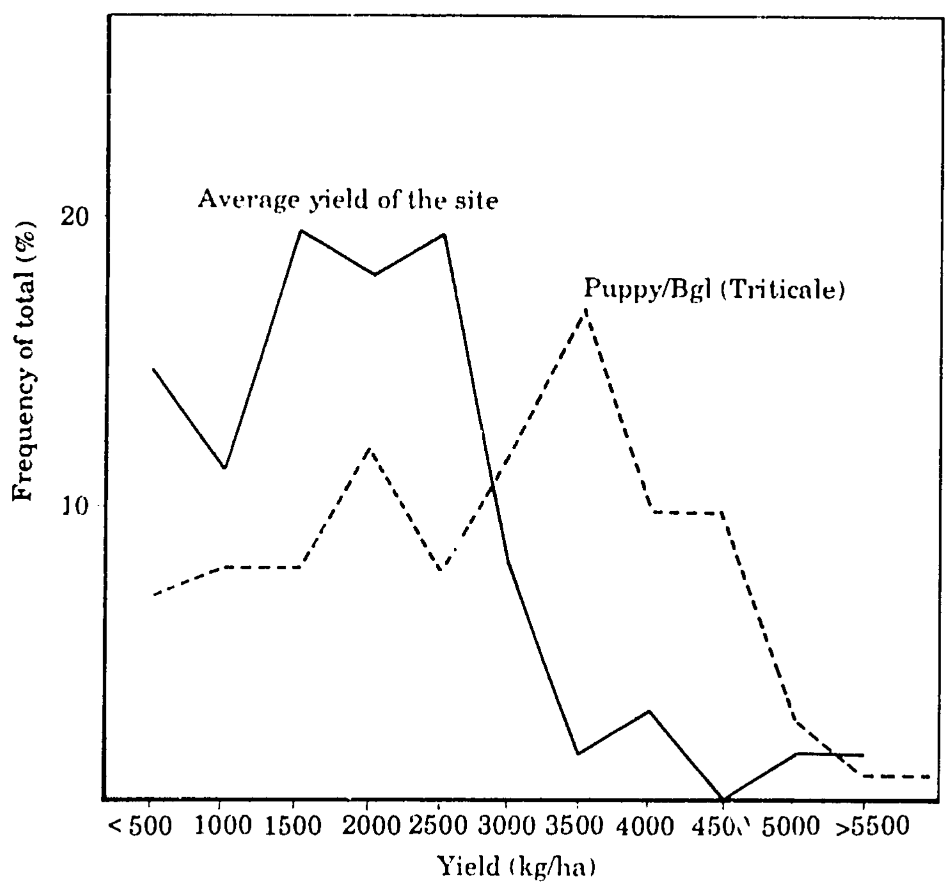


Figure 5. Distribution of bread wheat lines according to the coefficient of infection (CI) to stem rust 1987 (rainy season).

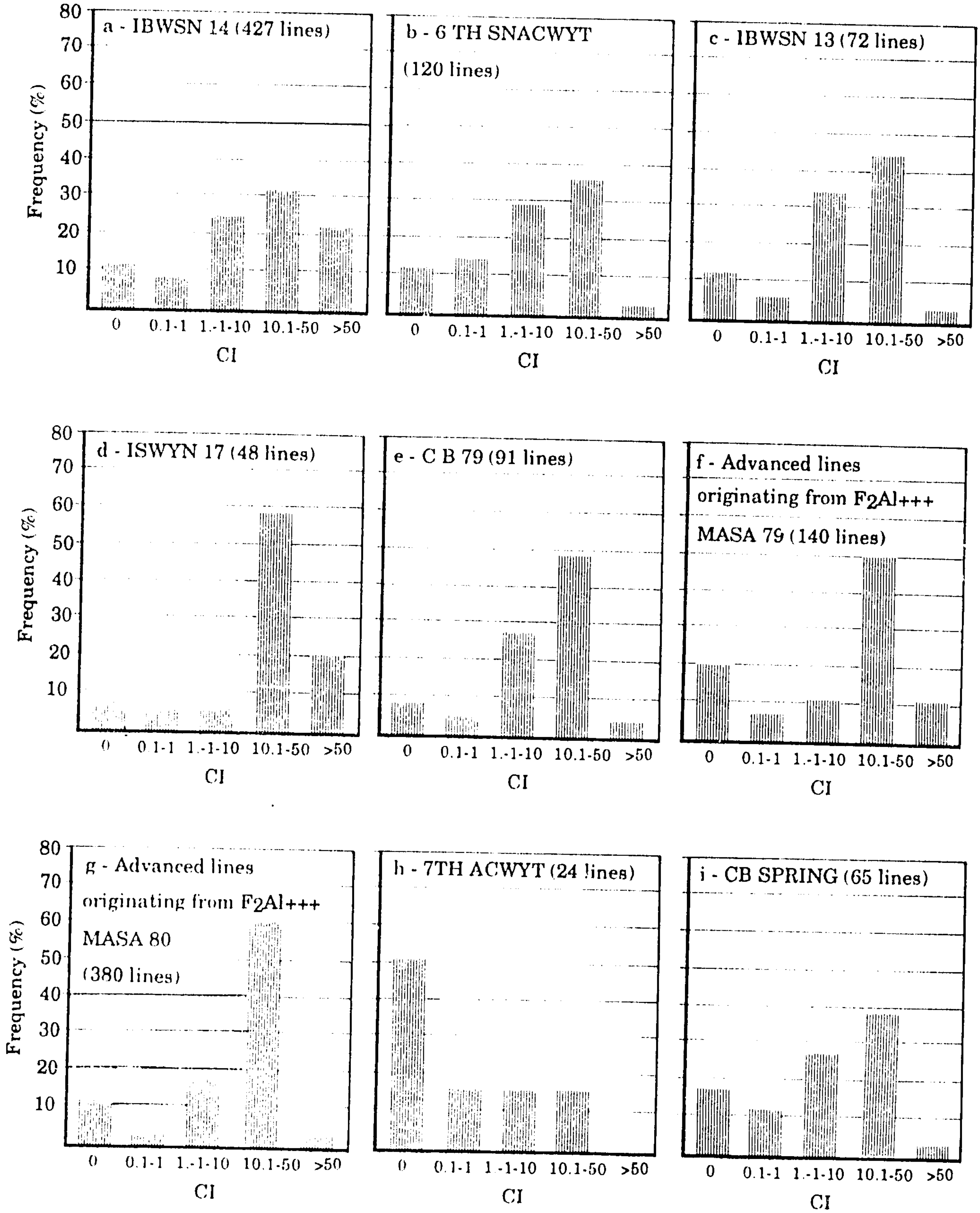


Figure 5. (continued)

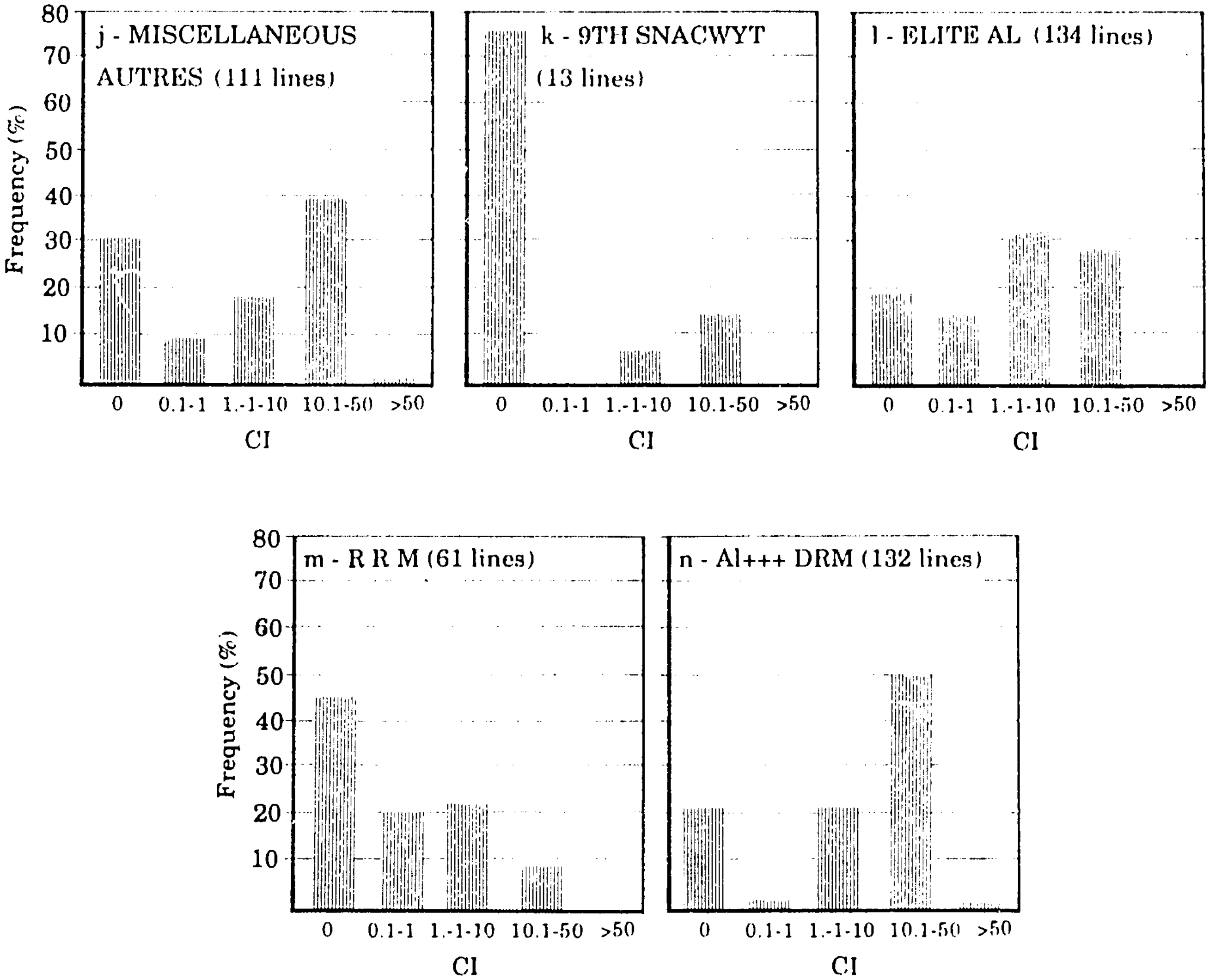


Figure 6. Distribution of triticale lines according to the coefficient of infection to stem rust, 1987 (rainy season).

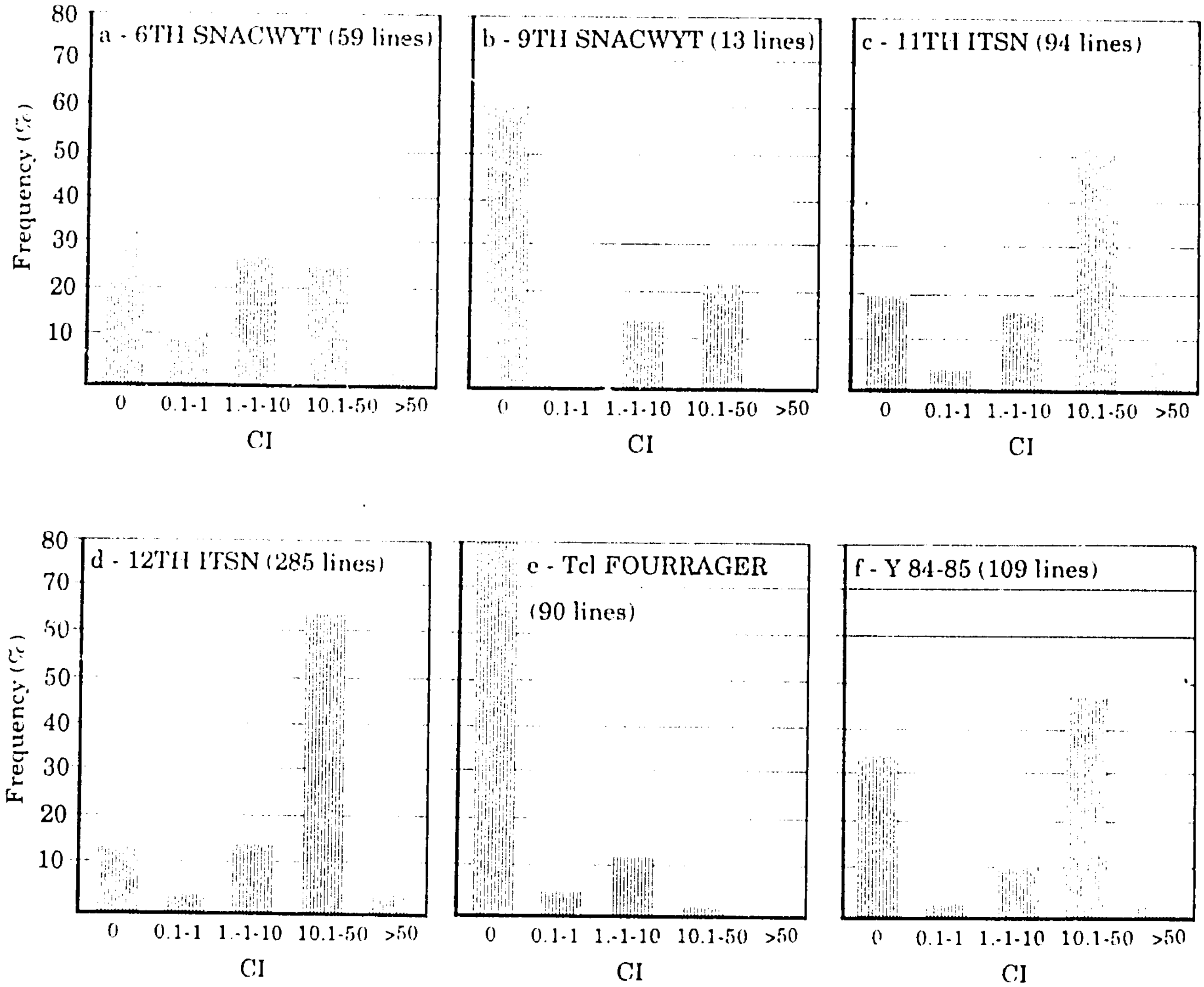


Figure 7. Development of stem rust on 5 groups of varieties having different types of reaction.

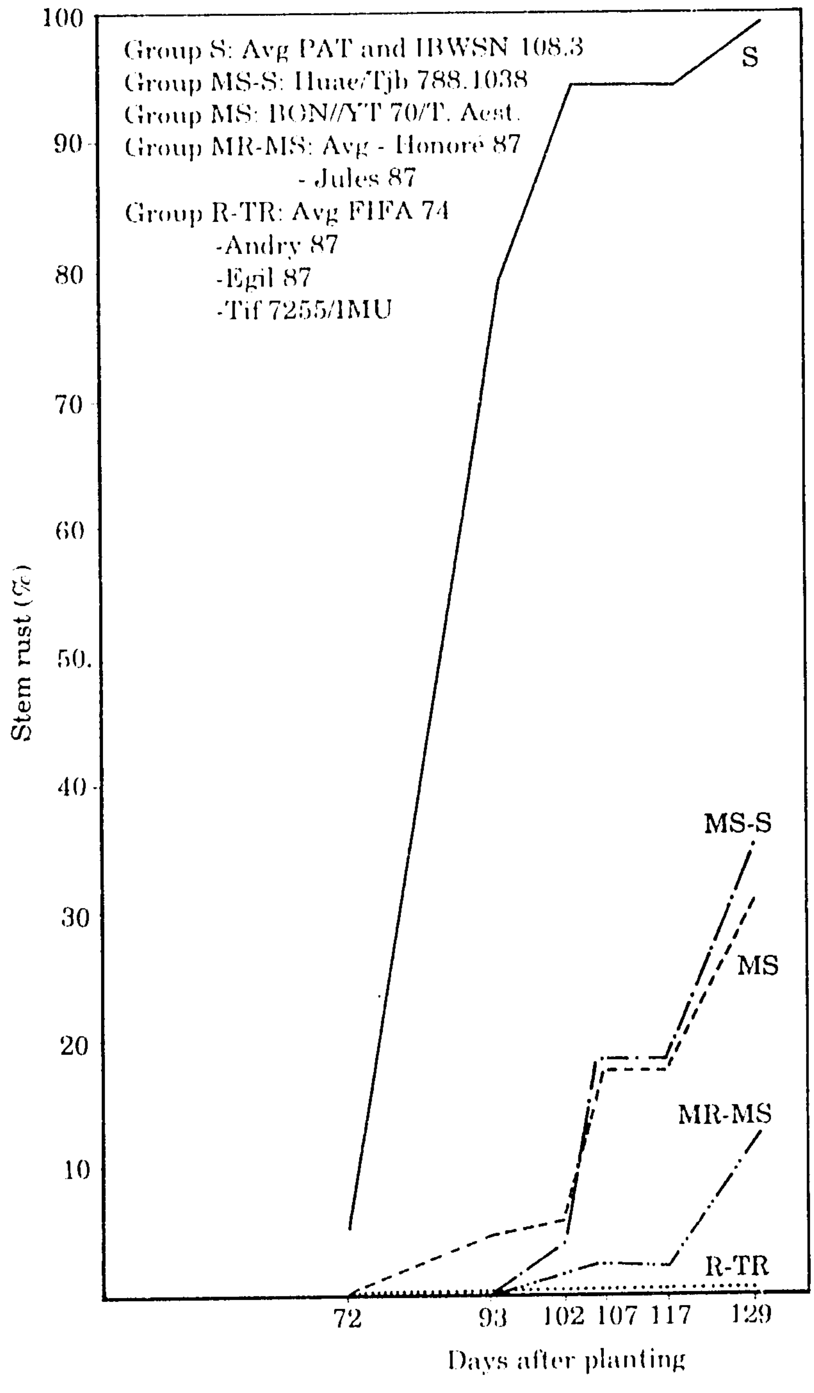


Figure 8. Development of stem rust in some bread wheat varieties included in the Trap Disease Nursery.

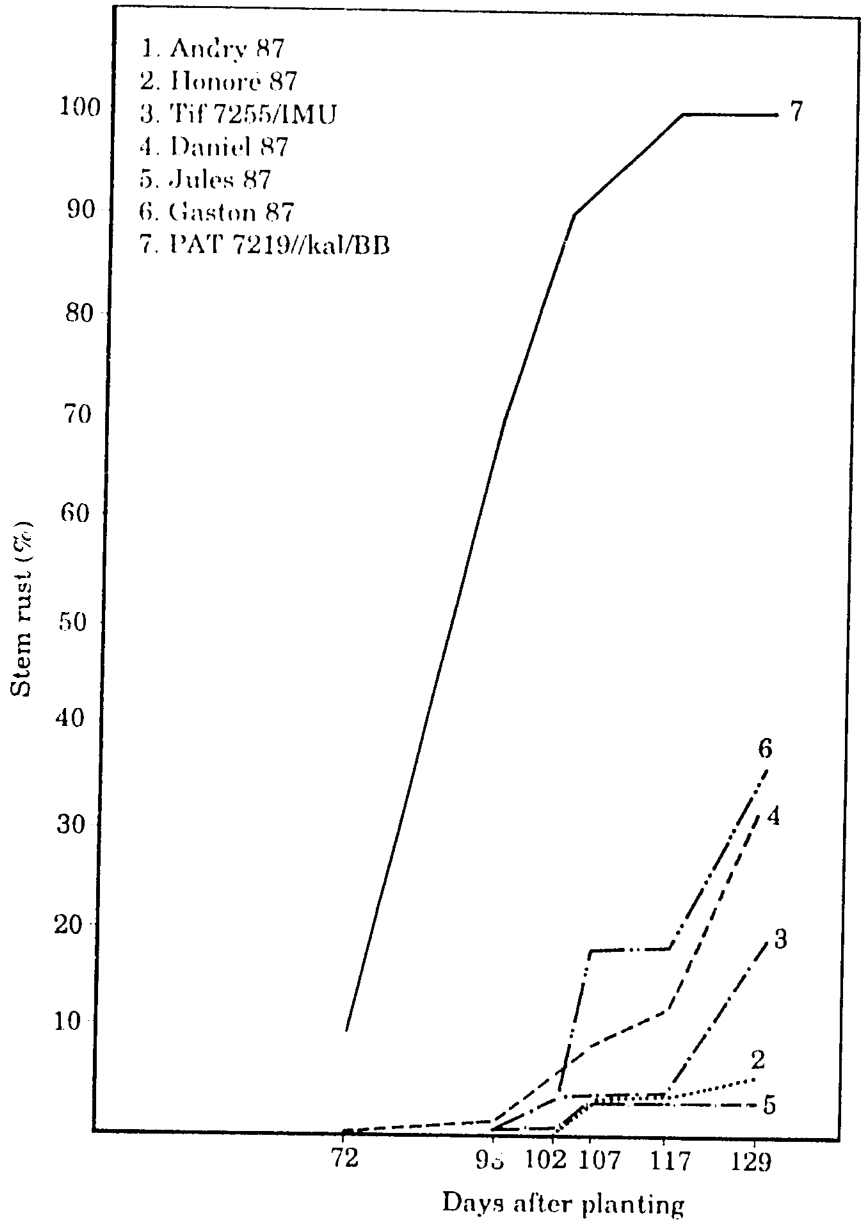
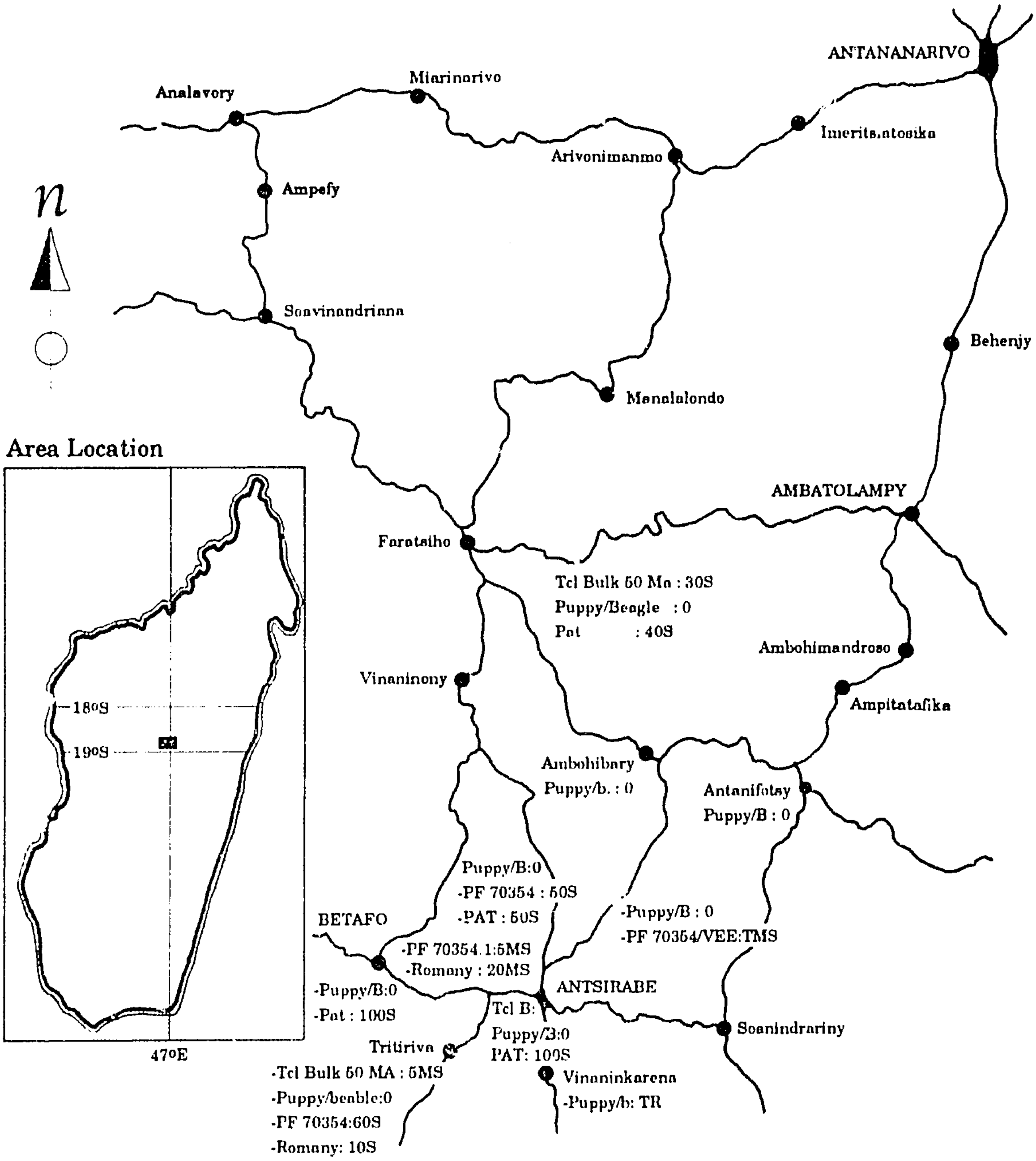


Figure 9. Rust Survey in the Vakinankaratra Area of Madagascar, Farmers' Fields, Rainy Season, 1987.



GRAIN YIELD STABILITY OF BREAD WHEAT CULTIVARS IN THE HIGHLANDS OF ETHIOPIA

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Abstract

Grain yield stability of six and eight bread wheat cultivars was studied across 37 and 23 environments, respectively, in order to determine grain yield potential and stability.

The combined analysis of variance showed that varieties were significantly different in grain yield. Regression of cultivar mean yield on environmental mean yield and the contribution of individual cultivars to the cultivar x environment variance component indicated that cultivars differed in their genetic yield potential to respond to a favorable environment. Regression coefficients for individual cultivars ranged from 0.86 to 1.13, with "6295-4A" and "Dashen" mean grain yields being 36.2 and 39.7 q/ha, respectively. Among the cultivars tested, two high-yielding cultivars, Dashen and "6106-9", appeared more productive where growing conditions are favorable. Hence, stability of yield data across environments and years may be helpful in cultivar recommendations for either specific or wide adaptation.

Introduction

Bread wheat (*Triticum aestivum L.*) is one of the major cereal crop grown in the medium and high altitude zones of the Ethiopian highlands, particularly in the South-Eastern, Central, and North-Western agro-ecological zones. In order to stabilize wheat production in these regions, there is a need for cultivars which give acceptable yield stability. The Ethiopian Bread wheat Improvement Program has placed top priority on developing cultivars for these zones.

Varieties respond differently when compared across environments and years resulting in significant genotype by environment interaction. According to Eberhart and Russell (1), a significant genotype x environment interaction often creates difficulty in identifying a superior variety. Hence, identifying genotypes that show minimum interaction with environments, or possess high yield stability (2) is an important parameter to be taken into consideration.

Stability analysis of individual genotype responses often uses regression techniques. The method widely used in stability analysis involves regression of mean yield of all genotypes across environments on mean yield of all genotypes in each environment (1, 2). A stable variety was considered having a mean yield across environments, a slope of the regression line close to 1.0, and a minimum deviation from regression (2). Non-stable varieties were considered to have slopes of b > 1.0 and said to be responsive to changing environments.

The objective of the present study was to determine genetic yield potential and stability of bread wheat cultivars in a range of environments and to identify cultivars for these environments.

Materials and Methods

The bread wheat cultivars included in this study were eight released cultivars and a local check. The varieties were "Enkoy", "6295-4A", "ET13", "Dashen", "Gara", "Batu", "6106-9" and "KKBB". Varieties ET13 and 6106-9 were not included in the 1985 cooperative variety yield trial. The other varieties were used in 1985, 1986 and 1987 yield trials. Each location in a given year was considered as an individual environment. Thus, there were 37 environments over the 3 year period using six cultivars. Using eight cultivars there were 23 environments over the 2 year period. The local checks were not included in the statistical analysis because the varieties names were not identified by cooperators and varied per location.

The experiments were carried out in a randomized, complete block design with two replications in 37 and 23 environments, respectively. For each respective location recommended seeding dates and fertilizer rates were used. The seeding rate was 150 kg/ha. Plot size was six rows 20 cm apart and 5m long. The center four rows were harvested for grain yield (quintals/ha).

A combined analysis of variance was calculated for grain yield. Grain yield stability parameters were calculated based on the methods of Finlay and Wilkinson (2) but without the use of the log 10 scale. Regression coefficients (b), coefficient of determination (r^2), and deviations from regression (Sd) were obtained by regressing mean yields of each variety (Y) on the mean yield of all varieties in an environment (environmental index). The regression coefficient of each variety was tested for its deviation from unity. Linear correlation coefficients between mean and stability parameters were calculated.

Results and Discussion

Stability analyses of six and eight bread wheat cultivars were evaluated over 37 and 23 environments (location x years) where locations differed in altitude, soil type, and annual precipitation.

The combined analyses of variances from 37 and 23 environments showed significant differences among varieties in grain yield (Tables 1 and 2, respectively).

In both cases, the interaction of variety x environment was highly significant for grain yield indicating that the ranking of varieties was not constant in all environments. Because the variety x environment component was significant, grain yield stability of varieties was analyzed based on the methods of Finlay and Wilkinson (2). It was assumed that there was a linear relationship between the performance of a variety and favorable growing conditions, taking into account all production constraints. The significant variety x environment mean squares indicated that the regression coefficients were not the same for all varieties. Dashen produced the highest overall mean grain yield (Tables 3 and 4). The variety 6295-4A produced the lowest mean grain yield.

Estimates of stability parameters are shown in Tables 3 and 4. All regression coefficients were not significantly different from unity except for 6295-4A. Of the top yielding varieties Dashen , KKBB, and 6106-9 had regression coefficients greater than 1.0, though not significantly different, suggesting that they were responsive to more favorable growing conditions. The regression coefficients for Enkoy, Gara, and ET13 were not significantly different from unity suggesting that they had stable performance across environments. There was a significant positive association ($r = 0.86^{*}$) between varietal mean yields and regression coefficients indicating that high yielding varieties responded favorably to improving environments. This is in agreement with Eberhart and Russell's (1) findings.

About 72 to 90% (Tables 3 and 4) of the variation in yield of individual varieties was accounted for by the variation in environmental index, which shows that the regression coefficients had considerable predictive value for the varieties tested. There was a negative correlation between r^2 values and standard error ($r = -0.73$ and -0.90^{*}) which is in agreement with findings of Langer et al. (3) who reported a negative correlation between deviation mean square and r^2 for three groups of cultivars. They suggested that these parameters could be used for measuring stability.

Based on the criteria for stability as described by Eberhart and Russell (1) and Finlay and Wilkinson (2), Enkoy, Gara, and ET13, which were quite high in yield compared to Dashen and 6106-9, with regression coefficients close to 1.0 and a minimum deviation from regression, were fairly stable in performance across diverse environments.

In environments where the growing conditions were favorable, Dashen, 6106-9 and KKBB in that order appear highly productive. On the other hand, 6295-4A appears relatively productive in low environments where growing conditions are not favorable. Our findings suggest that for cultivar recommendations for either wide or specific adaptation, stability analysis of yield data across environments and years is useful in a breeding program.

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Résumé

Une étude a été effectuée avec six et huit cultivars, dans respectivement 37 et 23 environnements, afin de déterminer leur rendement potentiel et la stabilité de leur rendement. L'analyse globale de la variance des rendements a montré que les rendements moyens des cultivars diffèrent significativement entre eux. L'analyse de la régression du rendement moyen d'un cultivar dans un environnement en fonction du rendement moyen de l'environnement et l'analyse de la contribution de chaque cultivar à l'interaction cultivar x environnement ont mis en évidence que les cultivars diffèrent dans leur potentiel génétique à répondre à un environnement favorable. Les coefficients de régression ont varié, selon les cultivars, de 0.86 à 1.13, alors que les rendements moyens des cultivars 6295-4 A et Dashen furent respectivement de 36,2 et de 39,7 q/ha. Parmi les cultivars comparés, deux cultivars, le Dashen et le 6106-9, furent plus productifs lorsque les conditions de culture furent favorables. Ainsi, les données sur la stabilité des rendements en fonction des environnements et des années est une aide précieuse pour recommander des cultivars sur base de leur adaptation spécifique ou élargie.

Table 1. Combined analysis of variance for grain yield of six bread wheat varieties grown in 37 environments (1985-1987)

Source	df	M.S.
Varieties (V)	5	64.55*
Environments (E)	36	1741.30**
Reps/Environment	37	40.29
V x E	180	57.32**
Error	185	22.18
C.V. %	13.2	

Table 2. Combined analysis of variance for grain yield of eight bread wheat varieties grown in 23 environments (1986-1987)

Source	df	M.S.
Varieties (V)	7	58.43*
Environments (E)	22	2266.08**
Reps/environment	23	44.31
V x E	154	62.68**
Error	161	26.73
C.V. %	13.5	

Table 3. Mean grain yield and estimates of stability parameters for grain yield of six bread wheat varieties in 37 environments

Variety	Grain Yield (q/ha)	Stability Parameters		
		b	Sd	r^2
Enkoy	36.1	0.99	0.063	0.88
6295-4A	34.1	0.89*	0.052	0.89
Dashen	36.7	1.13	0.075	0.87
Gara	35.8	0.98	0.068	0.86
Batu	34.8	0.95	0.075	0.82
KKBB	35.6	1.05	0.071	0.86

Table 4. Mean grain yield and estimates of stability parameters for grain yield of eight bread wheat varieties grown in 23 environments

Variety	Grain Yield (q/ha)	Stability Parameters		
		b	Sd	r^2
Enkoy	38.9	0.995	0.079	0.88
6295-4A	36.2	0.859*	0.077	0.86
ET13	38.2	0.987	0.071	0.90
Dashen	39.7	1.128	0.107	0.84
Gara	38.5	0.974	0.102	0.81
Batu	37.2	0.895	0.123	0.72
6106-9	39.2	1.085	0.079	0.90
KKBB	38.0	1.076	0.102	0.84

THE EFFECTS OF LIME ($Ca(OH)_2$) ON THE PERFORMANCE OF WHEAT CULTIVARS IN PLINTHIC FERRALSOLS (ELDORET SOILS) OF KENYA

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Abstract

Seven wheat cultivars (Triticum aestivum L.) were used as indicators of lime response in a greenhouse experiment with a Kenyan Plinthic Ferralsol (Eldoret) soil, which was limed from an initial pH of 5.5 to 6.5 using $Ca(OH)_2$ (calcium hydroxide). Two lime treatments were used: (1) No lime added (control), and (2) Equivalent of 3250 kg.ha of lime added. The analysis of variance (ANOVA) revealed that treatment x cultivar interaction was significant ($p \leq 0.05$) for grain yield, harvest index %, and number of seeds per plot. It was demonstrated that the cultivars could be separated into distinct groups based on their relative performance in limed and unlined soil, and that the degree of response to liming was cultivar dependent. Quantitative relationships between the characters measured, estimated by correlation coefficients were not significantly affected by the level of lime treatment.

Introduction

Acid soils are prevalent in some regions of Kenya. The detrimental effects of soil acidity on crop production have been reported by many investigators in the past (2, 5). Foy et al. (3) indicated that the performance of barley and wheat cultivars grown in acidic Blander soils was influenced by both lime treatment and the inherent cultivar factors. Other reports (4, 6) have also indicated that the performance of a crop in an acidic soil may be influenced by the application of lime, and by the nutrient status of a given soil as related to the amount of aluminium concentration in the soil solution. Hoyt et al; (6) reported that there was no significant yield increase in barley after liming soils of Peace River Region to a pH of 6.5 without an accompanied addition of phosphorus.

The objective of the present greenhouse pot study was to measure the response to lime treatment of some Kenyan wheat cultivars grown in Kenyan soils, and to evaluate some of the cultivar differences that are associated with the effect of lime treatment.

Materials and Methods

Soil--Soil samples of the taxonomic class Plinthic Ferralsol from Eldoret, Western Kenya, were used in a greenhouse study to determine the response to lime of seven wheat cultivars (listed in Table 3).

Two soil samples from Eldoret were obtained from the 0-22 cm top layer in fields which were previously cropped with wheat. The soil samples were air-dried and ground to pass through a 2-mm screen. Soil from the two sites was bulked to provide sufficient amount for the pot study. The physical and chemical properties of the samples that were used are presented in Table 1. The aluminium and manganese concentrations in the samples were not known at the time the study was started, but all soil samples used were known to be significantly acidic (i.e., $pH < 5.5$).

Soil pH calibration method--Soil pH was determined on a 1:5 (soil: water) suspension using a glass electrode and shaking time of 1 hr. Lime requirement for the soil samples was determined by the traditional method attributed to Bradfield and Alison (1), of adding measured volumes of 0.02 M $Ca(OH)_2$ to 20 g of soil samples, adjusting the volume to 100 ml with distilled water and determining the pH after a 4-day equilibration period. The pH values that were obtained by varying the amount of 0.02 M $Ca(OH)_2$ were regressed against the respective amounts of 0.02 M $Ca(OH)_2$ that were added, and the following regression equation was obtained:

(a) $Y = -0.273 + 0.047 X$

where Y represents the amount of grams of lime ($Ca(OH)_2$) that was required to amend 20 g of the study soil samples to a targeted pH, and X represents the targeted pH of 6.5. The soil samples were limed from an initial pH of 5.5 to a target pH of 6.5. The lime requirement and additional nutrients required are reported in kg/ha, assuming that a one hectare fallow slice has an equivalent of 2,000 tons of soil.

Greenhouse procedures--The experiment was conducted in a temperature controlled greenhouse at the University of Alberta with average day and night temperatures of 23^oC and 17^oC, respectively. Relative humidity was kept at approximately 70% and light intensity of 16,000 Lux (M^{-2} cd.Sr) was maintained. The design of the experiment was a completely randomized block with 7 cultivars, 2 lime treatments and 3 replicates. The lime treatments were: (1) No lime added (control), and (2) 3250 kg/ha equivalent of lime added, applied as pure $Ca(OH)_2$. The lime added was thoroughly mixed with 1.4 kg of air dry soil for each pot and the mixture was then placed in non-draining plastic pots 15 cm diameter by 15.5 cm deep. The mixture was allowed to incubate at field moisture capacity for 14 days before the seeds were sown.

Ten seeds of each cultivar were sown per pot and seedlings were thinned to four per pot (i.e., one plot) shortly after emergence. The pots were watered to field moisture capacity daily or more frequently during periods of high water demand. Pot positions on the bench were rotated on a three-day cycle within a replicate whilst each replicate was rotated every fifth day.

During the experiment, additional nutrients (N, P, K and S) were added at the following rates in kg/ha: 80 N, 100 P, 50 K and 20 S. These were supplied as NH_4NO_3, NH_4PO_4, KCl and $(NH_4)_2SO_4$.

Plant heights (cm) were measured at maturity immediately before harvesting. Harvested whole plants were oven dried at 60°C for 24 hours before grain yield (g), and biological yield (defined as the total dry weight above the soil level) were determined. Harvest index (HI %) was computed by dividing grain yield by biological yield multiplied by 100. The number of seeds per plot (S/PT) and the number of seeds per head (S/HD) were determined and used together with grain yield to estimate the 1000 kernel weight (TKW) g.

Statistical analysis--All sets of data were subjected to analysis of variance using a random linear additive model as described by Steel and Torrie (10). Duncan's Multiple Range Test (DMRT) at $P < 0.05$, and a paired t-test were used to determine cultivar mean value and treatment mean differences, respectively.

Results

The ANOVA (Table 2) indicated that there were significant ($P < 0.05$) treatment effects for all agronomic characters except for harvest index and S/PT. Cultivar effects were significant for biological yield, and for S/HD, and highly significant ($P < 0.01$) for all other agronomic characters.

Treatment x cultivar interaction (Table 2) was highly significant for grain yield, harvest index and seeds per plot. The significant treatment x cultivar interaction for these indicated that varieties were responding differently to the lime treatment.

DMRT ($P < 0.05$) indicated (Table 3) that there were significant differences between the cultivars for all agronomic characters. The cultivars could be separated into distinct performance groups for all characters except TKW. The cultivar Romany ranked first in terms of grain yield, S/HD, and S/PT, whereas the cultivar K. Swara and Siete Cerros ranked last in all the measured agronomic characters. A wide range between cultivar values was evident for some characters. For instance, the mean grain yield of Romany (3.7 g) and K.Swara (1.5 g) differed by a magnitude of greater than two-fold, and seeds per plot (11.8 and 20.5, respectively) for more than 5-fold.

A paired t-test comparison (Table 4) between the means of agronomic characters on limed vs. non-limed soil indicated that the application of lime resulted in a highly significant increase in biological yield, and a significant increase in plant height. No significant increase was found for grain yield, TKW, harvest index, S/HD and S/PT after liming the soil from the initial pH of 5.5 to the target pH of 6.5 using a lime rate of 3250 kg/ha. Large standard errors were observed in S/PT, that perhaps masked significant effects of the lime treatment.

Table 5 results indicated that grain yield was correlated ($P < 0.05$) with biological yield HI, S/HD, and S/PT in both limed and non-limed soils. A highly significant negative correlation ($r = -0.64$) was observed between TKW and S/PT on the limed soil but the correlation (r = 0.40) between the same characters was not significant on the non-limed soil. Other correlations were not affected by the level of lime treatment.

Discussion

The results of this investigation indicated that cultivars responded differentially to lime treatment, as indicated by significant cultivar x lime treatment interaction. Differential cultivar response was found for grain yield, HI % and S/PT.

Lafever et al. (7) reported that liming had differential effect on the yield of wheat cultivars. The responses of individual cultivars observed in this study are in close agreement with results of greenhouse studies reported earlier by other writers (3, 4); and it has been indicated (9) that those cultivars which perform relatively well in acidic soils are generally tolerant to aluminium toxicity. On the basis of this agreement, it was inferred that there may be differential tolerance to aluminium toxicity between he wheat cultivars used in the present study. The aluminium tolerance of the cultivars in this study has been assessed and differential Al^{3+} tolerances have been confirmed (Nyachiro and Briggs, 1987, submitted for publication).

Despite the complexities involved in testing the response of cultivars to soil factors influencing pH, this study indicated that lime had a significant differential effect on the yield of wheat cultivars, and that those which are not tolerant of acidic soils may benefit from lime application even at the pH 5.5 level.

Acknowledgments

The authors wish to acknowledge the financial assistance provided for this work by the National Sciences and Engineering Research Council of Canada, Grant No. A6029. The Senior author also acknowledges receipt of a Scholarship from the Government of Kenya/Canadian International Development Agency which made this study possible. Last but not least, we wish to thank the Director of Research, Ministry of Agriculture-Kenya for granting permission to publish this article, and Dr. E. Torres for his useful suggestions during the preparation of the manuscript.

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Résumé

Sept cultivars de blé (Triticum aestivum L.) ont été utilisés comme indicateurs de la réponse au chaulage au cours d'une expérimentation en serre realisée avec un plinthic ferralsol du Kenya (Eldoret). L'utilisation de $Ca(OH)_2$ à l'état pur a permis de faire passer le pH initial de 5,5 à 6,5. Deux traitements ont été utilisés: l'absence de chaux (témoin) et l'équivalent de 3 250 kg/ha de chaux. L'analyse de la variance a montré que l'interaction traitement x cultivar était significative ($p < 0,05$) pour le rendement en grains, l'indice de récolte (%) et le nombre de grains par parcelle. Il a été démontré que les cultivars pouvaient être classés en deux catégories selon leur performance relative en sol chaulé et non chaulé et que le degré de réponse au chaulage dépend du cultivar. Les relations quantitatives entre les caractères mesurés, estimées par des coefficients de correlation, ne furent pas significativement affectées par le niveau du chaulage.

Table 1. Characteristics of two samples of a Kenyan soil used in the experiment

Analysis[a]	Plinthic Ferralsols		
	Sample 1	Sample 2	Bulked Sample (1 + 2)
pH (H_2O)	5.5	5.3	5.5
pH ($CaCl_2$)	4.7	4.6	4.6
Na meq/100 g	0.14	0.13	0.14
K meq/100 g	1.67	1.69	1.74
Ca meq/100 g	2.77	2.73	3.46
Mg meq/100 g	1.31	1.58	1.48
Mn meq/100 g	0.28	0.21	0.24
Al meq/100 g	0.01	0.01	0.01
NH_3 meq/100 g	20.66	22.51	20.52
NH_4^+ -N ppm	1.67	1.61	1.70
NO_3^- -N ppm	0.13	3.25	2.32
Total P %	0.09	0.09	0.09
Total N %	0.11	0.12	0.12
Total C %	1.36	1.66	1.63
Clay %	58	46	-[b]
Sand %	30	44	-
Silt %	12	10	-

[a] Samples were analyzed using methods outlined by MaClean (8).
[b] Not estimated.

Table 2. Analysis of variance for agronomic characters for seven cultivars of spring wheat grown in Ferralsols (Eldoret soils) under two liming treatments (limed and unlimed)

Source of	d.f.[a]	Mean Squares Estimate						
		Grain yield (g)	Biological yield (g)	Harvest Index (%)	TKW[b] (g)	Plant Height (cm)	Seeds per Head (S/HD)	Seeds per Plot (S/PT)
Replicates	2	0.3	4.1	27.6	50.1	78.2	27.6	422.4
Treatments	1	1.4**	12.1**	0.4NSP	211.7**	495.1*	205.9**	247.7NS
Cultivars	6	3.7**	6.1*	304.5**	210.5**	387.8**	401.9**	5820.4**
Treatments x Cultivars	6	0.4**	0.4NS	79.5**	5.9NS	11.2NS	11.2NS	369.7**
Error	26	0.1	0.2	22.5	13.5	13.5	5.5	113.5
Total	41	-						

[a] Degrees of freedom
[b] TKW = 1000 kernel weight

*, ** Significant at $P \leq 0.05$ and 0.01, respectively
NS: Not significant at $P < 0.05$

Table 3. Mean values (averaged from limed and unlimed treatments) for seven wheat cultivars grown in Ferralsols (Eldoret soils) for seven agronomic characters

Cultivar[a]	Grain yield (g)	Biological yield (g)	Harvest Index (%)	TKW[b] (g)	Plant Height (cm)	Seeds per Head (S/HD)	Seeds per Plot (S/PT)
Romany	3.7 a[c]	9.3 a	39.9 a	33.4 bc	59.2 c	32.7 a	111.8 a
K.Fahari	3.3 b	7.6 c	43.3 a	40.9 ab	5 c	22.7 b	81.8 b
K.Tembo	3.3 b	7.5 c	43.7 a	34.8 bc	65.1 b	25.2 b	94.8 b
PF 7748	3.1 b	8.1 b	37.7 a	36.2 bc	69.6 a	23.2 b	84.7 b
K.Kongoni	2.3 c	7.5 c	30.6 b	46.8 a	52.8 d	17.5 c	52.5 c
Siete Cerros	2.1 c	6.5 d	31.9 b	31.1 c	46.6 e	14.3 d	52.5 c
K.Swara	1.5 d	6.3 d	24.6 c	44.6 a	51.3 d	7.3 e	20.2 d

[a] Cultivars are listed in order of grain yield.
[b] TKW = 1000 kernel weight (g).
[c] Means followed by the same letter within a column are not significantly different at $P \leq 0.05$ according to Duncan's Multiple Range Test.

Table 4. Effect of lime treatment on seven agronomic characters average for seven wheat cultivars. Data represent the mean values and standard errors for the limed and non-limed treatments in Ferralsol (Eldoret soils)

Variable	Limed pH 6.5		Non-Limed pH 5.5		t-test Mean Diff^.ence
	Mean	SE	Mean	SE	
Grain yield (g)	2.9	0.03	2.6	0.04	NS
Biological yield (g)	8.1	0.07	7.0	0.06	**
Harvest index (%)	35.9	2.51	35.9	4.50	NS
1,000 kernel weight	40.5	2.61	36.0	3.24	NS
Plant height (cm)	60.9	3.21	53.9	3.69	*
Seeds per head	22.6	2.64	18.2	3.72	NS
Seeds per plot	73.6	37.99	68.7	59.47	NS

*, ** Limed and non-limed mean values are significantly different based on the pairwise t-test at $P \leq 0.05$ and 0.1, respectively.

NS: Not significantly different, $P \leq 0.05$.

Table 5. Correlation coefficients[a] between seven agronomic characters for seven wheat cultivars. Correlation coefficients for unlimed and limed Ferralsol (Eldoret soils) are reported

Source of	Grain yield (g)	Biological yield (g)	Harvest Index (%)	TKW[b] (g)	Plant Height (cm)	Seeds per Head	Seeds per Plot	Lime treatment (kg/ha)
	Agronomic Character							
Grain yield (g)	-	0.78	0.92	- 0.15	0.62	0.87	0.92	0
		0.73	0.83	- 0.30	0.43	0.91	0.87	3250
Biological yield (g)	-	-	0.48	- 0.16	0.54	0.86	0.86	0
	-	-	0.24	- 0.23	0.49	0.80	0.73	3250
Harvest index (%)	-	-	-	- 0.12	0.56	0.69	0.80	0
	-	-	-	0.25	0.24	0.66	0.65	3250
1000 kernel weight(g)	-	-	-	-	0.05	- 0.33	- 0.40	0
	-	-	-	-	- 0.20	- 0.39	- 0.64	3250
Plant height (cm)	-	-	-	-	-	0.55	0.63	0
	-	-	-	-	-	0.49	0.43	3250
Seeds per head	-	-	-	-	-	-	0.95	0
	-	-	-	-	-	-	0.92	3250

[a] N = Correlation coefficients 0.43, and 0.55 are significant at $P \leq 0.05$ and 0.01, respectively.

[b] TKW = 1000 kernel weight.

COMPARISON OF F_2 SINGLE PLANT GRAIN YIELD AND TOTAL DRY MATTER AS ESTIMATORS OF YIELD POTENTIAL IN WHEAT

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Abstract

Two selection criteria, wheat grain yield (GY) and total dry matter (TDM) of F_2 single plants, were compared in two crosses for their relative effectiveness in estimating the yield potential of F_3 and F_4 bulks.

F_2 plants were space planted in the field with 60 cm between plants and between rows. At maturity, 75 F_2 plants having good agronomic characteristics were harvested from each cross and characterized for total dry matter (TDM), grain yield (GY), and grain protein. The top 20% of the F_2 plants in GY or in TDM from each of the crosses were earmarked and their performance closely monitored together with the rest of the lines in F_3 and F_4 bulk yield tests in separate 81 entry 5 m single row plots in triple lattice experiments with the cultivars Glenlea and Benito as check varieties.

The grain yield selection criterion identified five F_3 and six F_4 high-yielding bulks while the TDM selection criterion identified ten F_3 and eight F_4 high-yielding bulks from the two crosses, indicating that TDM selection criterion was superior to the GY selection criterion in identifying F_2 single plants having high yield potential.

Introduction

Early generation testing requires the identification of some specific selection criterion that can be used to pick out superior genotypes in the segregating F_2 material and subsequent generations. Many reports indicate that such selection criteria are difficult to identify.

Allard (2) and Hanson et al. (5) found that selection on the basis of single plant grain yield was ineffective. McGinnis and Shebeski (9) investigated the reliability of single plant selection for yield of wheat in the F_2 and concluded that there was no advantage in selecting F_2 plants for high yield. Knott (7) evaluated F_2 plants from eight wheat crosses and found that there was a great deal of over-lapping of the yield ranges of F_3 lines from good and poor F_2 plants. Some poor selections gave high-yielding F_3 lines whereas some good selections gave very low yielding F_3 lines.

De Pauw and Shebeski (3) evaluated the early generation yield testing procedure in a wheat cross and concluded that the criteria used for selecting individual F_2 plants were ineffective for increasing the mean yield of the progeny of the selected F_2 plants versus the population mean. More recently, Nass (13) indicated that breeding and selection of superior yielding spring wheat cultivars has been hampered by the inability to identify superior yielding individual plants in early segregating generations.

The ineffectiveness of early generation testing in identifying high yield segregants has been attributed to 1) heterosis, 2) heterozygosity and variability within a line, 3) genotype x environment interaction, 4) low heritability of F_2 yield, 5) lack of replication of the hybrids, and 6) soil variability. However, some researchers (1, 4, 7, 10, 11, 12) reported useful results of early generation testing.

This study was designed to compare the effectiveness of the F_2 single plant grain yield (GY) selection criterion with that of the F_2 single plant total dry matter (TDM) selection criterion in identifying superior genotypes.

Materials and Methods

The F_2 plants from two crosses were spaced planted in the field with 60 cm between plants and 60 cm between rows. At maturity a random sample of 75 F_2 plants with good agronomic characteristics was obtained from each cross and characterized for total dry matter (TDM), grain yield and grain protein. Grain protein was determined by the Kjeldahl method.

Two selection criteria, grain yield (GY) and total dry matter (TDM), were used for each cross. For the GY selection criterion, F_2 plants which had grain yields greater than one standard deviation above that of the population mean were selected. For the TDM selection criterion, F_2 plants which had TDM greater than one standard deviation above the mean TDM of the population were selected.

In order to compare the efficiency of the two selection criteria within and between crosses, an arbitrary selection intensity of 20% was used for all selection procedures in both crosses. Superior F_2 plants (15 plants) from each selection criterion and cross (Tables 1 and 2) were especially ear marked and yield tested together with the rest of the lines so that performance in the F_3 and F_4 bulks could be compared with all the other lines.

In 1983 and 1984 the F_3 and F_4 bulks were seeded in the field in separate 81 entry 5m single row plots in triple lattice experiments. At maturity all lines were harvested by hand and grain yield recorded. Grain protein was determined by the Kjeldahl method.

Lines previously identified as superior in F_2 by the GY or TDM selection criterion were traced in the top 20% high yielding F_3 or F_4 bulks.

Results

In cross 1 three F_3 and two F_4 bulks previously identified as superior by the F_2 grain yield selection criterion ranked among the top 20% high yielding bulks while seven F_3 and three F_4 bulks (Table 3) previously identified as superior by the F_2 TDM selection criterion ranked among the top 20% high yielding bulks.

For cross 2, two F_3 and four F_4 bulks previously identified as superior by the F_2 grain yield selection criterion ranked among the top 20% high yielding bulks while three F_3 and five F_4 bulks (Table 4) previously identified as superior by the F_2 TDM selection criterion ranked among the top 20% high yielding bulks.

Most of the previously identified superior F_2 plants by either selection method did not show the expected high yield progeny performance. However, TDM selection criterion identified more lines that were superior and ranked among the top 20% high yielding bulks than the grain yield selection criterion. Thus the F_2 plant TDM selection criterion was superior to the F_2 plant grain yield selection criterion in providing superior genotypes in the early segregating generation.

Discussion

The use of F_2 single plant TDM as a selection criterion for high yield was reported by McVetty and Evans (11). These authors successfully used F_2 TDM and F_2 grain yield to select for high yield F_4 bulks. Okolo (17) found that TDM or productivity was significantly correlated with F_3 and F_4 plot yields and recommended it as being effective in estimating yield potential in early segregating generations in wheat. Similar findings were reported by Ndondi (14), Neal and McVetty (15), Kao (6), and more recently Lulsdorf (8) found that TDM was highly correlated with grain yield in faba beans.

O'Brien et al. (16) pointed out that success in early generation selection depends on a high correlation between the performance of genotypes in F_2 and the performance of their progeny in later generations. Since many reports indicate that F_2 plant TDM is positively correlated with yield in later generations, it is not surprising that TDM is reliable in predicting cultivar performance. McVetty and Evans (11) indicated that TDM is the foundation upon which grain yield is built while Kao (6) concluded that TDM production might measure a genotype's ability to adapt to a particular environment.

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Résumé

Deux critères de sélection, le rendement en grains (RG) et la matière sèche totale (MST) de plantes F_2 prises individuelles, ont été comparés en utilisant deux en vue de déterminer lequel des deux critères croisements était plus efficace pour l'évaluation du potentiel de production globale de générations F_3 et F_4.

Des générations F_2 ont été plantées séparement aux champs avec un espacement de 60 cm entre les plantes et entre les lignes. Tous les croisements 75 F_2 présentant de bonnes caractéristiques agronomiques ont été fauchés à maturité et classés sur la base de la production de MST, RG et de la teneur en protéines des grains. Pour chacun des croisements, 20% des F_2 les plus performants pour ce qui est du RG et de la MST ont été sélectionnés et leurs performances ont été etudiées de près, comparativement au reste des lignes, sur la base d'éssais d'estimation de la production globale des F_3 et F_4 en 81 entrées individuelles de lignes 5 m uniques grâce à des expériences sur trois petites parcelles, avec les cultivars de Glenlea et de Benito souvant de contrôles.

Le critère RG a permis d'identifier cinq F_3 et six F_4 dont la production globale était plus élevée et la critère MST, dix F_3 et huit F_4 plus performants parmi les croisements. Cela veut dire que le critère de sélection MST était meilleur que le critère RG pour l'identification des F_2 à potentiel de rendement élevé.

Table 1. High yielding F_2 plants from cross 1 identified by grain yield (GY) or total dry matter (TDM) selection criteria

GY selection criteria			TDM selection criteria		
Plant No.	Yield (g)	Protein[a] (%)	Plant No.	TDM (g)	Protein (%)
3	69.9	18.0	3	180.0	18.0
9	63.9	17.6	12	180.0	17.6
12	75.1	17.6	16	188.0	17.3
14	64.4	18.0	18	174.0	18.4
16	81.3	17.3	21	176.0	19.2
22	66.1	17.7	22	190.0	17.7
27	63.8	17.4	23	220.0	19.7
32	66.1	16.2	25	185.0	16.5
36	63.4	16.3	39	198.0	19.5
40	66.3	18.9	40	190.0	18.9
54	69.7	18.8	49	176.0	19.2
59	71.9	16.7	53	176.0	18.2
65	65.0	18.0	54	218.0	18.8
66	63.7	17.3	63	180.0	18.8
70	63.1	18.0	70	175.0	18.0
Mean$\pm$S.D.	52.2$\pm$10.9	17.9$\pm$0.9	Mean$\pm$S.D.	149.6$\pm$25.6	17.9$\pm$0.9

[a] Grain protein content at 14% moisture.

Table 2. High yielding F_2 plants from cross 2 identified by the grain yield (GY) or total dry matter (TDM) selection criteria

GY selection criteria			TDM selection criteria		
Plant No.	Yield (g)	Protein[a] (%)	Plant No.	TDM (g)	Protein (%)
6	45.8	16.1	1	134.0	16.9
10	46.4	17.9	10	160.0	17.9
11	57.0	16.4	11	161.0	16.4
31	59.1	16.2	14	124.9	17.9
34	50.4	17.8	18	140.0	18.8
46	46.6	15.7	31	158.0	16.2
48	50.9	17.3	46	130.0	15.7
50	49.4	16.9	48	150.0	17.3
52	47.7	15.8	50	125.0	16.9
54	52.7	16.5	53	124.0	17.2
57	45.5	18.5	54	132.0	16.5
60	52.9	16.8	57	128.0	18.5
62	48.5	16.6	60	126.0	15.7
66	52.1	19.5	66	150.0	19.5
71	60.9	16.7	71	160.0	16.7
Mean±s.d.	31.0±14.1	17.8±1.3	Mean±s.d	92.1±31.4	17.8±1.3

[a] Grain protein content at 14% moisture.

Table 3. Mean grain yield and protein of the top 20% high yielding F_3 and F_4 bulks from cross 1

F2 derived F3 bulk lines			F2 derived F4 bulk lines		
Entry No.	Yield (g)	Protein[a] (%)	Entry No.	Yield (g)	Protein (%)
24	469.6	14.3	28	636.5	15.8
53**	454.5	14.8	16***	594.0	15.4
30	425.1	14.6	24	568.7	16.1
28	424.3	15.0	69	567.9	15.4
23**	417.9	15.5	4	559.5	15.9
18**	414.5	15.7	54***	556.4	15.0
36*	405.3	15.8	6	548.6	15.3
34	404.7	15.1	60	545.6	15.4
41	401.9	15.7	37	537.6	15.0
62	401.5	15.2	43	537.0	15.8
63**	401.2	14.7	68	535.3	14.8
25**	395.9	15.6	2	534.2	15.2
70***	394.0	15.2	21**	531.4	15.5
73	392.4	15.6	32	529.9	14.9
3***	391.2	15.5	38	527.0	15.2

[a] Grain protein at 14% moisture

* Lines identified by F2 grain yield (GY) selection criteria.

** Lines identified by F2 total dry matter (TDM) selection criteria.

*** Lines identified by both F2 GY and TDM selection criteria.

Table 4. Mean grain yield and protein of the top 20% high yielding F_3 and F_4 bulks from cross 2

F2 derived F3 bulk lines			F2 derived F4 bulk lines		
Entry No.	Yield (g)	Protein[a] (%)	Entry No.	Yield (g)	Protein (%)
10***	516.0	14.6	48***	653.9	15.2
59	503.8	13.4	7	631.4	15.2
77	455.2	13.3	10***	621.3	14.7
23	454	13.6	25	610.6	15.0
63	453.3	14.1	71***	604.6	14.6
48***	442.5	14.3	59	596.3	14.3
25	423.5	13.7	56	595.5	14.8
39	422.3	16.0	5	581.0	14.9
37	422.0	15.7	31***	578.8	14.6
29	418.0	15.7	67	573.5	14.5
18**	417.6	15.4	53**	563.4	15.5
73	414.4	13.8	37	562.1	15.0
70	412.7	13.8	41	553.3	14.8
49	407.7	15.2	8	552.8	14.8
72	407.4	13.7	32	551.6	14.9

[a] Grain protein at 14% moisture.
* Lines identified by F2 grain yield (GY) selection criteria.
** Lines identified by F2 total dry matter (TDM) selection criteria.
*** Lines identified by both F2 GY and TDM selection criteria.

A REVIEW OF BREEDING WHEAT FOR TOLERANCE TO ALUMINUM TOXICITY

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Abstract

Genetic variability for tolerance to mineral toxicities, and in particular to aluminum and manganese in acid soils, occurs in a number of crops, and has been widely exploited in wheat. Screening techniques in both the laboratory and the field are reviewed and the mode of inheritance of tolerance is indicated for a number of wheat varieties. In several cases, a single dominant gene is involved which can be easily and rapidly transferred into otherwise well-adapted varieties. Different genes may be involved in tolerance to different levels of toxicity, and to different toxic minerals. Tolerant varieties are now widely grown in many parts of the world, making production possible where none was possible before or increasing production in areas which were previously considered marginal.

The Problem

Soil acidity has been recognized as a problem for the cultivation of certain crop species for a very long time. However it is only more recently that the precise nature of the problem has been appreciated, in the form of toxic levels of minerals in the soil solution, e.g., a condition known as "crestamento" on wheat has been known in Brazil since 1925 (1).

Soils with low pH generally have high levels of exchangeable aluminum, iron, and manganese which are toxic to many plant and crop species. Such soils are also usually very deficient in calcium and phosphorus. Early workers in Brazil appreciated that the problem of "crestamento" was soil related and tried to explain it on the basis of soil acidity through pH, although there was not always a clear relationship between the severity of the symptoms and pH. It was Araujo (2, 3) who suggested that Al toxicity was the cause, based on the results of pot experiments.

The main soil types with low pH and high aluminum saturation in tropical Africa are the oxisols (ferrasols) and ultisols (acrisols) which usually found on old stable land surfaces from the Tertiary with a savannah vegetation, e.g the Miombo in Central Africa. Sanchez and Salinas (4) indicate that approximately 39% of the soils in tropical Africa are dominated by oxisols and ultisols representing 1143 million hectares.

Plants growing on acid soils are often considerably reduced in height and vigor such that semi-dwarf varieties of wheat may be unacceptably short when grown on acid soils. Such stressed plants also appear more susceptible to disease. Rooting is usually very shallow, so that the plants are loose in the soil, and the roots are short and thick and often swollen at the tip. In many

soils acidity increases with depth, so that while it may be possible to ameliorate the acidity in the upper layers, subsoil acidity remains a major problem. Shallow rooting results in the water stored in the subsoil being unavailable to the plant, making it very susceptible to even quite short periods of drought; several consecutive days without rain are common in most growing seasons in the tropics (5), and many of the acid soils are also inherently low in water holding capacity. This shallow rooting and the susceptibility to drought stress often results in low yields and presents a high risk to farmers cropping on these soils. Bouldin
(5) has calculated the depth of soil (initially at field capacity) to provide 6mm/day of evapo-transpiration for selected periods of consecutive days without rain on an oxisol at Planaitina near Brasilia (Table 1). The frequency at which these droughty periods occur is also indicated.

The Solution

The use of soil amendments (especially of lime, but also of high rates of phosphorus) is one strategy that has been successfully employed in combating soil acidity. Its success depends on the availability of suitable materials, preferably close to the areas where they are required, otherwise transport costs can make their use uneconomic.

Acid soils high in organic matter tend to complex aluminum. (6, 7). Thus the use of green manure or composts to increase organic matter content may also be beneficial in adsorbing Al and reducing its concentration in the soil solution (8).

The selection of better, less acid, soils is an obvious solution where such land is available in areas suitable for the production of a particular crop. With growing populations and greater pressure on the land, especially in the third world, this option becomes increasingly less tenable, and indeed, land previously not cropped because of its acidity, is now being brought into production.

A solution which the farmer may find easier to accept is the use of tolerant crops or cultivars. Of all the improved agriculture technologies the introduction of a new cultivar is probably the most easily accepted, giving immediate benefit over previous cultivars with very little, if any, need for a change in management practices.

Some crops are inherently more tolerant of acid soils than others e.g. cassava, cowpea, groundnut, pigeon pea, potato, rice, and rye (9) as well as tree crops such as coffee, tea, oil palm and rubber and fruit crops e.g. cashew nut, guava, citrus, pineapple and mango (10).

Cultivars tolerant to soil acidity in otherwise susceptible crops have been developed in bean, maize, sorghum, soybean, sweet potato and wheat.

Breeding for tolerance to soil acidity--For any breeding program to be successful there are four main requirements:

1) The setting of clear objectives.

2) The translation of these objectives into the required plant characters.

3) A suitable screening technique to identify preferred genotypes.

4) Genetic variability for the desired characters.

If any of these are lacking, progress will be slow or even non-existent.

Objectives and plant characters--Tolerance to soil acidity is a complex character involving not only tolerance to aluminum toxicity but, for some soils, tolerance also to manganese and iron toxicity and perhaps to phosphorus deficiency. Tolerance to these different factors may be inherited quite independently; as e.g., wheat (11). However once reduced to its component parts and provided the other requirements listed above are met, the development of cultivars tolerant to the soil acidity complex should be possible. Indeed even before the problem was fully defined wheat varieties tolerant to "crestamento" were being grown commercially in Brazil (1). However a greater understanding of the factors involved has led to a more systematic and rapid exploitation of the potential genetic solution to the problem of soil acidity.

Screening techniques--Genetic variability for characters such as height, days to maturity can be easily seen and measured by simple observation. Measurement of tolerance to mineral deficiencies presents a more complex problem; the reaction of the plants being determined by such factors as temperature, the concentration of the toxic mineral and also the concentration of major nutrients. The parameters which are to be used to indicate tolerance and how they are measured must also be considered. A further consideration is whether the screening is to be carried out in the laboratory or in the field.

A review of the some of the techniques that have used in small grain cereals (wheat, barley, rye, triticale and rice) is presented below.

1) Levels of Al: A range of Al levels, usually in nutrient solutions, have been used by various workers ranging from 1 to 30 ppm, although most work has been in the range of 5 to 10 ppm (12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26).

2) Time of exposure: Many workers have observed plants growing continuously in solutions containing aluminum for periods of up to 28 days (16, 17, 18, 19, 20, 21, 25, 27) while others have exposed plants to aluminum in nutrient solution for times ranging from 2 to 48 hours and then transferred them to solutions free of Al and observed their recovery (13, 14, 15, 22). Concentrations of Al in these latter studies have usually been higher than those where the plants have been grown continually in Al solutions.

3) Parameters measured: Most attention has been directed at measurements on root growth, mainly length after a certain period of time or the rate of extension, either in solutions with Al or after exposure to Al (14, 15, 17, 19, 20, 21, 22, 26, 28). Dry weight of roots (18) and dry or fresh weight of aerial parts (16, 17, 28) have also been measured. A root staining technique using haematoxylin after exposure to aluminum has been developed (29, 30, 31)--the greater the intensity of the stain, the greater the sensitivity. The stained root tip also acts as a reference point for measuring further growth.

The stress applied to the material under test will depend not only on the concentration and time of exposure to aluminum but also on other factors, such as temperature and the concentration of major nutrients. Camargo (32) has shown that for any given aluminum concentration in nutrient solution, the stress increases with increasing temperature and Camargo et al. (33) have shown that decreasing the level of the nutrients in the nutrient solution also considerably increases the stress (Table 2).

4) Field screening techniques: Yield comparisons of varieties grown on soils of different pH produced by liming acid soils have been used by several workers (e.g., 34). Others have recorded general plant growth and vigor of plants growing in acid soil (28, 35, 36).

In Zambia, a field screening technique on unlimed soil at Mbala has been used. The chemical analysis of this soil, classified as an acric ferrasol, is shown in Table 3, from which it can be seen that there are high levels of aluminum in the subsoil and up to 72% saturation in the 30-45 cm horizon.

These data are a mean of many samples taken over period of four years. There is however considerable variation throughout the field used for the nurseries and the trials. One or two 2-m rows of each cultivar under test are rated visually on a 0-9 scale for height and vigor at the soft dough stage relative to two checks, one tolerant (PF 7748 rated at 3) and one sensitive (Jupateco 73 rated at 8) on a 0-9 scale. The check varieties are planted at right angles to the test plots and also included as entries in the nurseries. The use of the check rows is essential so that the soil variation can be monitored.

Correlation between screening techniques and field performance--Where comparisons have been made between nutrient solutions and soil and/or field tests in assessing varieties for their tolerance to aluminum, good agreement is reported between the two methods despite differences in the techniques used (24, 25, 28, 37).

However, testing of the same material at different locations and on different soils or under different conditions in the laboratory will result in different assessments. Many entries in the CIMMYT Aluminum Tolerance Screening Nursery, previously tested in Brazil and Mexico, do not for example have sufficient tolerance when screened in Zambia under the conditions described above. Much of the wheat germplasm received from Brazil is highly tolerant but some lines with claimed tolerance do poorly, and the same is true of the performance of Zambian material in Brazil.

Genetic variability--The various screening techniques reviewed above, have indicated considerable genetic variability for tolerance to aluminum, manganese and iron in wheat and rice; tolerance to aluminum and manganese in triticale, rye and barley, soybean and common bean and to aluminum in sorghum.

Several studies have been carried out to determine the inheritance of tolerance to aluminum toxicity in wheat. Camargo (38) has worked principally with Brazilian varieties while Lafever and Campbell (23), and Polle et al. (29) have studied varieties from North America.

Camargo (38) investigated the inheritance of tolerance in four varieties of wheat showing different reactions to aluminum; BH1146, showing tolerance up to 10 ppm Al in nutrient solution; Atlas 66 tolerant up to 6 ppm; Tordo up to 2 ppm; and Siete Cerros which was totally sensitive.

The parents and F_1 and F_2 generations from crosses between varieties which were tolerant and sensitive to 6 ppm Al, were screened against both 3 and 6ppm Al. At 3 ppm the tolerance of BH1146 is dominant and the F_2 segregates in the ratio of 3 tolerant to 1 sensitive, indicating genetic control by a single pair of genes. However at 6 ppm the dominance is incomplete and in the F_2 there are roughly equal numbers of tolerant and sensitive plants.

In the cross between Atlas 66 and Siete Cerros, two pairs of dominant genes are involved; the F_2 segregating in the ratio of 15 tolerant to 1 sensitive when screened at 3 ppm. In all the crosses studied there was a gradual decrease in the dominance of the one or two pairs of genes, with increasing levels of Al in the nutrient solution.

In the cross between the two tolerant lines, BH1146 and Atlas 66 the F_1 was tolerant to 6 ppm and the F_2 segregated in the ratio 15:1 indicating the involvement of two dominant genes, while at 10 ppm the ratio was 12:4 (3:1) indicating that only one of the two genes was effective at this higher concentration, i.e. that from BH1146. The F_1 was not completely tolerant (9 tolerant plants to 6 sensitive) showing incomplete dominance and no additive effects. The additive effects of tolerant genes from different sources would be a benefit in a plant breeding program.

Table 4 summarizes the results of this study. Camargo recommends the use of BH1146 as a parent for Al tolerance with a single dominant gene, conferring tolerance up to 10 ppm. It has indeed been widely used in Brazil and elsewhere, and has been particularly useful in the breeding program in Zambia. A single gene conferring a high level of tolerance makes it very easy to handle in a breeding program and rapid advances in tolerance can be made by screening segregating populations only once or twice under Aluminum stress while concentrating on other characters in other generations.

Other workers have also studied the inheritance of tolerance in Atlas 66 (19, 20, 39) with somewhat differing results depending on the other parent used and the environmental conditions. Camargo's results (38) have indicated two dominant genes which is largely supported by Choudhry (20), who also indicates that some maternal effects are involved. These maternal effects have also been found by Klimashevskii (39). Campbell and Lafever (19) indicated a polygenic mode of inheritance with additive effects.

Studies involving other varieties of wheat e.g., Redcoat and Arthur (sensitive) and Seneca and Thorne (tolerant) (19, 23) have indicated that sensitivity to aluminum toxicity was controlled by a single recessive gene while tolerance was controlled in a polygenic manner. Other workers (29) have also concluded that aluminum tolerance is controlled by several genes and that these were independent of genes for tolerance to manganese.

Sapra et al. (26) have tested several diploid and tetraploid wheats and also, ryes and triticales for their root response to 0 and 8 ppm Al in nutrient solution. Their results indicate an association of aluminum tolerance or sensitivity with certain genomes. The A genome confers a high level of sensitivity while the B and R genomes confer tolerance. The E genome in *Agropyron elongatum* also confers a high level of susceptibility. Bread wheat having the A, B and D genomes and hexaploid triticale the A, B and R genomes therefore contain genes for aluminum tolerance.

Aniol and Gustafson (40) working with nullisomic-tetrasomic and ditelosomic lines of the cultivar Chinese Spring, and also rye addition and substitution lines of various wheat varieties have been able to determine the chromosomal location of certain tolerance genes. They conclude that tolerant genes occur on the following chromosomes arms:- 6AS, 7AS, 2DL, 4DL, 4BL, 7DL in wheat and 6RS, 3R and 4R in rye. Elliot (41) has also shown that a tolerance gene may be carried on chromosome 5D in Atlas 66.

Fisher and Scott (42) working with the variety Carazinho have shown its tolerance to aluminum to be controlled by a single dominant gene and its tolerance to Mn to be controlled by two recessive genes.

These and other studies show that in many cases tolerance is quite simply controlled and should be easily used in breeding programs.

One variety which has been widely and successfully used in breeding for acid soil tolerance is Alondra, which was released in Brazil in 1980. When screened against aluminum, Alondra is quite sensitive. This apparent anomaly may be explained by the fact that it is reported (43) to extract and utilize phosphorus very efficiently at low levels of availability in the soil. This character would be of considerable value in acid soils which are usually very low in available phosphorus.

Results

Many acid-soil tolerant cultivars have been released for a number of crops over the last ten years or so, particularly for wheat. Tolerant cultivars of beans, soybeans, sorghum, and maize are now also available. In Zambia wheat production under rainfed conditions, is now possible. The most reliable areas for production appear to be at higher altitudes (above 1500 m) where the annual rainfall is over 1000 mm causing considerable leaching of the soils resulting in high level of acidity. The release of two cultivars of Brazilian origin with aluminum tolerance have made it possible for farmers to achieve yields of 2t/ha. Yields in trials are now approaching 3t/ha. Figure 1 shows yield improvements over the last six years in entries in the final stages of variety testing in Zambia relative to the control variety Whydah which was released in 1984. Data for the trial mean, the top three entries and the highest yielding entry are shown. A general steady rise in all three indicators is apparent. It should be pointed out however that this increase in yield is due not only to increasing aluminum tolerance, but also to increased disease resistance (particularly to *Helminthosporium sativum*) and straw strength. There is a small yield decrease in 1986-87, resulting from a deliberate policy of maintaining certain aluminum sensitive lines in the program for use in areas of the country where aluminum toxicity is not a problem. Figure 2 indicates the increase in aluminum tolerance scores over the same period where the same trends can be seen.

Benefits

The use of tolerant cultivars:

1) Allows crop production without liming in soils where production would be impossible or uneconomic without tolerance. This is particularly important when opening new land.

2) Reduces the lime requirement compared with a susceptible cultivar.

3) Increases production even on limed land where subsoil acidity is a factor.

4) Allows a longer period of production before the need for lime on marginal land, where the use of fertilizer may increase the acidity above a critical level.

At Mbala, Zambia, a trial was set up in 1981-82 to investigate the effect of incorporating various rates of lime to different soil depths on the yield of wheat (44). The soil chemical analysis data for the site without lime are shown in Table 3. The residual effects of these treatments have been investigated on a number of wheat varieties with different levels of aluminum tolerance. The data (mean of 6 years) is presented in Fig. 3 for three varieties of wheat, Jupateco 73 (intolerant), PF72640 and Hornbill (moderately tolerant), Whydah (tolerant). With zero lime the yield of Jupateco 73 is extremely low (0.2t/ha) while that of Whydah is 1.3t/ha. Even with the addition of 3t/ha lime, incorporated in the top 15 cm of the soil, the yield of Jupateco is less than that of Whydah without lime. ie. the level of tolerance in Whydah is equivalent in value to at least 3t/ha lime under these particular conditions. Also Jupateco yields on land with 6t/ha, incorporated to a depth of 30 cm. are significantly lower than Whydah with 3t/ha lime. The moderately tolerant varieties PF72640 and Hornbill respond to lime to a much greater extent than the tolerant variety Whydah; 67% yield increase with 3t/ha lime and 90% with 6t/ha compared with 18 and 50% respectively for Whydah.

Conclusions

The breeding of lines tolerant to soil acidity offers a very effective method of increasing crop production in areas that have previously been considered unsuitable or marginal without the use of soil amendments or their use at relatively low levels. The introduction of a new variety can usually be achieved with the minimum disturbance of the farmers' management practices and offers and immediate improvement over previous varieties. The inheritance of tolerance to individual mineral stresses is, in many crops, quite simply controlled, making it easy to handle in a breeding program. However tolerance to individual mineral stresses is usually inherited quite independently. Tolerance is often inherited in a dominant fashion and effective screening methods can be developed for use in either the laboratory in nutrient solution or in the field on acid land.

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Résumé

La variabilité génétique pour la tolérance aux toxicités minérales, et en particulier aux toxicités aluminiques et manganiques dans les sols acides, est observable chez de nombreuses plantes et a été largement exploitée chez le blé. Les techniques de sélection, tant au laboratoire qu'au champ, sont passées en revue et le mode de transfert génétique de la tolérance est précise pour quelques variétés de blé. Dans plusieurs cas, un seul gène dominant est impliqué. Il est aisément et rapidement transférable aux variétés présentant déjà d'autres caractères d'adaptation intéressants. A différents niveaux de toxicité et à différentes toxicités minérales correspondraient différents gènes. Des variétés tolérantes sont maintenant largement cultivées de par le monde. Elles permettent de produire dans des régions incultes ou d'augmenter la production dans des régions considerées précédemment comme marginales.

Table 1. Depth of soil required to provide 6 mm/day of evapotranspiration for selected periods of consecutive days without rain (5)

Consecutive Days without rain	Frequency at Brasilia	Depth of Soil (cm) initially at field capacity, reduced to wilting point
8	3/year	40
10	2/year	50
13	1/year	65
18	2 years in 7	90
22	1 year in 7	110

Table 2. Root extension (mm) in a 72-hour period in an aluminium-free, complete-nutrient solution following 48 hours exposure to different levels of Al in different concentrations of nutrient solution

	5 ppm Al				10 ppm Al				20 ppm Al			
Cultivar	1 1	1 2	1 5	1 10	1 1	1 2	1 5	1 10	1 1	1 2	1 5	1 10
BH1146	110	90	60	40	93	78	44	3	71	59	33	1
IAC 5	110	93	57	28	70	64	33	1	55	46	20	2
Siete Cerros	9	0	0	0	0	0	0	0	0	0	0	0

Adapted from Camargo et al. (33)

Table 3. Soil Chemical Analysis--Katito, Mbala, Zambia. Field used for screening for Aluminium Tolerance

Depth	Ex Ca meq/100g	Ex Mg meq/100g	Ex K meq/100g	Ex Al meq/100g	Sol Al ppm	%Al sat	Av P ppm	Mn ppm	pH $CaCl_2$
0-15cm	0.6	0.3	0.19	1.08	13	40	4	9	4.3
15-30cm	0.5	0.3	-	1.19	21	51	-	12	4.2
30-45cm	0.3	0.2	-	1.30	27	72	-	16	4.1

Table 4. Genetic relationship between four wheat cultivars in their tolerance to aluminium toxicity

Crosses between cultivars	Concentration of aluminium	Segregation in F_2
	ppm	
Tordo/Siete Cerros	2	3:1
BH1146/Tordo	3	3:1
BH1146/Siete Cerros	3	3:1
Atlas 66/Siete Cerros	3	15:1
BH1146/Atlas 66	6	15:1
BH1146/Atlas 66	10	12:4

Source: Camargo (38)

Figure 1. Wheat yields in Zambia National Variety Trials 1982-1987.

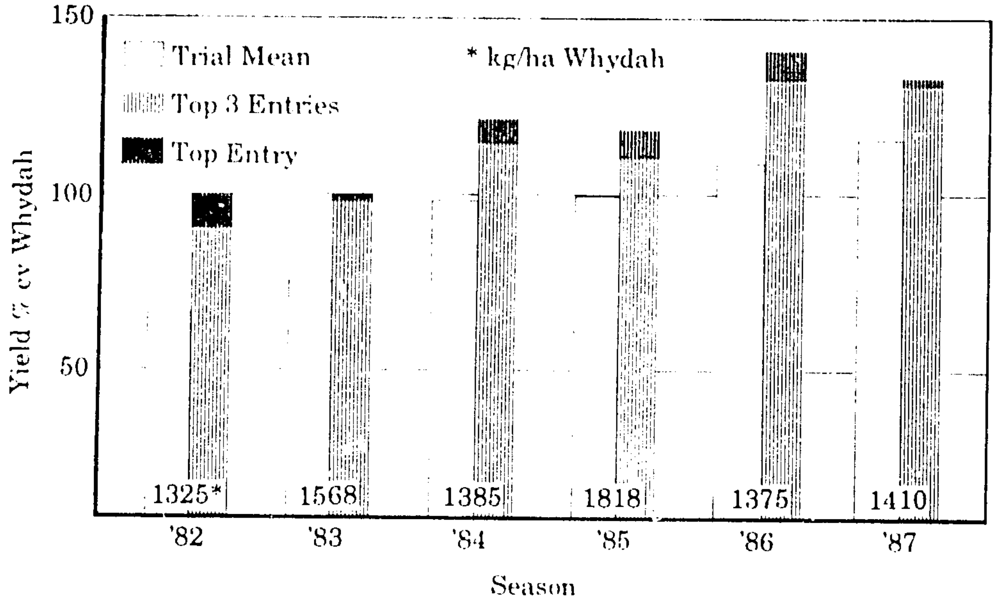


Figure 2. Aluminum tolerance ratings in Zambia National Wheat Variety Trials 1982-1987.

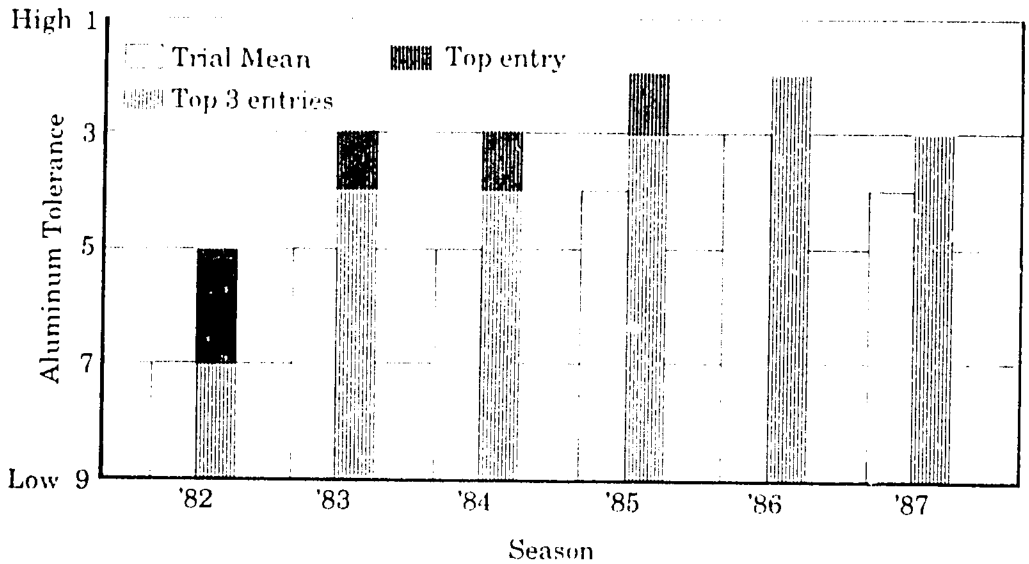
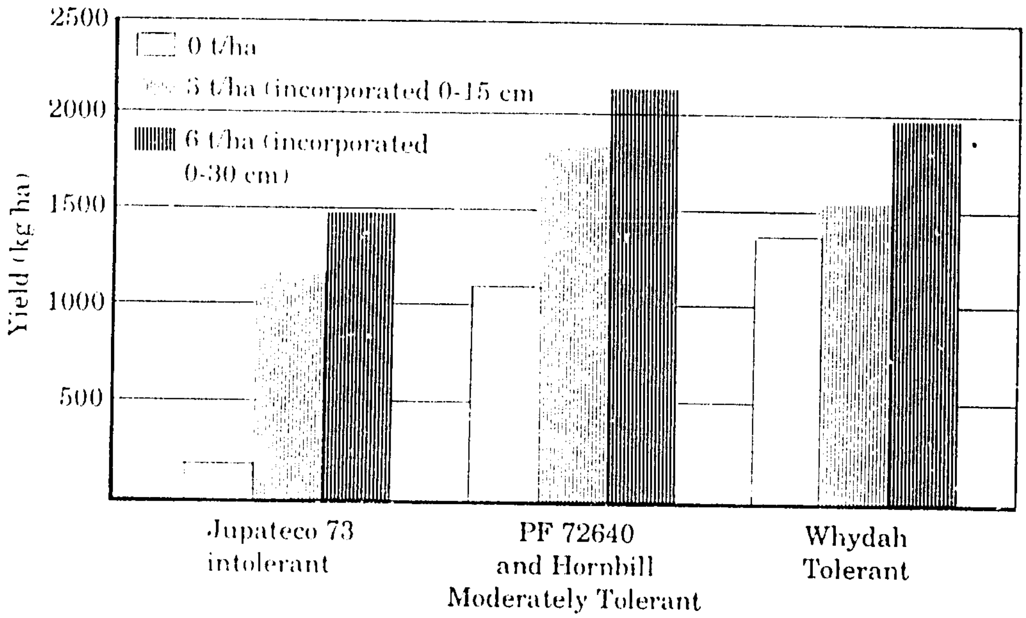


Figure 3. Yield response to liming of three cultivars of wheat with different levels of tolerance to aluminum. Mean of Five Years (1982/3-1986/87), Mbala, Zambia.



COMPARISON OF THE SINGLE SEED DESCENT (SSD) METHOD, THE MULTIPLE SEED DESCENT METHOD (MSD) AND THE BULK POPULATION METHOD FOR YIELD AND PROTEIN IMPROVEMENT IN WHEAT

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Abstract

The bulk population (BP), multiple seed descent (MSD) and single seed descent (SSD) methods were compared in a cross to determine their relative effectiveness in a yield and protein improvement program. F4 BP, F6 SSD and F6 MSD lines were seeded in 81-entry 5 m single row plots in a triple lattice experiment and 12-entry randomized completed block trials, respectively, with the cultivars Glenlea and Benito as check varieties.

Breeding methods did not influence mean grain yield or grain protein, but ranges in grain yield and grain protein, as well as phenotypic variances, were greater for the MSD lines than in lines derived by either the SSD or BP method. The top 20% of the best-performing lines, whose yields were closest to mean grain yield of the check variety Glenlea, were mostly lines derived by the MSD method, followed by the ones derived through the BP method. With respect to the mean grain protein, the lines that came closest to check variety Benito were the ones derived by the MSD method, while the SSD and BP methods were equally effective in providing high protein lines (lines having a protein level equal to or higher than check variety Benito).

A direct comparison of 36 BP lines with their corresponding 36 SSD lines and top ranking 36 MSD sister lines (lines originating from the same F2 single plant) indicated that 52.7% of the MSD lines were high yielding compared to only 5.6% and 16.7% for the SSD and BP lines, respectively. For grain protein, 52.8% of the MSD sib lines had mean grain protein equal to or higher than the mean grain protein of Benito compared to 50% and 41.7% for the SSD and BP lines respectively. The proportion of corresponding lines that combined both high yield and high protein was 19.4% for the MSD lines, and 2.8% of the BP lines, respectively. The MSD method was superior to the SSD and BP methods in breeding for high yield alone and it also provided the greatest number of lines which combined both high yield and high protein content.

Introduction

Yield and protein content are important aspects of wheat production. Breeding methods for producing wheat cultivars which combine both high yield and high protein have not been defined and efforts to improve these traits simultaneously have met with very little success. This may be due to 1) the commonly observed negative relationship between yield and protein, 2) the complexity of selecting segregants with the right combination of genes for both yield and protein, since both are quantitative characters, and 3) the ineffectiveness of traditional plant breeding methods currently used by plant breeders.

This study was designed to compare the effectiveness of the traditional bulk population (BP) and single seed descent (SSD) methods with the non-traditional multiple seed descent (MSD) method of improving grain yield and grain protein simultaneously.

The BP method involves taking a random seed sample from each F_2 plant to grow F_3 populations, then harvesting all plants from each population to propagate the next generation. Yield and protein determinations are therefore done on each bulk harvested from each population and selection is practised among lines or within bulk populations.

The SSD method consists of advancing hybrid populations by taking a single seed from each F_2 plant to produce the F_3 generation. The process is repeated for the F_4 and subsequent generations, followed by seed increase for replicated yield and protein tests at one or more locations (2).

The MSD method involves taking ten to fifteen seeds from each F_2 plant to produce the F_3 generation. A single seed is then taken from each F_3 plant to produce the F_4 generation. The process is repeated for the F_5 and subsequent generations, followed by seed increase for replicated yield and protein tests at one or more locations (7).

A number of breeding methodology studies have compared methods other than the MSD method. Tee and Qualset (9) compared the SSD and BP methods for heading date, plant height and grain yield and concluded that the methods differed substantially only for characters such as height, that had large competitive effects in populations. Knott and Kumar (5) compared early generation yield testing with the SSD procedure and found that the SSD lines were at least as good as the best generation tested lines.

Empig and Fehr (3) compared the SSD, restricted cross-bulk (RCB), maturity-group bulk (MGB) and cross-bulk (CB) methods in soybean using three crosses and found no significant differences among method means for yield. Wright and Thomas (10) reported that the SSD method produced as many lines worthy of advanced trials as the pedigree method. Haddad and Muehlbauer (4) compared the BP and SSD methods in three lentil crosses at two locations for seed weight and grain yield. They found that seed weight was significantly heavier for lines developed by the BP method than lines derived by the SSD method; and pointed out that, in general, the SSD method maintained more high yielding lines than the BP method. Muehlbauer et al. (6) compared the BP and the SSD methods by computer simulation to determine which breeding method retained the most additive genetic variation after four generations; and found that the additive genetic variance of F_6 populations from the BP method was smaller than in those from the SSD method. Park et al. (8) compared 52 doubled haploid (DH) lines with lines developed by the pedigree (PD) and the SSD methods and found no differences in grain yield, heading date or plant height between the three methods, while Boerma and Cooper (1) compared the SSD method with other breeding methods in soybean.

The objective of this study is to compare a new method, that is the multiple seed descent, with the traditional bulk population (BP) and single seed descent (SSD) methods.

Materials and Methods

The two parental lines used in this study were line 62, a high yielding low protein Glenlea derivative and line 99, a low yield high protein type. A cross between these lines was made in 1980 and F_2 seed produced in the green house. The F_2 material was spaced planted in the field 60 cm between rows with the high yielding and high protein check cultivars Glenlea and Benito in alternate rows.

A random sample of 100 F_2 plants with good agronomic characteristics was obtained and advanced one generation in the field by the BP method. At maturity 75 F_3 families which had enough seed for a three replicate yield test were retained for further testing.

For the SSD method one seed from each of the same 100 F_2 plants was planted and advanced twice in the greenhouse to obtain F_4 generations. Seeds from the F_4 plants were grown in the field in 3-m head-rows for seed increase. At maturity 75 F_5 SSD families which had enough seed for a three replicate yield test were retained for further testing.

For the MSD method, 12 seeds from each of the same 100 F_2 plants were planted separately in the greenhouse to propagate the F_3 generation. A single seed was then taken from each F_3 plant and seeded in the greenhouse to obtain the F_4 generation. Seeds from F_4 plants were grown in the field in 3-m head-rows for seed increase. At maturity 36 MSD families, each with a minimum of 10 sibs (360 lines in total) and represented in the families derived by the BP and SSD methods were retained for further testing.

In 1984, the 75 F_4 lines derived by the BP method, 75 F_6 SSD lines and the 36 F_6 families (360 lines) derived by the MSD method were tested for yield and protein. The 75 F_4 bulks and 75 F_6 SSD lines were seeded in 9x9 triple lattice experiments in 5m single row plots; each including also, four parental lines and two check cultivars, i.e., Glenlea for yield and Benito for grain protein. The 36 F_6 MSD families each of 10 sister lines were planted in 36 separate but contiguous yield tests as 12 entries (10 sib lines plus the varieties Glenlea and Benito as checks) replicated three times in randomized complete block experiments in 5-m single row plots. All experiments were seeded on the same block of land which was under summer fallow the previous year. The plots were maintained weed-free by hand. At maturity, all lines were harvested by hand and grain yield recorded. Grain protein was determined by the Kjeldahl method.

Analyses of variance for grain yield and grain protein were done for each trial. In order to compare the three methods, entry means for yield and protein were expressed as percentages of the check mean, i.e. for grain yield as a percentage of the mean yield of Gleanlea, and for grain protein as a percentage of the mean grain protein of Benito.

The criteria for comparison of the three breeding methods were: 1) method means, 2) character range, 3) phenotypic variance, and 4) means of the top 20% of selected lines

Results and Discussion

Results indicated that yield and protein method means were similar for the three methods (Table 1). Grain yield method means for the three methods were lower than the check mean, while grain protein method means were closer to their respective mean protein check.

The range of grain yields of the 75 BP lines was 48.7%, that of the 75 SSD lines was 40.2% while that of the 360 MSD lines was 61.2%. Grain protein range for the BP lines was 15.2%, with 20.8% and 36.3% for the SSD and MSD lines respectively (Table 2). The MSD method had larger ranges than the others for both grain yield and grain protein.

Phenotypic variance (calculated on an entry mean basis) among the line means was greatest in MSD lines and that of SSD lines was greater than those of BP lines (Table 3). A large proportion of this variance of advanced generation lines could have resulted from genotypic variance.

At a selection intensity of 20%, 15 out of 75 BP and SSD lines and 72 out of 360 MSD lines were selected. One BP line and four MSD lines had mean grain yields greater than the mean yield of Glenlea. Seven BP, 2 SSD and 28 MSD lines had mean yields 90 to 100% of the mean yield of Glenlea (Table 4) indicating that the MSD method provided the most lines that best approximated (i.e. greater than 90%) the mean yield of Glenlea.

By the same classification, for grain protein all BP and SSD lines and 54 MSD lines of the top 20% had mean grain protein greater than the mean grain protein of the check cv. Benito (Table 5). Three MSD lines had mean grain protein equal to Benito.

Implications and merits of the MSD method over the classical BP and SSD methods were further assessed in terms of 1) the frequency of high yielding sister lines in each MSD family, 2) the range and amount of variation within MSD families and 3) the proportion of MSD lines that combine both high yield and high protein.

The proportion of high yielding sister lines (lines with mean yield over 90% of the mean yield of Glenlea) within each MSD family was small. Ten MSD families included one high yielding line, two families had two, six families had three, one family had five and two families had seven high yielding lines. Fifteen MSD families had no high yielding lines.

There were significant differences among the 10 sib lines of each of the 36 MSD families in both grain yield and grain protein indicating that the MSD procedure provided for selection within MSD families as well as selection among families. The range in grain yield within MSD families varied from

2.4% to 16.2%. Grain yield and grain protein ranges among MSD families were 67% and 21% respectively, indicating that the range among families for the two characters studied was greater than the range within families.

A direct comparison and classification of the 36 BP lines and their corresponding (lines originating from the same F_2 single plants) 36 SSD and top ranking 36 MSD sibs indicated that 52.8% of the MSD top ranking sibs, 16.6% and 5.6% of the BP and SSD lines (Table 6) had mean yields greater than 90% of the mean yield of Glenlea, respectively.

For grain protein, 50% (18 out of 36) of the SSD lines, 41.6% (15 out of 36) of BP lines and 52.7% (19 out of 36) of the MSD top ranking sister lines had mean grain protein equal to or greater than the mean grain protein of the check cv. Benito (Table 7) indicating that the proportion of high protein lines derived by the SSD procedure and that derived by the MSD procedure were very similar.

One BP line and 7 MSD lines combined high grain yield and high grain protein. None of the high yielding SSD lines were also high protein lines, indicating that the MSD method was superior to the BP and SSD methods in providing lines which combine both high yield and high protein.

Conclusion

This study indicated that the MSD method was superior to the BP and SSD methods in providing high yielding lines per se and in combining high yield and high protein. The BP method was superior to the SSD method in providing high yielding lines per se. The MSD and SSD methods were equally effective in providing high protein lines. This may have been due to the fact that most of the SSD lines with high protein were low yielding lines. It was apparent from direct comparison of SSD lines and their corresponding high ranking MSD sister lines that the SSD method failed to exploit the potentially available yield levels in the cross. The advantages of the SSD procedure have been described by Brim (2). The MSD method has all the advantages of the SSD method plus the following additional advantages:

1) It permits carrying a large number of lines until they attain reasonable homozygosity, thus maximizing genetic variability of a cross.

2) It reduces the risk of loss in genetic variability due to germination failure of a single seed, seedling survival and the ability of each plant to produce at least one seed.

3) Selection within and between families can be done on the advanced generation lines, thus providing the opportunity to exploit all possible potential of a cross, compared to the SSD method where selection is limited to between lines.

The major limitation of the MSD method is that it requires more space to evaluate the advanced generation lines. However, the savings in labor and space over the generation advancement period which would otherwise have been geared to extensive and costly early generation testing will definitely outweigh this disadvantage; making the MSD method a viable method for yield and protein improvement programs.

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Résumé

Les méthodes basées sur la population en vrac (BP), le multiple seed descent (MSD) et le single seed descent (SSD) ont été comparées pour déterminer leur efficacité relative, dans le cadre d'un programme d'amélioration des rendements et de la teneur en protéines. Les variétés F4 BP, F6 SSD et F6 MSD ont été semées en lots expérimentaux à trois parcelles, en lignes uniques avec 81 entrées espacées de 5 m, et les éssais de production en vrac ont porté sur 12 entrées choisies de manière aléatoire, respectivement, des cultivars de Glenlea et de Benito servant de contrôles.

Les méthodes de sélection n'ont pas eu d'incidence sur le rendement moyen en grain ou sur la teneur en protéines des grains; toutefois, l'éventail des rendements en grains et des teneurs en protéines des grains, ainsi que les variances phenotypiques, étaient plus importants chez les lignées MSD que chez les lignées dérivées des méthodes SSD et BP. Les 20% choisis parmi les lignées les plus performantes, c'est-à-dire, dont les rendements étaient les plus proches des rendements moyens de la variété témoin Glenlea, étaient constitués en majorité des lignées provenant de la méthode MSD. S'agissant de la teneur moyenne en protéines des grains, les lignées les plus proches de la variété Benito, qui servait de contrôle, ont été celles dérivées de la méthode MSD, alors que les lignées SSD et BP ont démontré des performances égales pour la production de grains à teneur élevée en protéines (c'est-à-dire, égale ou supérieure à celle du Benito).

Il est ressorti d'une comparaison directe entre 35 lignées BP et leurs 36 lignées correspondantes SSD et 36 variétés parentales (provenant de la même génération F2 unique) MSD à haut rendement que 52,7% des lignées MSD étaient des variétés à haut rendement en protéines, contre seulement 5,6% et 16,7% pour les lignées SSD et BP, respectivement. S'agissant de la teneur en protéines des grains, 52,8% des lignées descendantes ont produit des grains avec une teneur moyenne en protéines égale ou supérieure à celle du Benito, contre respectivement 50% et 41,7% pour les SSD et BP. La proportion des lignées correspondantes pour ce qui est des rendements élevés et des hautes teneurs en protéines des grains était de respectivement 19,4% pour les MSD et 2,8% pour les BP. La méthode MSD s'est révelée la meilleure par rapport aux méthodes SSD et BP pour la sélection de variétés à haut rendement et elle a également produit le plus grand nombre de lignées performantes pour ce qui est à la fois des rendements élevés et des hautes teneures en protéines.

Table 1. Grain yield and grain protein expressed as percentage of check means for BP, SSD and MSD methods

Method	Yield	Protein
BP	80.8 ± 1.0	98.8 ± 0.3
SSD	72.8 ± 0.9	100.6 ± 0.4
MSD	80.7 ± 0.5	103.1 ± 0.2

Table 2. Range of grain yield and protein expressed as percent of check means for the BP, SSD and MSD lines

Method	Ranges of means expressed as % of check means Yield	Protein
BP	56.0-104.7(48.7)[a]	92.7-107.9(15.2)[a]
SSD	55.7-95.9 (40.2)	89.9-110.7(20.8)
MSD	46.1-107.3(61.2)	90.0-126.3(36.3)

[a] Figures in brackets are ranges for yield or protein.

Table 3. Phenotypic variances for grain yield and grain protein for the BP, SSD and MSD methods

Character	BP	SSD	MSD
Yield	2811.86**	2853.70**	3707.51**
Protein	0.22**	0.33**	0.56**

** Significant at the 0.01% probability level.

Table 4. Classification of the mean yields of the top 20% of the lines from BP, SSD and MSD methods in relation to the mean yield of the check cv. Glenlea

Mean yield relative	No. of lines		
to Glenlea	BP	SSD	MSD
>Glenlea	1(6.6)[a]	0(0.0)	4(5.6)
(90-100)%	7(46.7)	2(13.3)	28(38.9)
(80-89)%	7(46.7)	11(73.3)	27(37.5)
<80% of Glenlea	0(0.0)	2(13.3)	13(18.0)

[a] Percentage of selected lines in each class.

Table 5. Classification of the mean grain protein of the top 20% of the lines from the BP, SSD and MSD methods in relation to the mean grain protein of the check cv. Benito

Mean grain protein compared to Benito	No. of lines BP	SSD	MSD
(1) >Benito	15(100)[a]	15(100)	54(75.0)
(2) =Benito	0(0.0)	0(0.0)	3(4.2)
(3) <Benito	0(0.0)	0(0.0)	15(20.8)

[a] Percentage of selected lines in each class.

Table 6. Classification of 36 BP lines and their corresponding 36 SSD and 36 top ranking MSD sib lines in relation to the mean grain yield of the check cv. Glenlea

Mean grain yield compared to Glenlea	No. of lines BP	SSD	MSD
>Glenlea	1(2.8)[a]	0(0.0)	3(8.3)
(90-100)% of Glenlea	5(13.8)	2(5.6)	16(44.4)
(80-89)% of Glenlea	16(44.4)	8(22.2)	13(36.1)
80% of Glenlea	14(39.0)	26(72.2)	4(11.2)

[a] Percentages of selected lines in each class.

Table 7. Classification 36 BP lines and their corresponding 36 SDD and 36 top ranking MSD sib lines in relation to the mean grain protein of the check cv. Benito

Mean grain yield compared to Glenlea	No. of lines BP	SSD	MSD
>Benito	12(33.3)[a]	16(44.4)	16(44.4)
=Benito	3(8.3)	2(5.6)	3(8.3)
<Benito	21(58.4)	18(50.0)	17(47.3)

[a] Percentages of selected lines in each class.

PHOSPHORUS NUTRITION OF WHEAT IN ACID LATOSOLS AND VOLCANIC SOILS

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Abstract

The soils with which we will concern ourselves in this paper, namely volcanic and latosolic acid soils, present special problems regarding phosphorus use and therefore demand special solutions vis-a-vis the management of this nutrient.

Volcanic soils are characterized by their capability to react rapidly with large amounts of phosphorus, particularly under acid conditions. Consequently, the availability to plants of soluble phosphates applied as fertilizer is quickly depressed, and only about 10% of the applied phosphorus is utilized by most upland crops. The response to phosphorus follows a normal response curve even though its efficiency may be reduced in comparison to other soils.

It should also be pointed out that phosphorus fixed on the soil colloids is not totally unavailable to plants. In fact, it is thought that it is slowly available and the amount of available P builds up in these volcanic soils with repeated P application as shown by the work in Chile of Schenkel and Baherle.

In the case of wheat, application of phosphate fertilizers in the form of granules in the row is better than broadcasting because the fertilizer is then available in the early stages of growth.

Workers in Chili have noted a good correlation between phosphorus level in the soil (Olsen method) and the response of wheat to phosphorus application.

Latosolic acid soils are characterized by two main problems from the point of view of crop growth: 1) low pH with its accompanying high exchangeable aluminum saturation and 2) inherently low soil phosphorus levels.

Many factors affect the availability of phosphorus to plants in these soils. Among the most important is the clay content of the soil. As clay content increases, more P needs to be applied to maintain the levels of P available for plant uptake. A good strategy for these soils may be to apply a large quantity of phosphorus to begin with and maintain the soil fertility level with lower annual applications. Of course, there are many factors that affect the choice of a fertilizer source, such as ease of availability, price, etc.

Single Superphosphate (SSP) is a very attractive fertilizer for these soils because it contains 60% by weight of gypsum ($CaSO_4.2H_2O$) and is therefore a useful source of both Ca and S. The use of SSP has also been very useful in

moving calcium down the profile. Small amounts of calcium moving down the profile should increase effective rooting depth.

Because of the high needs of phosphorus on this soil, a calibration method for the response of wheat to phosphorus is essential. Brazilian workers are using the Mehlich method and getting a good correlation between soil P levels and yield.

Introduction

Phosphorus is classified as the second most important element for crop production. It is deficient in most soils around the world to achieve maximum yields. Because phosphorus is a natural mineral resource, its amount is finite and therefore, it has to be used with the greatest efficiency possible.

The soils with which we will concern ourselves in this paper, namely volcanic and latosolic acid soils, present special problems regarding phosphorus used and therefore, demand special solutions vis-a-vis the management of this nutrient. Much of the agricultural production of the developing world occurs on these volcanic and latosolic soils. They are naturally low in phosphorus and also have certain characteristics that reduces the efficiency of applied phosphorus. Therefore, if we are going to increase production on these soils, phosphorus will play a key role.

We should draw on previous experiences of other researchers to orient our own research. The experiences I bring to you today are mainly those of Latin American researchers and while the data presented may not have direct application here in East Africa, I hope it can form the basis of discussion for further work in this very important area of agricultural research within your region.

Volcanic Soils

General properties--Volcanic soils or andosols occur under a wide range of climatic conditions from cold subalpine regions to humid equatorial tropics in various parts of the world (18). The common profile of volcanic soils consists of a thick loose A horizon with a high content of organic matter which resembles that of a Chernozem and a brownish structural B to BC horizon. Most mature andosols are so highly weathered that the clay content often amounts to about one half of the total soil mass. The principal component of the clay fraction is allophane. Most of the special properties of these soils are a consequence of the properties of this allophane (4).

The principal cause of the extraordinary accumulation of organic matter in andosols is thought to be the comparatively stable combination of organic matter with allophane. Soils with a high content of allophane characteristically contain more organic matter than do soils developed under similar conditions but without allophane. The relatively high water-holding capacity of the soils is perhaps an additional factor in the accumulation of organic matter. Ishizuka and Black (4) and Kanno (5) analyzed 23 samples of A and A_1 horizons of soils of the Ando group and found that the organic matter content ranged from 7.6% to 40.3% with an average of 18.1%.

Figure 1 shows the distribution of organic matter in soil samples taken from different areas in Chile. The majority of the samples from the non-volcanic soil have an O.M. content of below 4%. Those derived from volcanic material show a much higher level of organic matter. Only 1% of the samples were below 2% O.M. The majority of the samples was distributed between 8% and 16% organic matter. Investigacion Agropecraria (3) and Kosaka and Iseki (7) investigated the combination of organic matter with inorganic matter in andosols and found that organic matter was combined with aluminum and iron.

The solid phase of the soils occupies only 20 to 30 percent of the soil volume. Consequently, the bulk density is low and the porosity and water-holding capacity is high (4). The cation exchange capacity of the soils at pH 7 is relatively high but the effective cation exchange capacity is considerably lower because the soils are generally acid and the cation exchange capacity is highly pH-dependent. The action exchange sites show preferential sorption of calcium and magnesium over ammonium and potassium presumably because of the predominance of organic over inorganic exchange sites (4)

From the viewpoint of soil productivity volcanic soils have generally been regarded as poor but as shown in Chile high levels of productivity can be reached on these soils with proper management (Table 1).

Phosphorus in volcanic soils--Volcanic soils are characterized by their capability to react rapidly with large amounts of phosphorus particularly under acid conditions. Consequently the availability to plants of soluble phosphates applied as fertilizer is quickly depressed, and only about 10% of the applied phosphorus is utilized by most upland crops (4).

The low availability of native and applied phosphorus for plants in volcanic soils is undoubtedly one of the most important limiting factors in crop production in these soils. How to reduce the loss of availability of applied phosphorus and how to increase the availability of native and previously applied phosphorus are very important problems for these soils.

The "phosphorus sorption coefficient" of the soil is commonly used in Japan as an index of the ability of the soil to react with applied phosphorus. It is measured as follows:--A 50-g sample of soil is treated with 100 ml of a natural 2.5% $(NH_4)2HOP_4$ solution for 24 hours at room temperature with occasional shaking. The suspension is then filtered and the phosphorus content of the filtrate is determined. The amount of phosphorus sorted, calculated as mg of P_205 per 100g of soil is called the phosphorus sorption coefficient (4). Some data for different soils in Japan are shown in Table 2 (7). There are very large differences in the P sorption capacity of soils derived from volcanic ash and those derived from other parent materials.

In those derived from volcanic ash and the range was from 1887 mg P_2O_5/100 g soil to 267 mg P_2O_5/100 g soil, while the range on soils derived from other material was 263 mg P_2O_5/100 g soil to 655 mg P_2O_5/100 g of soil, about a fivefold difference. The strong affinity of volcanic soils for phosphorus is a consequence of the allophane they contain. Wada (17) found that ammonium phosphate reacts with allophane to form an insoluble phosphate. The reaction takes place rapidly at pH 4 and more slowly at pH 7

The reaction between soil and phosphate solution continues over a period of time. The first stage is a surface reaction and it takes place rapidly. The aluminum phosphate thus formed separates from the surface and changes gradually to a stable crystalline phase. The so-called phosphorus sorption coefficient may be considered to represent the phosphate sorted on the clay surface in the first stage. It is not the maximum amount of phosphate that could be sorted by the soil. The relationship between pH and phosphate sorption has been studied by several researchers and their results show that lowering the pH of volcanic soils causes an increase in phosphate sorption (4).

Phosphorus fertilization--The efficient application of phosphorus is one of the most important agronomic factors for increasing yields in volcanic soils. The process of phosphorus fixation and described previously reduces phosphorus use efficiency but does not mean that economic response cannot be had from phosphorus application, or that large amounts of phosphorus need to be applied. The response to phosphorus follows a normal response curve even though its efficiency may be reduced in comparison to other soils. It should also be pointed out that phosphorus fixed on the soil colloids is not totally unavailable to plants. In fact, it is thought that it is slowly available and the amount of available P builds up in these volcanic soils as shown by the work in Chile of Schenkel and Baherle (13) in Table 3.

As can be seen that even with moderate rates of P_2O_5 such as 100 kg/ha per year there can be large difference in available P in the top 15 cm after three years.

Methods of application--Data from both Japan and Chile has shown that granular fertilizers give better results than powdered fertilizers in organic soils. The major reason is that phosphorus in granules makes less extensive contact with the soil than does phosphorus in powdered fertilizers. This effect is shown in Figure 2 where phosphorus applied in solution, to achieve maximum contact with the soil is compared with a granulated fertilizer. The difference in response is very big at the lower level of application with fivefold differences in yield (3). What this means is that the least amount of contact fertilizer phosphorus has with the soil the greater the response.

In the case of wheat, application of phosphate fertilizers in the form of granules in the row is better than broadcasting because the fertilizer is then available in the early stages of growth (15). The lower the level of native phosphorus in the soil, the greater is the benefit of band application in comparison with broadcasting.

Response to P application--A typical response of wheat to nitrogen and phosphorus volcanic soils is shown in Table 4 (16). These data are from Chile and are the average responses from 37 sites ranging in a P Olsen soil test from 3.5 to 12.5 ppm. The average potential yield of the area is about 4500 kg/ha while the check yield is 1820 kg/ha giving a yield gap in terms of fertilizer response of 2700 kg/ha. There is very little to N and P when applied alone. However, there is a strong N x P interaction with one of the lower applications 75-100 giving a yield response 1500 kg/ha. It is also useful to look at the response efficiencies of the different treatments as shown in Table

5. When N and P are combined in the proper amounts reasonable nutrients efficiency is achieved such 8.6 for the treatment 75-100 and 8.8 for the treatment 225-100. When excess fertilizer is applied nutrient efficiency drops off drastically such as for the 300-400 treatment which has an efficiency of only 3.7 kg grain/kg nutrient.

This variability in response leads us to the question of the calibration of a soil test for phosphorus response in wheat in volcanic soil. A calibration curve for these soils in Chile is shown in Figure 3. This calibration was done for the Soil Series Santa Barbara using 26 field experiments. The response is expressed as percentage increase over the check as produced by 200 or 400 kg of P_2O_5/ha (the highest of either one) in the presence of 100 kg N/ha. This calibration gives a good fit ($r=0.70^{**}$) and this method is being used widely in Volcanic soils in Chile for the past 25 years.

According to this calibration, the soils are classified as follows as regards P Olsen content (3):

0-5 ppm P--very poor
5-10 ppm P--poor
10-20 ppm P--intermediate
> 20 ppm P--adequate

Latosolic Acid Soils

The soils most suitable for wheat in the tropical sawannah areas of the world are the red-yellow latosols and the dark red latosols. Typical of these soils are the Cerrado soils of Brazil and I will draw on data from this area. These soils are characterized by two main problems from the point of view of crop growth: 1) low pH with its accompanying high exchangeable aluminum saturation and 2) inherently low soil phosphorus levels.

Lopes and Cox (10) in a survey showed the extremely low fertility levels of these soils. These results are shown in Table 9. Almost all soils parameters that are normally used for satisfactory plant growth are below the sufficiency levels. Virgin soils normally have a reasonable level of organic matter but with increasing cropping these levels are decreased and nitrogen needs to be added to obtain satisfactory yields of cereal crops.

Phosphorus fertilization--Phosphorus is highly and universally deficient in these Latosols. Therefore, the correction of this deficiency is imperative for crop production.

Many factors affect the availability of phosphorus to plants in these soils. Among the most important is the clay content of the soil. The relationship between P in solution and absorbed P in soil with different clay levels is shown in Figure 4 (14). As clay levels increased, more P is absorbed relative to P in solution, which means that as clay content increases more P needs to be applied to maintain the levels of P available for plant uptake. The response of various crops to various levels of P_2O_5 are shown in Figure 5 (9). The different crops respond differently to phosphorus fertilization with maize showing much higher response than either soybeans or wheat. However, maximum responses are achieved at high levels of P_2O_5 with economic levels being in the range of 250 to 500 kg P_2O_5/ha.

Methods of phosphorus application--Much work had been carried out on phosphorus management and use. Banded vs broadcast were compared as were large single applications versus smaller repeated applications. The results are shown in Table 10 (8).

The cumulative yields are the same and depend only on the total amount of phosphorus applied irrespective of the method or the timing of application. However, there were large differences in the yield of the tenth crop depending on when the application was made. This is because the residual effect of phosphorus decreased over time. This decrease in residual effect is shown in Figure 6 (11). Therefore, a good strategy for these soils may be to apply a large quantity of phosphorus to begin with and maintain the soil fertility level with lower annual applications.

Sources of phosphorus--All work done on acid soils would show that there are differences in their efficiency, they are ranked in terms of decreasing efficiency as follows:

1) Triple Superphosphate and Single Superphosphate.
2) Thermophosphates.
3) Rock phosphates (2).

Of course, there are many factors that affect the choice of a fertilizer source such as; ease of availability, price, etc. Seen from this aspect, it would only seem logical that the phosphates with the highest concentration of nutrient such as Triple Superphosphate (46% P_2O_5) would be favored. However, in the case of some soils such as those of the Brazilian, Cerrados where there are other mineral deficiencies other sources which contain nutrients other than P may have to be considered (2).

For example, it has been shown that Single Superphosphate (SSP) is a very attractive fertilizer for these soils because it contains 60% by weight of Gypsum ($CaSO_4.2H_2O$) and is therefore a useful source of both Ca and S. The use of SSP has also been very useful in moving calcium down the profile. As shown in Figure 7 (12), wheat growth responds very dramatically to small concentrations of calcium therefore, small amounts of calcium moving down the profile should increase effective rooting depth. The rate and movement of calcium down the profile is an electrically neutral phenomenon. Every Ca^{++} ion must be accompanied by two monovalent anions such as Cl^- or one divalent anion such as SO_4^{--}. The accompanying anion therefore plays a very important role.

When calcium carbonate ($CaCO_3$) is applied, it is neutralized by hydrogen ions at the soil surface; therefore, there is no anion to accompany the calcium down the profile. This results in very little calcium movement from this source. $CaSO_4$ or gypsum when it dissolve leaves the SO_4^{--} anion free to be leached through the profile and this helps to distribute Ca throughout the profile.

The practical way of achieving good distribution of calcium in the soil is to apply one of the following: 1) $CaSO_4$ (gypsum) and 2) Single Superphosphate (SSP).

The effect of various rates of SSP on calcium and magnesium movement down the profile are shown in Figure 8 (12). As rates of SSP increase the calcium and magnesium contents increase with depth. This increases rooting and therefore better water use efficiency.

Phosphorus calibration--Because of the high needs of phosphorus on this soil a calibration method for the response of wheat to phosphorus in essential. The Brazilian workers are using the Mehlich method and getting a good correlation between soil P levels and yield. Such a curve for soybeans is shown in Figure 9 (1).

On the basis of this analysis, soils are classified as regards P content as follows:

0-5 ppm--low
5-10 ppm medium
> 10 ppm high

Based on this classification the following recommendation for wheat are made as shown in Table 11 (2). However, it should be pointed out that while these recommendations work, the economic circumstances of the farmer and local soil characteristics should also be taken into account when making recommendations.

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Résumé

Les sols volcaniques et les latosols acides présentent des problèmes spécifiques en ce qui concerne l'alimentation en phosphore et exigent des techniques particulières pour une meilleure utilisation de cet élément.

Les sols volcaniques sont caracterisés par leur aptitude à fixer rapidement de grandes quantités de phosphore, particulièrement en conditions acides. Par conséquent, la disponibilité pour la plante des phosphates solubles appliqués sous forme d'engrais régresse rapidement et seulement 10% environ du phosphore appliqué est utilisé par la majorité des cultures. La réponse au phosphore dans ces sols suit une courbe de réponse normale même si son efficience peut être réduite en comparaison avec d'autres sols.

Le phosphore fixé sur les colloïdes du sol n'est pas totalement inassimilable pour la plante. Il est assimilable progressivement et la quantité de phosphore assimilable augmente peu à peu avec l'application répétée d'engrais, selon les travaux effectués au Chili par Schenkel et Baherle.

Dans le cas du blé, la localisation du phosphore dans les sillons sous forme de granules est préférable à l'épandage à la volée car l'engrais est alors disponible dans les premiers stades de la croissance.

Selon des travaux effectués au Chili, une bonne corrélation a été observée entre la teneur en phosphore du sol (méthode Olsen) et la réponse du blé à l'apport de phosphore.

Deux problèmes principaux caractérisent les latosols en ce qui concerne la croissance des plantes: 1) pH faible accompagné d'une saturation élevée en aluminium échangeable et 2) faible teneur naturelle du sol en phosphore.

De nombreux facteurs affectent la disponibilité en phosphore dans ces sols. L'un des plus importants est leur teneur en argile. Lorsque celle-ci augmente, davantage de phosphore doit être appliqué pour maintenir des niveaux en phosphore assimilable satisfaisants pour la plante. Une bonne stratégie adaptée à ces sols consiste à appliquer au départ une quantité importante de phosphore et à maintenir le niveau de fertilité du sol par de faibles apports annuels.

Le choix de la source d'engrais phosphaté est lié à plusieurs facteurs, tel que la disponibilité en engrais, le prix, etc.

Le superphosphate simple (SSP) convient bien à ces sols car il contient 60% en poids de gypse et est, par conséquent, une source utile en Ca et S. L'emploi de SSP est également utile car, en permettant une migration du Ca dans le profil, il favorise le développement radiculaire.

Vu les besoins élevés en phosphore dans ces sols, une méthode calibrée d'évaluation de la réponse du blé au phosphore est essentielle. Les chercheurs brésiliens utilisent la méthode MEHLICH et obtiennent une bonne corrélation entre la teneur en phosphore du sol et la réponse des rendements.

Table 1. Yields and agronomic practices of three high yielding production plots in southern Chile. National Wheat Production Contest 1985-86. (Source: Resultados del Concurso de Produccion de Trigo Chile, 1985-86 INIA)

Farmer	Yield (kg/ha)	Previous crop	Fertilizer (Kg/ha) N	P_2O_5	K_2O
Guillermo Geisse	10890	Potato	176	220	102
Pablo Schlack	10620	Sugar beet	128	190	74
Egon Winkler	9790	Sugar beet	132	220	114

Table 2. Coefficient of phosphorus sorption of different Japanese soils (7)

Soil Parent Material	Soil Series	Depth (cm)	P_2O_5 sorted per 100g of soil (mg)
Volcanic Ash	Kamisato	0 - 15	2270
		15 - 35	2670
		35 - 80	2530
	Miyagasaki	0 - 26	1887
		26 - 40	2442
		40 - 100	2312
Other than Volcanic	Komukai	0 - 10	289
		10 - 25	289
		25 - 40	418
	Nishikai	0 - 15	263
		15 - 75	330
		75 - 90	655

Table 3. Changes in available P content (Olsen ppm) induced by 3 years of P fertilization soil series Vilcun (13)

Depth (cm)	Fertilizer Rate (Kg P_2O_5/yr) 0	100	400
		P - Olsen (ppm)	
0 - 5	14.7	18.0	23.3
5 - 10	7.8	15.5	18.9
10 - 15	9.9	12.9	13.2
15 - 20	4.7	8.6	12.3

Table 4. Average yields (kg/ha) of wheat (n=37) at various rates of N and P_2O_5 on the volcanic soils of Nuble and Malleco, Chile (16)[a]

Kg P_2O_5/ha	Kg N/ha 0	75	150	225	300
0	1820		2440		2470
100		3320		3810	
200	2490		4200		4170
300		3920		4490	
400	2590		4520		4400

[a] P Olsen Range = 3.5-12.5 ppm.

Table 5. Average response efficiency (Kg grain/kg nutrient) of wheat (n=37) at various rates of N and P_2O_5 on the volcanic soils of Nuble and Malleco, Chile (16)[a]

Kg P_2O_5/ha	Kg N/ha 0	75	150	225	300
0			4.1		2.2
100		8.6		8.8	
200	3.4		6.8		4.7
300		5.6		5.1	
400	1.9		4.9		

[a] P Olsen Range = 3.5-12.5 ppm.

Table 6. Average yield (kg/ha) of wheat at various rates of N and P_2O_5 on the volcanic soils of Nuble and Malleco, Chile (16)[a]

Kg P_2O_5/ha	Kg N/ha 0	75	150	225	300
0	1320		2960		2390
100		4730		5040	
200	3020		5760		6120
300		5450		6350	
400	3190		5860		5250

[a] P. Olsen = 5.5 ppm

Table 7. Average response efficiency (Kg grain/Kg nutrient) of wheat at various rates of N and P_2O_5 on the volcanic soils of Nuble and Malleco, Chile (16)[a]

Kg P_2O_5/ha	Kg N/ha 0	75	150	225	300
0			10.9		3.6
100		19.5		11.4	
200	8.5		12.7		9.6
300		11.0		9.6	
400	4.7		8.3		5.6

[a] P. Olsen = 5.5 ppm.

Table 8. Average Yield (Kg/ha) of Wheat at Various Rates of N and P205 on the Volcanic Soils of Nuble and Malleco, Chile (16)[a]

Kg P_2O_5/ha	Kg N/ha 0	75	150	225	300
0	3890		3910		3900
100		4350		3610	
200	4310		4300		3190
300		5030		3670	
400	3850		3970		2650

[a] P. Olsen = 12.5 ppm.

Table 9. Fertility status of a range of soils from the Cerrados area of Brazil

Parameter	Range	Median	Sufficient Level SL	Percent of SL
pH	4.30- 6.7	5.0	5.0	48% below
Extractable phosphorus	0.10-16.5 ppm	0.4 ppm	10 ppm	92% below
Extractable potassium	0.02- 0.6 meq/100 ml	0.08 meq/100 ml	0.15 meq/100 ml	85% below
Exchangeable calcium	0.04-6.81 meq/100 ml	0.25 meq/100 ml	1.5 meq/100 ml	96% below
Extractable zinc	0.20-2.2 mg/ml	0.6 mg/ml	0.8 mg/ml	81% below
Extractable copper	0-9.7 mg/ml	0.65 mg/ml	1.0 mg/ml	70% below
Aluminum saturation	1.10-84.9%	59%	20%	91% above
Organic matter	0.70-6.0%	2.2%	--	60% between 1.5 and 3.0%
Cation exchange capacity (CEC)	0.35-8.1 meq/100 g	1.1 meq/100 g	--	--

Source: Lopes and Cox (10)

Table 10. The influence of the rate and placement of phosphorus fertilizer on the cumulative yield of 10 crops of maize on dark red latosol, Brasilia, D.F. Brazil

Phosphorus Application (Kg P_2O_5/ha)			Maize Yield 10th crop		Maize Yield Total 10 crops	
Broadcast	Banded	Total	t/ha	% of best treatment	t/ha	% of best treatment
320	0	320	0.55	10	27.85	45
0	30 (x4)	320	0.88	16	30.09	49
640	0	640	1.47	27	42.67	69
0	160 (x4)	640	1.90	35	44.05	71
320	30 (x4)	640	1.35	25	43.89	71
1960	0	1960	5.38	100	61.64	100

Source: Lobota (3)

Table 11. Phosphorus Fertilizer Recommendations (kg P_2O_5/ha) for Cerrado Soils.

Soils P level Mehlich (ppm)	Corrective Broadcast	Corrective Banded	Maintenance
0 - 5	240	60	80
5 - 10	120	60	80
- 10	0	60	80

Source: Goedert et al. (2).

Figure 1. Distribution of soil samples with respect to organic matter content.

(Source: Investigacion Agropecuaria, INIA, Chile, 1970)

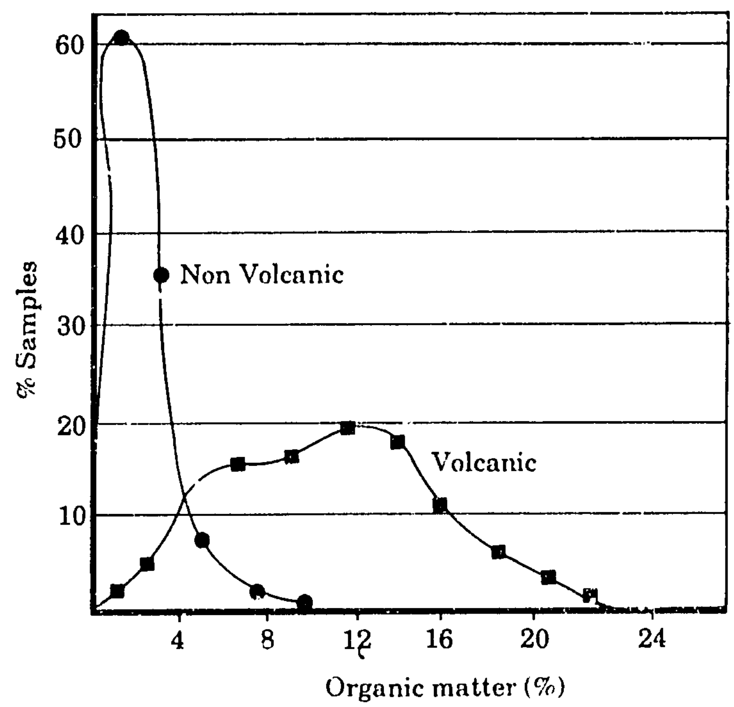


Figure 2. Effect of granulation on wheat yields in a volcanic soils series, Santa Barbara, Chile.

(Source: Investigacion Agropecuaria, INIA, Chile, 1970)

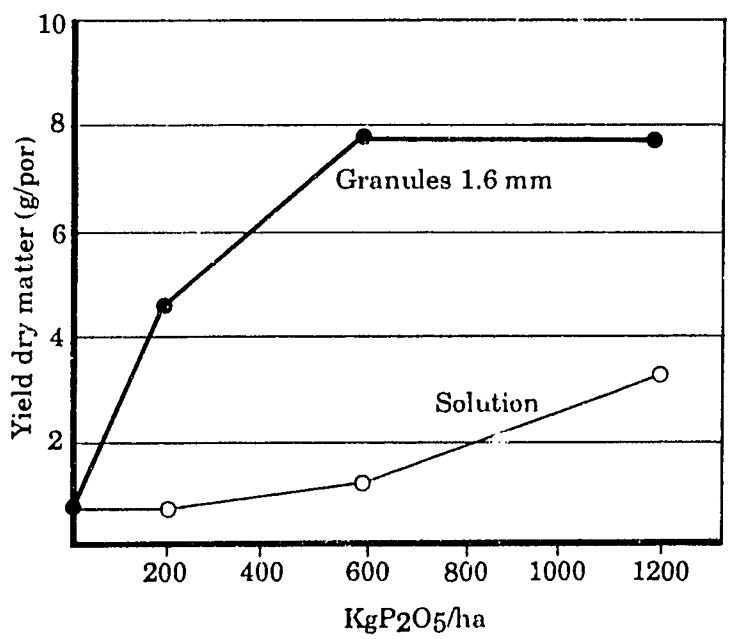


Figure 3. Relation of P Olsen (ppm) and what response to P in A Volcanic soil series Santa Barbara, Chile (in the presence of 100 kg/N/ha).

(Source: Investigacion Agropecuaria, INIA, Chile, 1970)

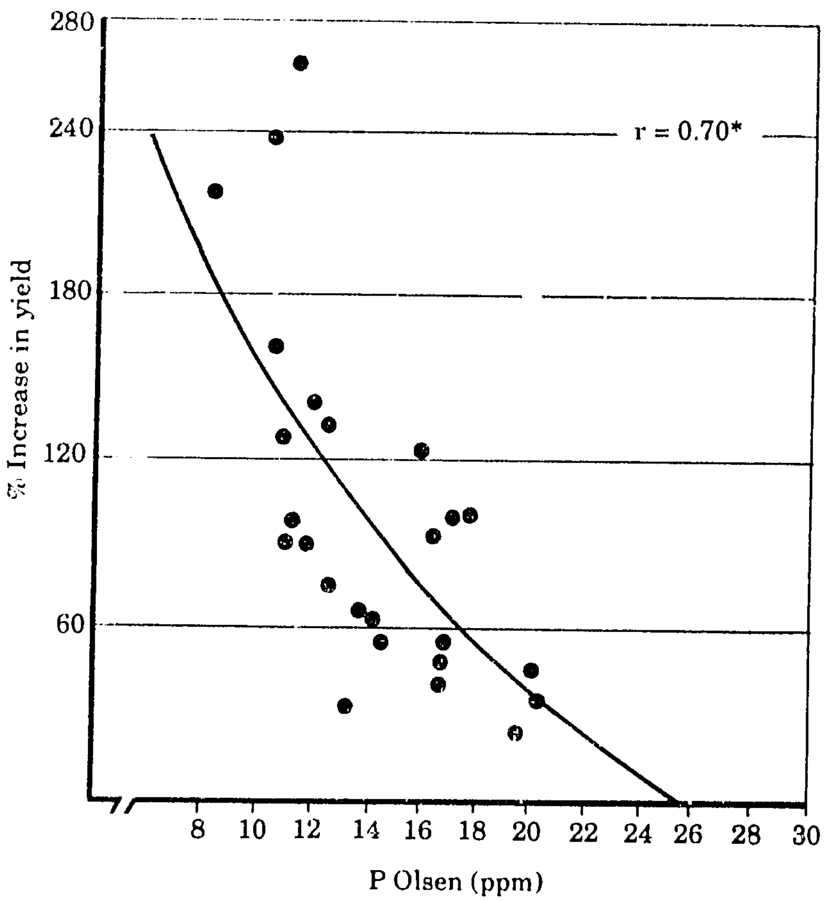


Figure 4. Relation between absorbed P and solution P in five cerrado soils differing in clay content.

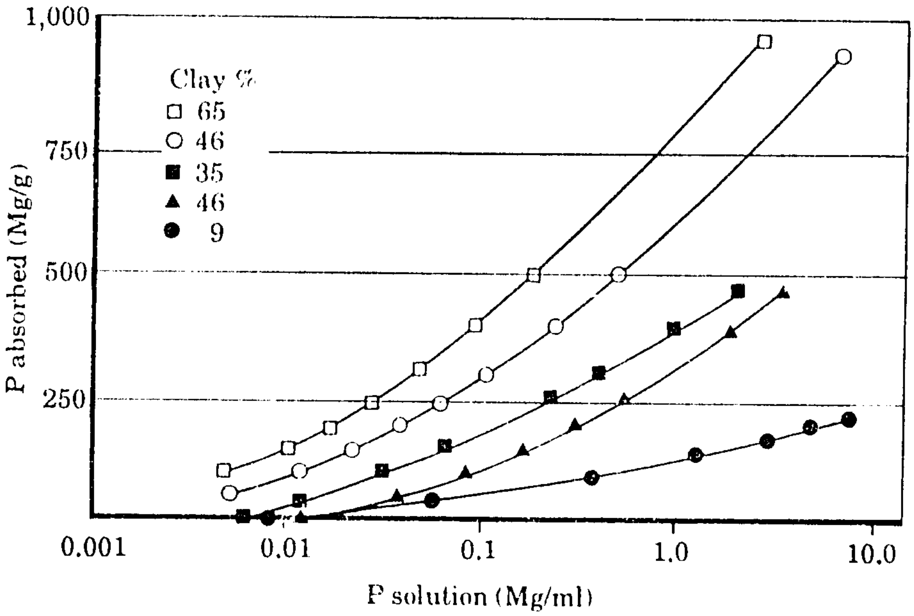


Figure 5. Response to broadcast applied P of three crops on a dark red latosol.

(Source: Lobato 1982)

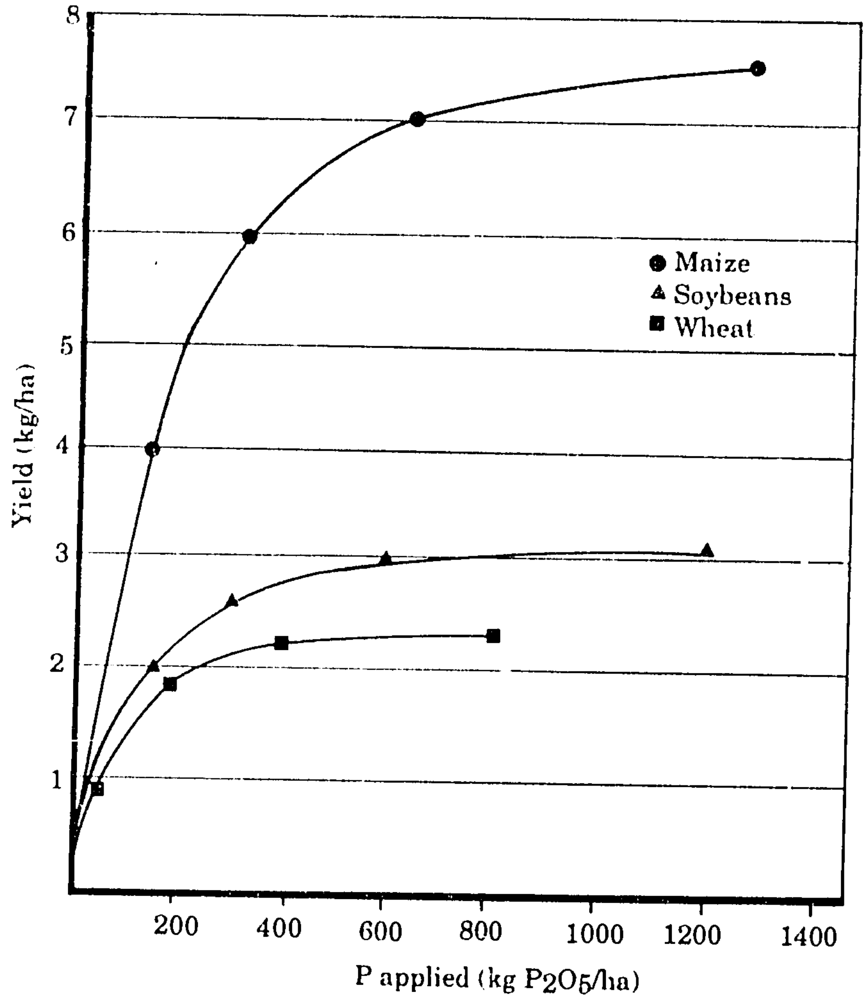


Figure 6. Residual effect of applied phosphorus (Broadcast) on the first crop. 100% is the production of the first crop.

(Source: Miranda *et al* 1980)

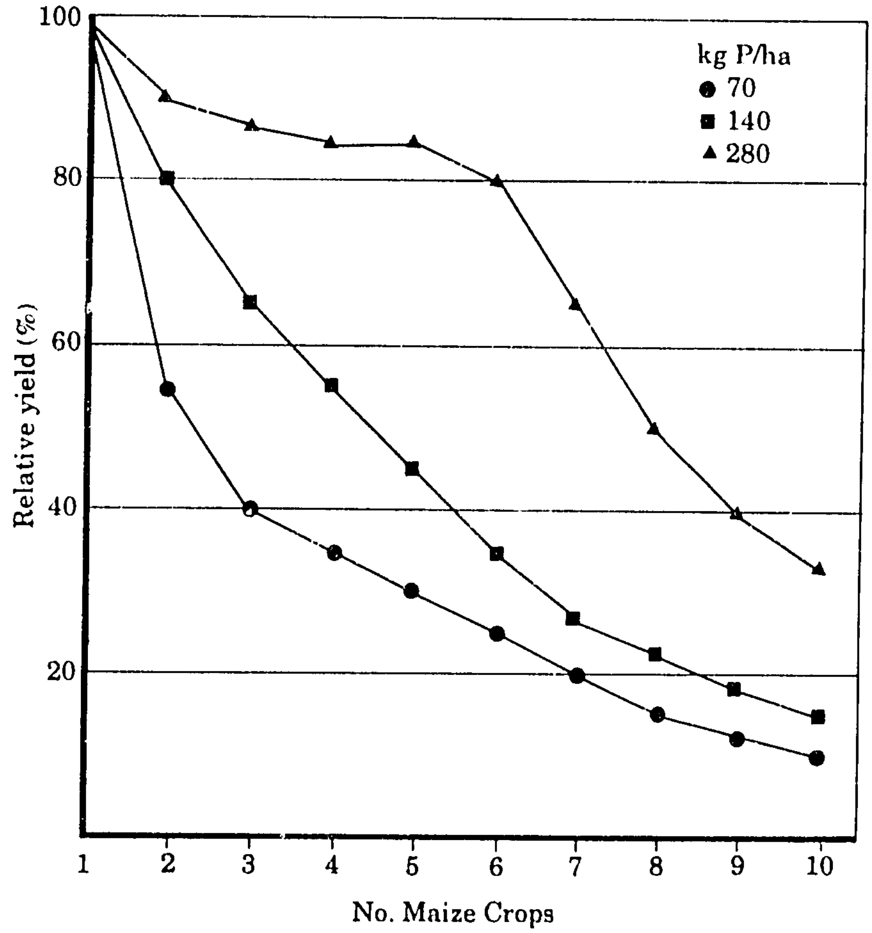


Figure 7. Wheat root growth as affected by calcium in samples taken from the subsoil of a red yellow latc?ol.

(Source: Ritchey *et al* 1980)

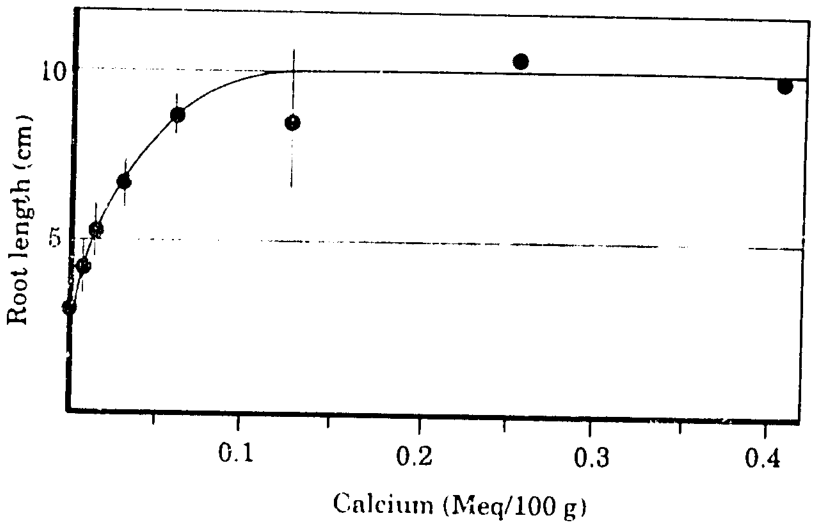


Figure 8. Effect of varying rates of phosphorus (kg/ha) as SSP on the distribution of calcium + magnesium in the soil profile of a dark red latosol, Brazil

(Source: Ritchey *et al* 1980)

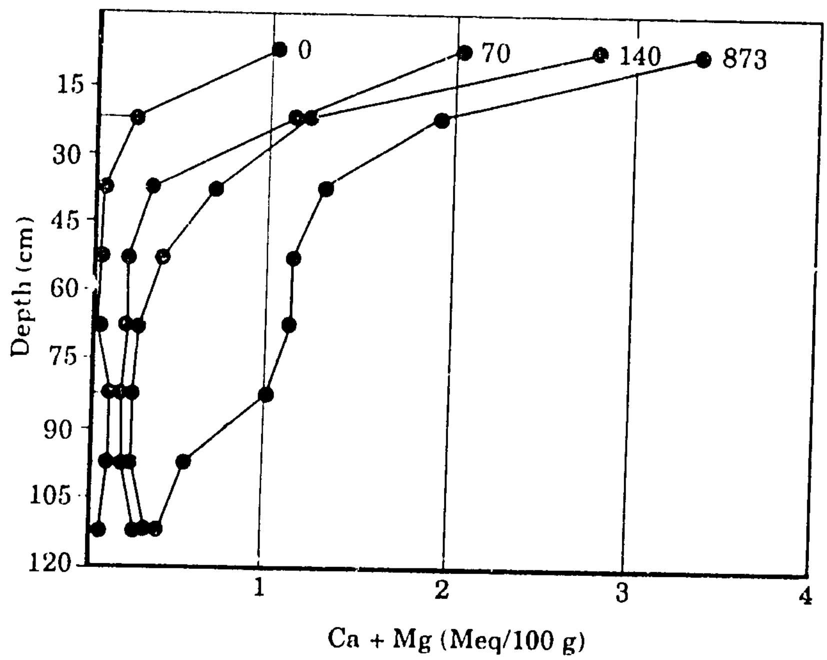


Figure 9. Relative yields of soybean in relation to extractable P (Mehlich) in an Acid clay soil of the Cerrados.

(Source: EMBRAPA/CPAC 1981)

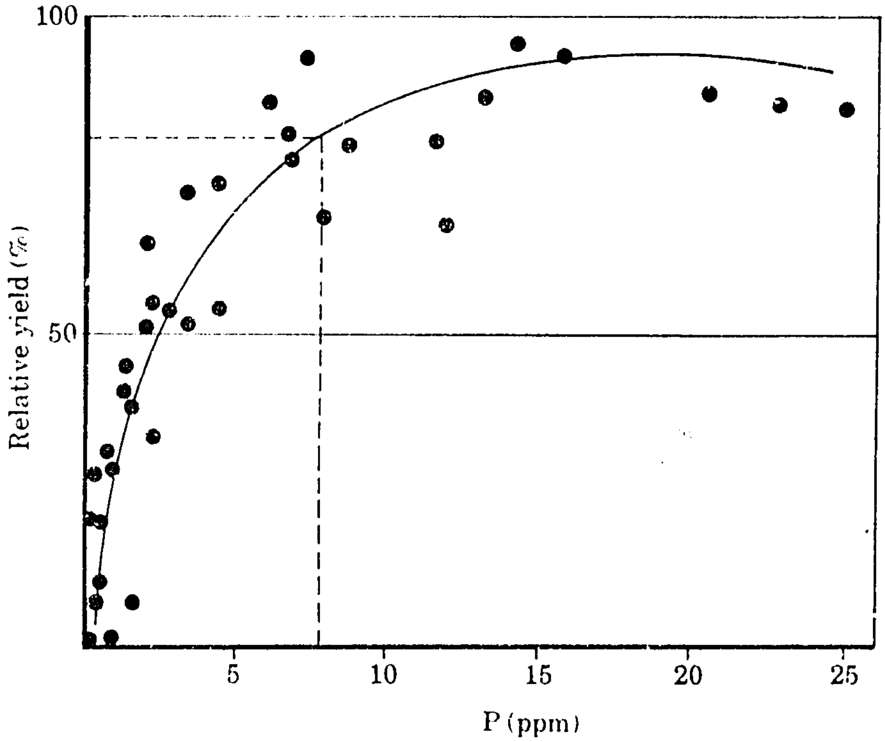
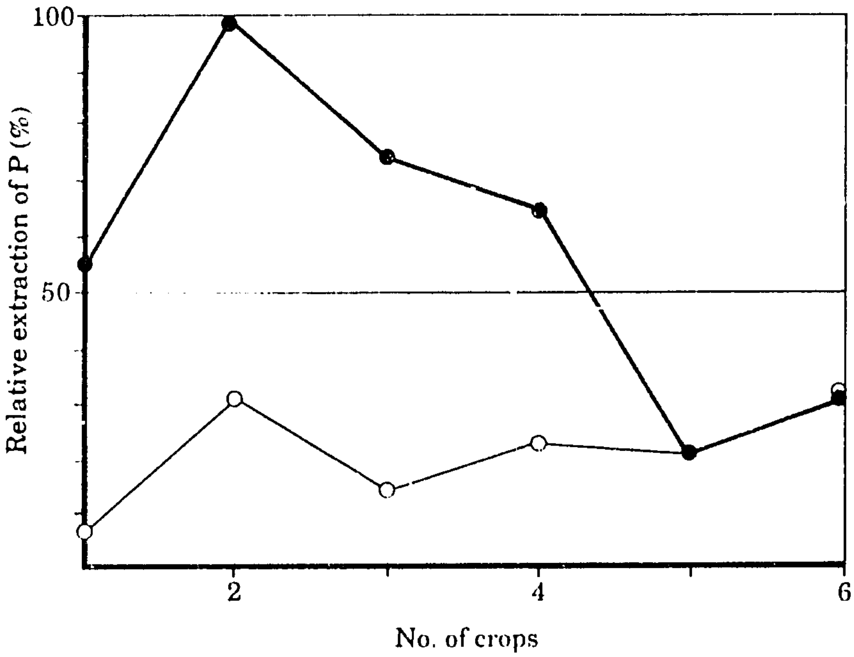


Figure 10. The relative extraction by six consecutive crops from a soil which received 44 ppm initially in two different sources of phosphorus.

(Source: Goedert 1983)



DIFFERENTIAL REACTION OF WHEAT AND TRITICALE TO PHYSICAL AND CHEMICAL PROPERTIES OF SOILS IN MUGAMBA, BURUNDI

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Abstract

In a series of 55 on-farm trials conducted in 1985, the effect of Mugamba soil properties on the yields of wheat (Triticum aestivum L. cv. Romany) and triticale (X Triticosecale Wittmack, cv. Mizar) was investigated. No mineral fertilizers were applied to the trial plots. In northern Mugamba, the soils are moderately to weakly acid and are predominantly hygrokaolisols with a few kaolintic brown soils. The mean yields of wheat and triticale on these soils were similar (1.6 t/ha). However, in southern Mugamba where the soils are dominated by humiferous kaolisols, which are strongly acid and which often have high levels of exchangeable aluminum, the mean yields of wheat and triticale were 1.2 and 1.7 t/ha, respectively. The differential response of wheat and triticale, in respect to the soil types, is discussed in relation to the topsoil chemical characteristics (the different levels of acidity, base saturation, exchangeable aluminum and available phosphate).

Introduction

In Burundi, wheat (*Triticum aestivum* L.) is cultivated mainly in regions above 1900 m elevation in the Zaire-Nil ridge and, for the most part, during the second crop cycle (March-August). In 1984 area sown to wheat in the Mugamba region totalled about 7700 ha, of which 6600 were planted during the second season (2). The use of varieties like Romany, which are well adapted to the not very fertile soils of the region, would result in mean yields of 1.3 t/ha with weed control and no manure application (18).

Introduced in Burundi in 1975, triticale (X. *Triticosecale* Wittmack) quickly appeared to be the cereal of the future on very acid soils. In multilocational varietal trials in 1980, mean yields of the best triticales were 3.9 t/ha, 20% better than those of wheat variety Romany. Triticale's superiority over wheat, however, varied from site to site. On very unsaturated and acid soils (pH 4.9) where Romany produced only 0.9 t/ha, the best triticales outyielded it by 70-140% (20).

A study of the differential reaction of these two cereals to physical and chemical soil properties was begun in 1984 and continued in 1985. Its objective was to identify the most adequate soils for each of these crops, as well as potential yield levels, in order to make the best recommendation to farmers concerning the allocation of their natural resources.

Articles on this subject have already been published, based on the 1984 results (16, 21, 24) where soils were classified using the INEAC scale (26). A more detailed analysis has also been presented (17) that takes into account the results of two years of testing and uses the prototype classification established for tropical, nonvolcanic, humid regions (15).

This report is based essentially on the 1985 results and uses the INEAC soil classification scale adopted at the beginning of the study. It complements the paper presented at the preceding Regional Wheat Workshop at Njoro (21).

Materials and Methods

In 1985 wheat variety Romany (origin: Colotana x Yaktana) and triticale variety Mizar (origin: Maya II x Arm.), bred in Kenya (8) and Italy (29), respectively, were compared in 55 trials conducted on farmers' fields in Mugamba. These trials, situated at 1900-2200 m, were distributed over six subregions (Figure 1).

The trials were planted in three randomized complete blocks and basic 8 m^2 plots, using a seeding density of 140 kg grain per hectare, with 20 cm between rows, after maize (*Zea mays* L.) intercropped with beans (*Phaseolus vulgaris* L.). All trials were conducted with no mineral or organic fertilization and were weeded manually. They were planted on 21-29 March north of the Bugarama-Muramvya axis, and 28 March-9 Aprii south of the axis (Figure 1).

The chemical analysis of the topsoil (0-20 cm) in each plot was done on a composite of 40-samples taken before or just after planting. Soils were classified using the INEAC scale (26).

Results and Discussion

Climatic conditions--Based on climatic data for Nyakararo and Munanira (Figure 1), total rainfall and its distribution over the growth cycle were similar for all the research area (Table 1). Since April is the rainiest month in Burundi, there was ample water for wheat and triticale from seeding through the beginning of stem elongation. Heading and grain-filling, on the other hand, took place during the dry season beginning the last 10 days of March.

Mean temperatures, characteristic of a highland equatorial regime, showed little variation throughout the cycle, although at Nyakararo they were slightly lower during the dry season. Mean temperatures were slightly higher in northern Mugamba, causing a shortening of the vegetative cycle (Table 1).

All trials were planted during the best seeding period. Parallel testing done in 1985 showed that planting dates from 20 March to 3 April in northern Mugamba and from 27 March to 10 April in southern Mugamba did not affect wheat yields (22). It can therefore be assumed that yields produced by Romany and Mizar in each trial adequately reflect their response to natural soil fertility at each site.

Distribution and physical and chemical properties of soils in Mugamba--According to Opdecamp et al. (17), the Mugamba region is made up of two main landform and pedological areas situated on either side of the axis that joins Bugarama to Muramvya (Figure 1).

Northern Mugamba, a hilly to mountainous area, is composed mainly of hygrokaolisols, while southern Mugamba, cut by valleys, is composed mainly of humiferous kaolisols. Although brown kaolinitic soils are occasionally found in northern Mugamba, hygrokaolisols and humiferous kaoliosols are more or less equally distributed in the wheat-producing area of Mugamba.

A correlation between terms of the classification scale that was used and those of the American scale (28) cannot be attempted unless certain approximations are accepted. Hygrokaolisols are classified preferably in the agrudalf, paleudult and palehumult subgroups, humiferous kaolisols in the palehumult, haplohumox and sombrihumox subgroups, and brown soils in the agrudalf and palehumult subgroups.

Of the 55 trials, 25 were planted in humiferous kaolisols, 26 in hygrokaolisols and 4 in brown kaolinitic soils. Trials planted in humiferous kaolisols were situated south of Bugarama, while those planted in hygrokaolisols were situated north of it. Trials planted in brown soils were situated in the Munanira subregion (Figure 1).

Topsoil chemical properties of the 55 sites, classified according to soil type, are summarized in Table 2.

Humiferous kaolisols are characterized by an accumulation of humus, which can sometimes be 1 m deep in this locality. Because of the high organic content, generally between 8 and 13% in the topsoil, they have a high cation exchange capacity (T = 23-30 meq/100 g). These soils range from heavy to very heavy (65-85% clay), if derived from basic schist (60% of the soils), or have a lighter (45-60 % clay) texture if they are composed of acid micaceous rock (30% of the soils). In spite of their high clay content, they are very permeable.

Hygrokaolisols and brown soils generally contain 3-5% organic matter and have a cation exchange capacity of 11-18 meq/100 g. Dry soils, 90% of which are derived from basic schist, have a heavy to very heavy texture (65-85% clay).

According to criteria mentioned by Boyer (3), the soils of the 55 sites should have good levels of exchangeable potassium; their potassium content is higher than deficiency thresholds set at 0.1 meq/100 g or 2% of the sum of exchangeable cations. Moreover, the Mg/K and Ca + Mg/K ratios are below the threshold of 25, and 40-50 above ratios at which unbalanced potassium nutrition is normally observed.

Calcium and magnesium levels are generally good in absolute terms. However, if one refers to Boyer's criteria (3), certain soils, especially humiferous kaolisols, could present calcium and magnesium deficiencies caused by an imbalance between these elements and potassium, when the Mg/K and Ca + Mg/K ratios are lower than the thresholds by 3-4 and 12-18, respectively.

Humiferous kaolisols are, on average, more acid (pH 4.9-5.5) than hygrokaolisols and brown soils (pH 5.6-6.4). In humiferous kaolisols, plants would have difficulty assimilating phosphorus. Indeed, it is assumed that at levels below pH 5.5, a high proportion of this element is in the form of ferric compounds that are not very soluble (3). On-farm trials with phosphate fertilizer and using only wheat variety Romany indicate that it responds better to available phosphorus on humiferous kaolisols than on hygrokaolisols and brown soils (23).

Humiferous kaolisols have high levels of exchangeable aluminum. For the 25 trials planted in this type of soil, the level of exchangeable aluminum in the topsoil is an average of 2.0 meq/100 g or, at most, 3.9 meq/100 g. Kamprath's m index, which conditions the effect of exchangeable aluminum on plants, shows a 0-62 variation. Many authors (12, 14) cited by Boyer estimate that on Brazil's acid soils it is no longer possible to grow most crops above m = 45-50, and that there is practically no risk of aluminum toxicity below m = 5-10.

Soil-plant interactions--Mean yields of triticale variety Mizar are similar in northern and southern Mugamba, while wheat variety Romany mean yields are 36% better in the north (Table 3). The highest yields for both cereals were produced on brown soils rich in bases (Tables 2 and 4). Thus these results confirm the 1984 results (21).

Mean yields of wheat and triticale do not differ significantly on hygrokaolisols and brown soils. In contrast, on humiferous kaolisols triticale's mean yields were higher by 30-40% than those of wheat, depending on the year (Table 4). Triticale's good performance on humiferous kaolisols was also observed in 1985 by the Highland Village Cultivation Project (CVHA, Projet Cultures Villageoises en Haute Altitude) (18). On 252 demonstration plots without mineral fertilizers, Mizar's mean yield, 1.60 t/ha, was 32% better than Romany's. However, triticale's superior yields on humiferous kaolisols vary from site to site. In 1985 trials, the standard deviation associated with production gains indicates that they fluctuate between -10% and +120% (Table 2).

A separate analysis of results obtained on humiferous kaolisols and on hygrokaolisols shows that wheat and triticale yields increase in a highly significant fashion depending on the sum of exchangeable cations and that they decrease as acid and aluminum levels rise (Table 5 and Figure 2).

Significant correlations between yields and the level of exchangeable aluminum observed on hygrokaolisols have only limited impact since 24 of 26 sites have a Kamprath m index of 6 or lower. The analysis of results of these 24 sites, where there should be no aluminum toxicity, indicates that on hygrokaolisols wheat and triticale yields are closely related to calcium and magnesium levels (Table 5). Nevertheless, it is impossible to determine whether the effect of either of these elements is dominant over the other, since they are closely correlated (r = 0.75).

Regression lines linking wheat yields on humiferous kaolisols to acid and base levels in the soil continue lines observed on hygrokaolisols (Figure 2). Poor wheat yields on humiferous kaolisols thus seem to be linked to high acid levels, though it is not possible to determine their main effect (calcium and/or magnesium deficiency, low availability of assimilatable phosphorus below pH 5.5, unfavorable effect of high aluminum content). Potassium deficiency in humiferous kaolisols is not evident despite a highly significant correlation between phosphorus content in the soil and yields (Table 5). Humiferous kaolisols are richer in exchangeable potassium than hygrokaolisols (Table 2) and mineral fertilizer trials on humiferous kaolisols have shown that potassium input has no significant effect on wheat yields when, without manure, they reach at least 0.9 t/ha (23). The significant yield/potassium correlation would be due to a close link between potassium content and calcium and magnesium levels (r = 0.49 and 0.62, respectively).

Upon examining correlation coefficients estimated for the 51 trials planted in humiferous kaolisols and hygrokaolisols, it is apparent that the relative value of triticale production gains, compared to wheat, increases with acid and exchangeable aluminum levels, whether expressed in absolute value or by Kamprath's m index (Table 5). These results go hand in hand with the lack of significant correlations between triticale yields and acid and exchangeable aluminum levels; in contrast, wheat yields are significantly correlated to these two soil characteristics.

Mizar also seems less susceptible to aluminum toxicity than Romany. Even when triticale yields on humiferous kaolisols decrease because of exchangeable aluminum levels, they are on average 40% higher than wheat yields (Figure 2). On humiferous kaolisols, however, triticale production gains compared to wheat are not linked to aluminum content (Table 4). Musa (13) thinks triticale's improved aluminum tolerance probably explains why it is superior to wheat on soils with 25-50% aluminum saturation in the subsoil. Many authors have nevertheless shown that triticale's aluminum tolerance is not generalized and that certain varieties are susceptible to aluminum (6, 11, 13). Mugwira et al. (10) suggest two mechanisms in certain triticale varieties which may explain their aluminum tolerance: aluminum precipitation in the root area caused by raising the pH level, as in certain aluminum-tolerant wheat varieties, or the ability to fix high aluminum concentrations in the roots without transferring the element towards the upper part of the plant, as rye has (*Secale cereale* L.).

Correlation coefficients estimated for the 51 trials planted in humiferous kaolisols and hygrokaolisols also show that triticale yields and the relative value of production gains, compared to wheat, are significantly linked to phosphorus content in the soil. A similar tendency is observed on humiferous kaolisols (Table 5). It can thus be hypothesized that triticale's good performance on humiferous kaolisols is caused by its ability to assimilate phosphorus more easily than wheat in very acid soils when aluminum is present. Triticale production gains compared to wheat would thus be even higher on acid soils with high aluminum content because they are rich in phosphorus. Andrew and Vanden Berg (1) have demonstrated with different forage leguminous plants grown in nutrient solution that in an aluminum-tolerant species, versus a susceptible one, phosphorus absorption and transference will take place when there are high aluminum levels in the solution. According to Fleming et al. (7), the response to phosphorus of an aluminum-tolerant plant (*Eragrostis curvula* (Schrad.) Nees) is not affected by high levels of aluminum in the solution. On the other hand, an aluminum-sensitive plant (*Festuca arundinacea* Schref.) shows a feeble response to phosphorus, which is noticeable especially in its poorly developed root system.

Conclusions

The Mugamba region presents landform and pedological contrasts along a north-south axis. In the hilly region of northern Mugamba hygrokaolisols predominate, though there are some brown kaolinitic soils. On these soils, with pH 5.6-6.4 and good base availability (an average of 8.7 meq/100 g), Romany and Mizar have similar yields, an average 1.6 t/ha, without mineral fertilizers. In the valleys of southern Mugamba, humiferous kaolisols predominate. They have high organic content and pH 4.9-5.5, are moderately rich in exchangeable bases (5.7 meq/100 g, on average) and are characterized by an aluminum saturation rate of the exchange complex that ranges between 0 and 62%. On humiferous kaolisols, Romany's mean yield without mineral fertilization is 1.2 t/ha. On the other hand, Mizar is as productive on humiferous kaolisols as on hygrokaolisols and brown soils, so that on humiferous kaolisols, its mean yield is 35% higher than Romany's. The study thus confirms triticale's good adaptation to acid soils, which was observed in Kenya (27), Madagascar (19), Uganda (30), Zambia (25), Rio Grande do Sul in Brazil and the State of Michoacan in Mexico (5, 29).

In the differential reaction of wheat and triticale to soil type, it is difficult to disassociate the effect of exchangeable aluminum from the other properties of acid soils, such as calcium and magnesium deficiencies and low phosphorus availability. Knowledge of the genetic and physiological basis for the differential reaction of these two cereals could lead to more efficient crop improvement technologies both for wheat and triticale.

Acknowledgments

The authors wish to express their sincere gratitude to the many collaborators who took part in this study; the agronomists and people in charge of the Highland Village Cultivation Project (CVHA); J. Gourdin, P. Hollebosch and Mrs. Kibiriti of ISABU Agricultural Chemistry Laboratory; C. Otoul of ISABU Biometric and Data Processing Services, as well as the farmers of Mugamba who allowed us to establish an observation network.

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Résumé

L'incidence des propriétés des sols du Mugamba sur les rendements du blé (Triticum aestivum L. var. Romany) et du triticale (X Triticosecale Wittmack; var. Mizar) a été étudiée en 1985 dans une série de 55 essais réalisés en milieu rural sans fertilisation minérale. Dans le nord du Mugamba, constitué principalement d'hygrokaolisols et occasionnellement de sols bruns kaolinitiques, moyennement à faiblement acides, les rendements moyens des deux céréales furent similaires (1,6 t/ha). Dans le sud du Mugamba où dominent les kaolisols humifères fortement acides et souvent à fortes teneurs en aluminium échangeable, les rendements moyens du blé et du triticale furent respectivement de 1,2 t/ha et 1,7 t/ha. Le comportement différentiel du blé et du triticale selon le type de sol est discuté en fonction des caractéristiques de l'horizon de surface (acidité, teneurs en bases et en aluminium échangeables, teneur phosphore assimilable).

Table 1. Total rainfall (P) and average daytime temperatures (T) recorded during the main development stages of Romany (R) and Mizar (M).

Southern Mugamba[a] (Southern Bugarama, Ijenda and Tora)				Northern Mugamba[b] (Munanira, Remera and Teza)			
Duration (days)		P	T	Duration (days)		P	T
R	M	(mm)	(°C)	R	M	(mm)	(°C)
Sowing–stem elongation							
40	40	336	16.0	34	34	434	16.8
Stem elongation–heading							
34	35	42	15.1	31	32	63	17.4
Heading–maturity							
63	70	5	14.2	59	65	10	17.3

[a] Mean planting date: 3 April, 1985

[b] Mean planting date: 26 March, 1985

Data from Nyakararo and Munanira weather stations.

Table 2. Topsoil (0–20 cm) characteristics and yields of Mizar (M) and Romany (R) in different soil types. Mean values (X) and standard deviation (S). 1985 trials

Soil chemical properties and yields	Humiferous kaolisols n=25[a] X and S	Hygro-kaolisols n = 26 X and S	Brown soils (kaolinitic) n = 4 X and S
C (%)	6.14+ 1.65	2.22+ 0.40	2.52+ 0.35
N (%)	0.50+ 0.12	0.20+ 0.04	0.24+ 0.02
C/N	12.1 + 1.2	10.9 + 1.1	10.5 + 1.1
P (ppm)[b]	92+40	64+36	68+47
pH H_2O	5.2 + 0.3	5.9 + 0.4	6.2 + 0.5
T (meq/100 g)[c]	26.8 + 3.6	14.2 + 3.1	[illegible] + 2.6
S (meq/100 g)[d]	5.7 + 3.2	8.5 + 2.7	10.0 + 2.9
Ca(meq/100 g)	3.7 + 2.3	5.8 + 2.1	6.4 + 1.7
Mg(meq/100 g)	1.2 + 0.8	2.1 + 0.7	2.3 + 0.3
K (meq/100 g)	0.8 + 0.4	0.6 + 0.3	0.5 + 0.4
Mg/K	1.5 + 0.7	4.5 + 2.4	9.1 + 7.9
Ca + Mg/K	6.2 + 3.2	17.1 +10.1	35.5 +31.9
Al (meq/100 g)[e]	2.0 + 1.1	0.1 + 0.3	0.1 + 0.1
m[f]	29+18	2+4	1+1
Mizar (t/ha)	1.70+ 0.58	1.46+ 0.59	2.62+ 0.48
Romany (t/ha)	1.21+ 0.47	1.50+ 0.59	2.58+ 0.37
M/R (%)	154+66	100+21	102+10

[a] n = number of soils

[b] (2) Olsen method modified by Dabin

[c] T = cation exchange capacity measured using ammonium acetate N at pH 7

[d] S = sum of exchangeable bases (Ca + Mg + K = Na)

[e] K Cl 1 N extraction

[f] m = 100 Al/Al + S

Table 3. Mean yields of Romany and Mizar observed in southern and northern Mugamba. 1984 and 1985 trials

	Southern Mugamba	Northern Mugamba	N-M/S-M
1984			
Romany	1.15 a	1.56 b	136
Mizar	1.49 a	1.58 a	106
Number of trials	34	43	
1985			
Romany	1.21 a	1.64 b	136
Mizar	1.70 a	1.62 a	95
Number of trials	25	30	

a-b: yields of the same line followed by the same letter do not differ at the 5% probability level. The other yields differ at the 1% probability level (F.P.D.S.). Source of 1984 data: Schalbroeck (21).

Table 4. Mean yields of Romany and Mizar in Mugamba in different soil types. 1984 and 1985 trials

Soils and years	Number of trials	Romany t/ha	Mizar t/ha	Mizar % Romany
	Southern Mugamba			
Humiferous kaolisols				
1984	34	1.15 a	1.49 b	130
1985	25	1.21 a	1.70 b	140
	Northern Mugamba			
Hygrokaolisols				
1984	36	1.50 a	1.46 a	97
1985	26	1.50 a	1.46 a	97
Brown soils				
1984	7	1.86 a	2.18 a	117
1985	4	[illegible]58 a	2.63 a	102

a-b: yields of the same line followed by the same letter do not differ at the 5% probability level. Yields on humiferous kaolisols differ at the 1 and 0.1% probability levels for 1984 and 1985, respectively (F.P.D.S.). Source of 1984 data: Schalbroeck (21).

Table 5. Linear correlation coefficients between the topsoil (0-20 cm) chemical properties of humiferous kaolisols and hygrokaolisols and Mizar (M) and Romany (R) yields. 1985 trials

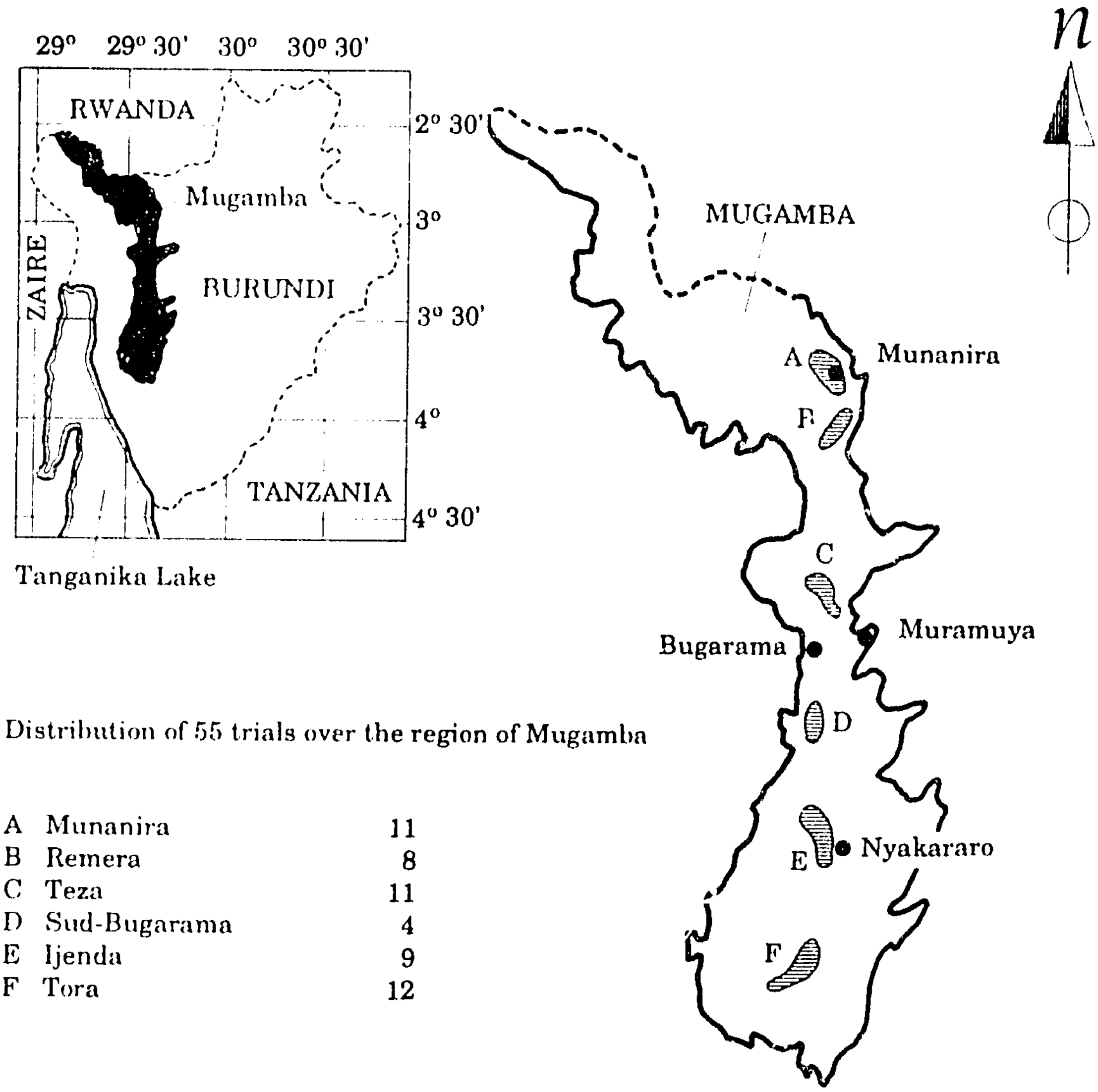
	M	R	M/R	M	R	M/R
	All soils (n = 51)			Humiferous kaolisols (n = 25)		
pH	0.18***	0.52***	-0.40**	0.[illegible]***	0.39**	-0.04
S	0.48**	0.65***	-0.26	0.62**	0.5[illegible]**	-0.03
Ca	0.4[illegible]**	0.6[illegible]***	-0.26**	0.56**	0.52**	-0.04
Mg	0.36***	0.60	-0.36	0.60***	0.52**	-0.09
K	0.[illegible]3	0.15**	0.22**	0.72*	0.52*	0.05
Al	-0.09	-0.[illegible]2**	0.43**	-0.[illegible]4*	-0.[illegible]3*	0.10
m	-0.13*	-0.4[illegible]	0.41*	-0.50	-0.[illegible]7	0.37
P	0.32	0.06	0.31	0.30	0.09	0.23
	Hygrokaolisols (n = 26)			Hygrokaolisols with m < 6 (n =24)		
pH	0.50***	0.54***	-0.21	0.38**	0.40***	-0.14
S	0.66***	0.70***	-0.19	0.62**	0.65***	-0.12
Ca	0.66**	0.69***	-0.16	0.60*	0.66*	-0.09
Mg	0.53	0.61	-0.28	0.43	0.51	-0.25
K	0.[illegible]*	0.07*	0.03	0.07	-0.04	0.09
Al	-0.[illegible]3*	-0.[illegible]7*	0.11	--	--	--
m	-0.[illegible]	-0.[illegible]8	0.16	--	--	--
P	0.23	0.26	0.02	0.19	0.19	0.08

*, **, *** Significant at the 5, 1, and 0.1% probability levels, respectively.

Correlation coefficients estimated for mean yields of each trial.

n = number of trials.

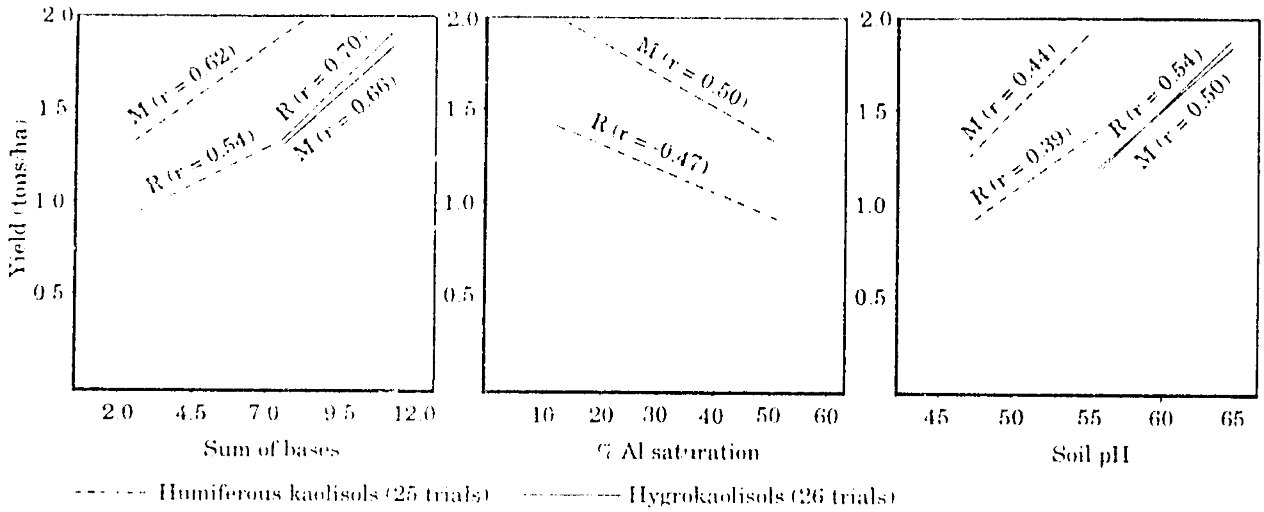
Figure 1. Location of Mugamba and Nyakararo and Munanira weather stations and distribution of trials within the six experimental subregions (A, B, C, D, E, F).



Distribution of 55 trials over the region of Mugamba

A	Munanira	11
B	Remera	8
C	Teza	11
D	Sud-Bugarama	4
E	Ijenda	9
F	Tora	12

Figure 2. Yields of wheat variety Romany (R) and of triticale variety Mizar (M) according to levels of base saturation, aluminum saturation and topsoil acidity (0-20 cm) of humiferous kaolisols and of hygrokaolisols.



EFFECT OF SOWING DATE ON THE GROWTH OF WHEAT IN THE MID ALTITUDES OF BURUNDI

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Abstract

In the mid-altitude zone of Burundi (1700 m), sowing date trials were conducted in both growing seasons over 2 years. Fou. dates were selected for each season; the first date corresponds to the beginning of the growing season and the others follow at 2-week intervals.

During the first growing season, yields were significantly higher for treatments sown from October 15 to November 1. Regarding the other agronomic parameters, the best sowing dates resulted in tall plants with early maturity, but their 1000 grain weight was significantly lower.

In the second growing season, early-sown treatments yielded significantly more than the others. Regarding the other agronomic parameters, heading and maturity were variable because of irregular rainfall. Nevertheless, the 1000 grain weight was higher for the best sowing dates and dropped dramatically for the last sowing dates.

Introduction

Le blé est cultivé au Burundi principalement dans les altitudes supérieures à 1900 m sur la Crète Zaïre-Nil.

Le but de ces éssais en moyenne altitude était de déterminer, dans cette zone non traditionnelle de culture, les meilleures époques de semis en vue d'introduire la culture du blé dans cette zone. En effet, les emblavures sur la Crète Zaïre-Nil atteignent 6000 à 7000 ha, dont uniquement 1000 ha environ pour la première saison culturale (1). Cette production sert uniquement à l'auto-consommation et la minoterie de Muramvya reçoit moins de 1% de ses besoins de la production nationale (2). Les besoins de la minoterie étant estimés à 21 600 T. par an (3), les ventes nationales vont de 40 à 120 T en général. Pour pallier à ce problème, on a donc songer à étendre la zone de culture dans la région naturelle du Kirimiro, situé sur les plateaux à l'est de la Crète Zaïre-Nil.

Matériel et méthodes

Environnement pédo-climatique--Les éssais ont été effectués au centre agricole de Rutegama à environ 1700 m d'altitude. Le climat de la région appartient essentiellement au type AW (tropical humide) selon la classification de Koppen. Considérant les moyennes normales des chutes de pluies de la décennie 70, la cote udométrique varie entre 1100 mm à 1300 mm de pluies (4). On relève en général le fait que les précipitations sont irrégulièrement réparties avec des variations notables concernant le début et la fin de saison (sèche ou pluvieuse) d'une année à l'autre et les totaux pluviométriques annuels diffèrent parfois significativement de la normale. La saison sèche couvre normalement trois mois, mais peut s'étendre sur quatre à cinq mois.

La température moyenne annuelle est comprise entre 18 et 20°C. Les moyennes annuelles des maxima sont peu variables et leur fourchette de variation s'étend de 25 à 27° C. Pour les minima, leur fourchette s'étale entre 11 et 14° C. Les températures les plus basses sont enregistrées au mois de juillet en pleine saison sèche et les plus hautes, au début de la saison pluvieuse (mois de septembre-octobre-novembre).

Les sols du site étudié sont des hygro-xeroferrisols et sont en général bruns, argileux et leur texture est legère (dérivant des roches micacées acides) (4).

Dispositif expérimental et techniques culturales--Quatre éssais ont été effectués, dont deux en 1ère saison culturale et deux autres en seconde saison culturale. La variété de blé utilisée pour l'expérimentation était Cowbird, étant donné qu'elle s'était révelée supérieure au cours des éssais multilocaux de 1983 (BT 8305/B). Les semis se sont effectués chaque fois échelonnés de 15 jours, c'est-à-dire le 1er octobre, 15 octobre, 1er novembre pour la première saison culturale, et le 1er février, 15 février, 1er mars et 15 mars pour la seconde saison culturale. Les éssais ont débuté en seconde saison culturale de 1985.

Le dispositif expérimental est celui des blocs aléatoires complets avec quatre répetitions avec des parcelles élémentaires de 10 m^2. Les semis se sont faits en lignes espacées de 20 cm à raison de 120 kg de grains par ha, avec application à la volée le jour du semis de 40-40-40 unités N-P_2O_5, K_2O par ha.

Résultats et discussion

Durant la 1ère saison culturale, les semis du 1er octobre ont été affectés par une sécheresse prolongée (Graphique No 1). Les semis tardifs du 15 novembre sont affectés par la petite saison sèche de fin décembre (durant la période de tallage), ainsi qu'une forte attaque de septoriose. Ceci explique les faibles rendements des semis du 1er octobre et du 15 novembre. Pour les autres dates de semis, on remarque que les pluies, sans être optimales, ont été plus importantes. Les rendements des semis du 15 octobre et du 1er novembre ont été plus performants.

En comparant les rendements de deux années, on constate le niveau des rendements plus élevé de 1986 dû au sol plus fertile et plus homogène comparé au sol choisi en 1987.

D'où les rendements du 15 octobre et du 1er novembre de cette année, quoique numériquement supérieurs au témoin, n'ont pas été significativement différents à cause du coefficient de variation très élevé enregistré.

Le terrain ayant été plus homogène aurait permis de déceler les différences réelles qui existent entre le témoin et les meilleures dates.

Concernant les autres paramètres agronomiques, la meilleure date de semis donne des plantes de haute taille. Pour l'épiaison, la meilleure date de semis entre en épiaison tardivement, sinon les autres y entrent précocement mênre la derniere date. La date de maturité des plantes ainsi que le poids de 1000 grains ont décru régulièrement avec les dates de semis pour chuter très fort avec la dernière date de semis. D'où les meilleures dates ont été plus précoces, sauf la dernière date qui a subi un grand stress climatique incitant à la maturation. Le poids de 1000 grains des meilleures dates est faible par rapport au temoin et il chute très fort avec la derniere date de semis.

La meilleure époque de semis se situe entre le 15 octobre et le 1er novembre pour la première saison culturale en moyenne altitude (1700-1900 m d'altitude). Les résultats de la 1ère saison culturale 1986 et 1987 sont repris au Tableau 1.

En analysant les résultats de la seconde saison culturale 1985, on remarque en général la supériorité des semis précoces: ceux-ci du 1 février et du 15 février.

Les dernières dates de semis accusent des chutes de production dues au déficit hydrique, car les pluies deviennent très irrégulières 45 jours après les semis, c'est-à-dire durant le tallage et deux semaines avant le début de l'épiaison. A cette époque, le blé a besoin d'une bonne pluie régulière pour bien taller et former des futurs épis bien remplis. D'après les éssais installés en haute altitude au Burundi où les composantes de rendement ont été analysées, le nombre de grains par épi reste déterminant pour le rendement du blé (5).

Pour les autres paramètres agronomiques, plus les semis seront tardifs, plus la durée à l'épiaison aura tendance à être longue, contrairement à la 1ère saison culturale, mais il n'y a pas eu de différence significative pour la maturité. Pour la taille des plantes, seule la dernière date a eu des plantes courtes. Concernant le poids de 1000 grains, seul le semis du 15 février montre une différence significative avec les autres dates, mais elle est faible.

En seconde saison culturale de 1986, les résultats diffèrent uniquement suite à la répartition différente des pluies comparée à celle de 1985 (Graphique No 2).

Les résultats montrent que les dernieres dates ont été les meilleures pour le rendement, la taille des plantes et une durée à l'épiaison courte. Concernant la période à la maturité, les meilleures dates ont été plus tardives.

Les résultats des deux mêmes saisons ont été différents et ceci s'explique en analysant le Graphique 2 où l'on voit la répartition journalière des pluies de février 1985 et février 1986. En février 1986, les pluies ont été moins abondantes, plus sporadiques. Il n'y a pas eu suffisamment de pluies, ni le jour du semis ni même quelques jours après, lors des semis du 1er février et du 15 février. Par contre, en 1985, les pluies ont été régulières, plus abondantes et surtout il y a eu chaque fois une bonne pluie le jour de semis.

Cela a été bénéfique pour une levée des plantes vigoureuse et aussi pour rendre efficient les engrais appliqués le jour du semis, surtout l'azote.

En 1986, les pluies manquant pendant quelques jours ont fait que l'azote n'a pas été bien profitable. Les plants sont alors devenus chétifs; ce qui se remarque par leur taille (Tableau 2).

On constate que par rapport à l'année de référence (1951-1980), l'année 1986 a accusé un déficit hydrique au mois de mars pendant justement la période où le blé a besoin d'une pluie suffisante, alors que l'année 1985 a connu un mois excédentaire (Graphiques 3 et 4).

Comme tous les semis ont été effectués avant ou pendant le mois de mars, ce déficit hydrique a affecté le niveau général des rendements de 1986 comparés à ceux de 1985. L'irrégularité des pluies de 1986 explique par contre la différence des résultats de ces deux années.

Les résultats de la deuxième saison 1986 ne valent pas ceux de la même saison en 1985 à cause de cette irrégularité anormale de la tombée des pluies, ainsi que du coefficient de variation plus élevé.

En 1985, la saison a été normale et la répartition des pluies a été plus régulière et donc les résultats à prendre en considération sont de cette année.

Par conséquent, les meilleures époques de semis en deuxième saison culturale se situent entre le 1er février et le 15 février. Les résultats sont repris au Tableau 2.

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Résumé

Dans la zone de moyenne altitude au Burundi (1700 m), des éssais de détermination de l'époque optimale de semis ont été effectués en 1ère et 2nde saisons culturales durant deux années.

Quatre dates ont été choisies pour chaque saison, la première date correspondant au début d'une saison agricole et les autres dates étant échelonnées de deux semaines.

En premiere saison agricole, les rendements étaient significativement supérieurs pour les semis de 15 octobre et du 1er novembre. Quant aux autres paramètres agronomiques, les meilleures dates donnaient des plantes de haute taille avec une maturité précoce, mais leurs poids de 1000 grains etaient significativement inférieurs.

En deuxième saison agricole, les semis précoces ont eu des rendements significativement supérieurs aux autres. Quant aux autres paramètres agronomiques, l'epiaison et la maturite ont été variables suite à l'irrégularité des pluies. Neanmoins, les poids de 1000 grains étaient les plus élevés pour les meilleures dates de semis et chutaient très fort pour les semis ultérieurs.

Tableau 1. Rendements et autres caracteristiques agronomiques en fonction des differentes dates de semis en 1ere saison culturale a 1700 m d'altitude

Dates	Rendement kg/ha		Hauteur (cm)		Epiaison (jours)		Maturite (jours)		Poids de 1000 grains (en g)	
Annee	1986	1987	1986	1987	1986	1987	1986	1987	1986	1987
1 Octobre (temoin)	1275	726.25	68	60.75	60	81	114	125	32.77	31.3
15 Octobre	2008.5**	1084.25	77	66.25	62**	67	108**	111	29.63*	28.75*
1 Novembre	1825.5	813.25	71.5	64.75	58**	66	102**	106	29.08*	28.43*
15 Novembre	1211	798.75	71	66.5	55**	59	93**	99	23.48**	23.51**
C.V. (%)	18.6	31								

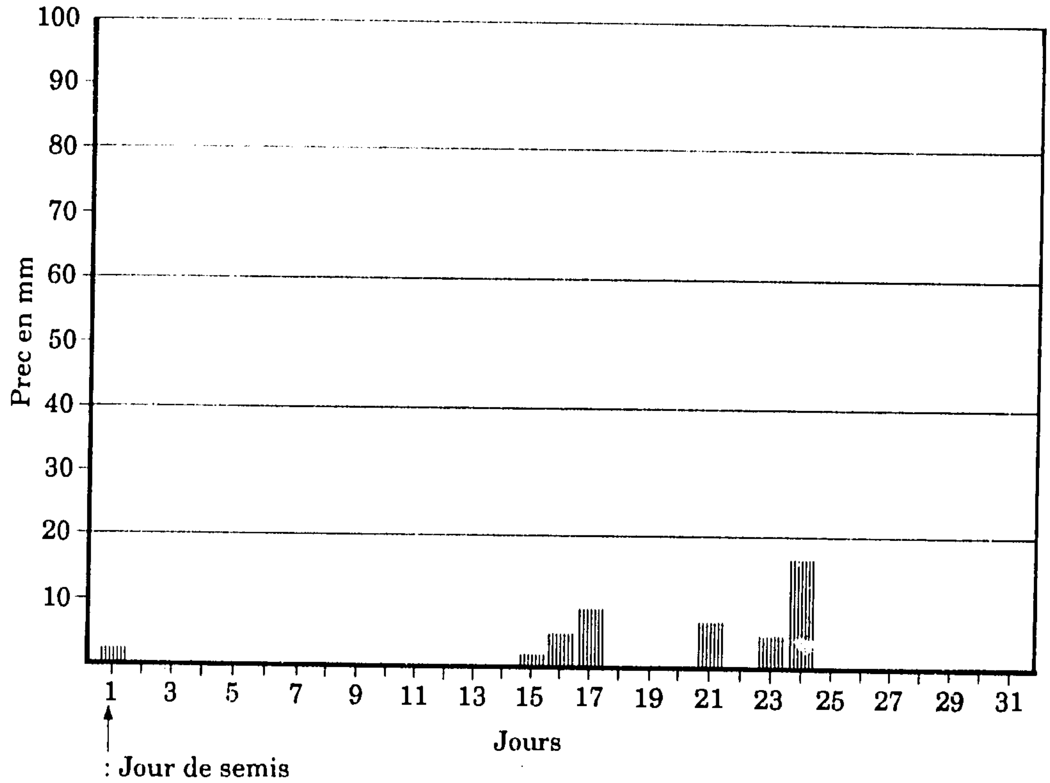
*, **, Significativement differents aux seuils de 5 et 1%, respectivement.

Tableau 2. Rendements et autres parametres agronomiques en fonction des differentes dates de semis de la seconde saison culturale a 1700 m d'altitude

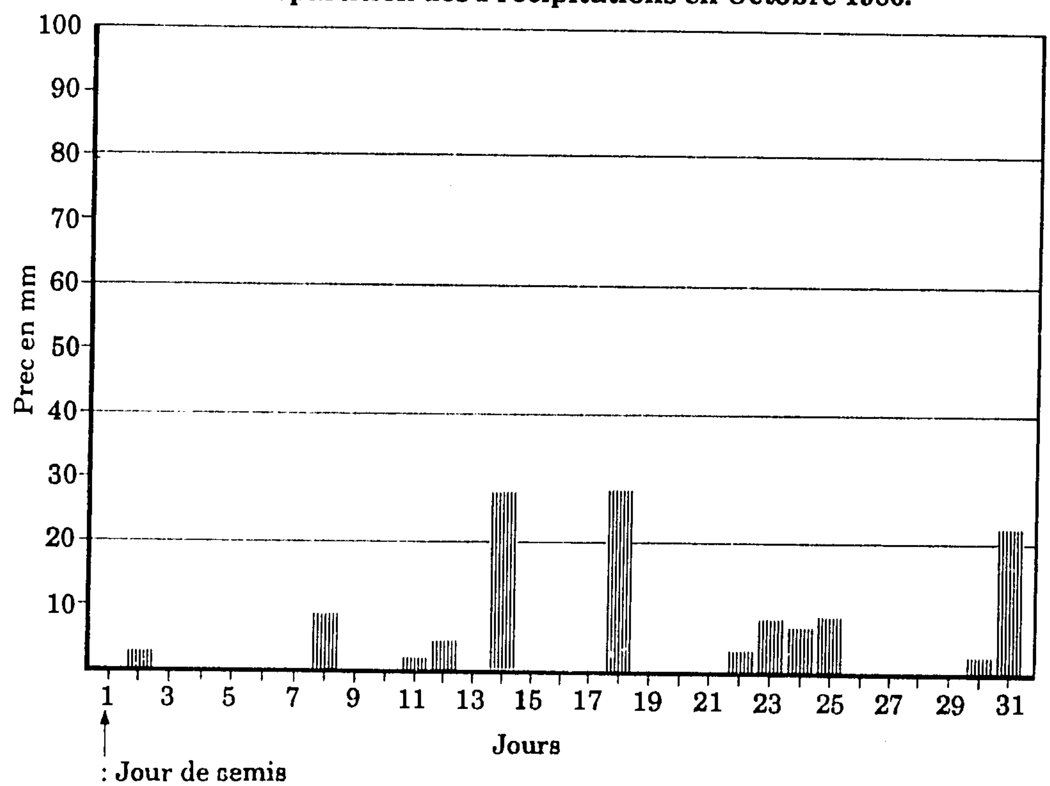
Dates	Rendement kg/ha		Hauteur (cm)		Epiaison (jours)		Maturite (jours)		Poids de 1000 grains (en g)	
Annee	1985	1986	1985	1986	1985	1986	1985	1986	1985	1986
1 Fevrier	1443.7	245.75	79	44.2	53	63	105	81	31.47	--
15 Fevrier	1166.2	233	75.5	51.7	59**	56***	104	109***	34.40*	--
1 Mars	1142.5	458.75**	76.25	59.5***	60**	56***	104	108***	29.15	--
15 Mars	586.2**	366.5*	56.75**	53.2***	59**	54***	103	99	24.85	--
C.V. (%)	17.9	23.32								

*, **, *** Significativement differents aux seuils de 5, 1, et 0.1% respectivement.

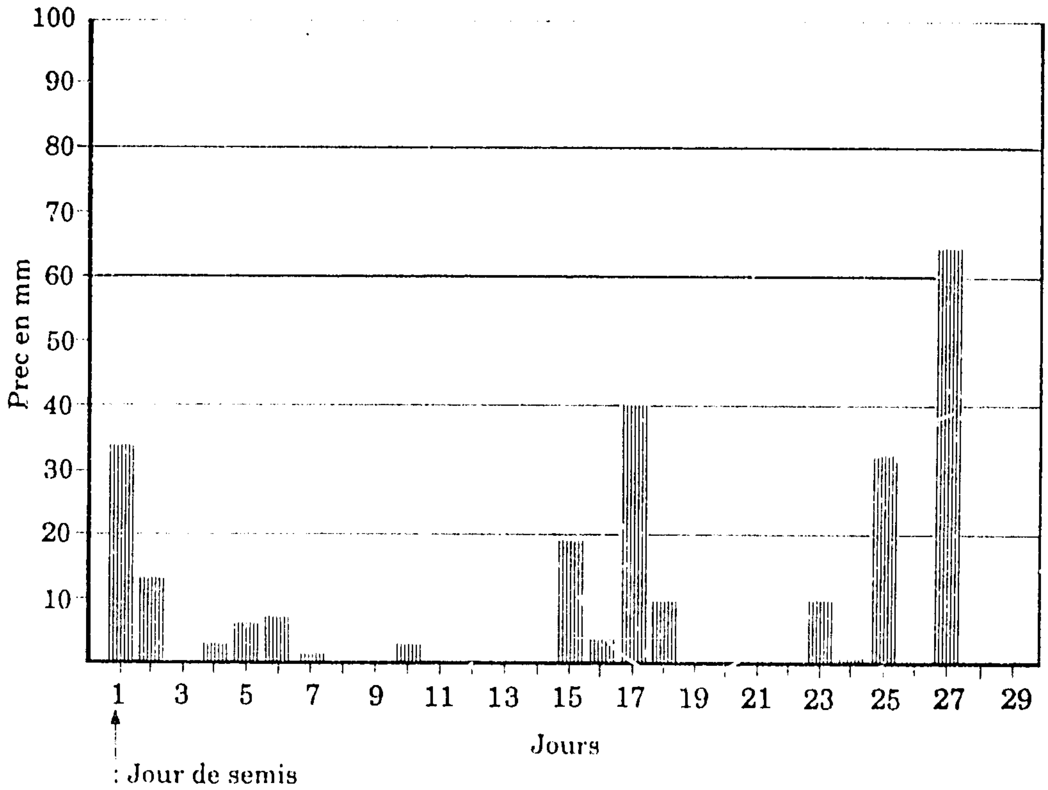
Graphique 1. Repartition des Precipitations en Octobre 1985



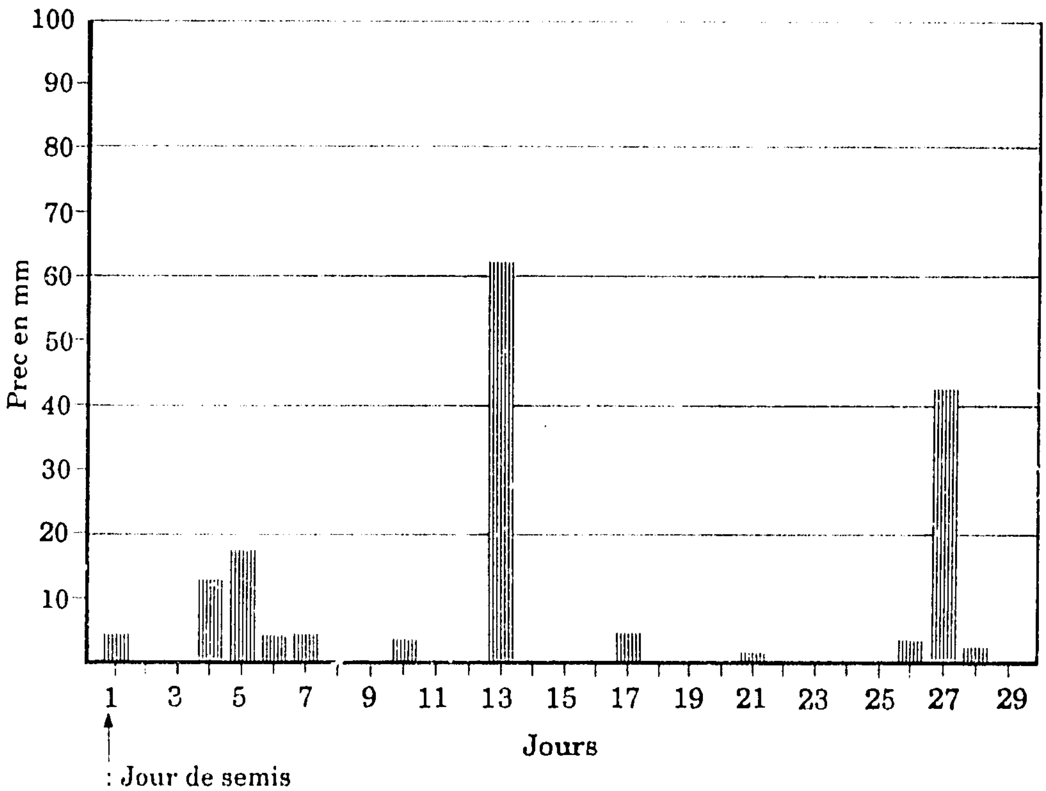
Repartition des Precipitations en Octobre 1986.



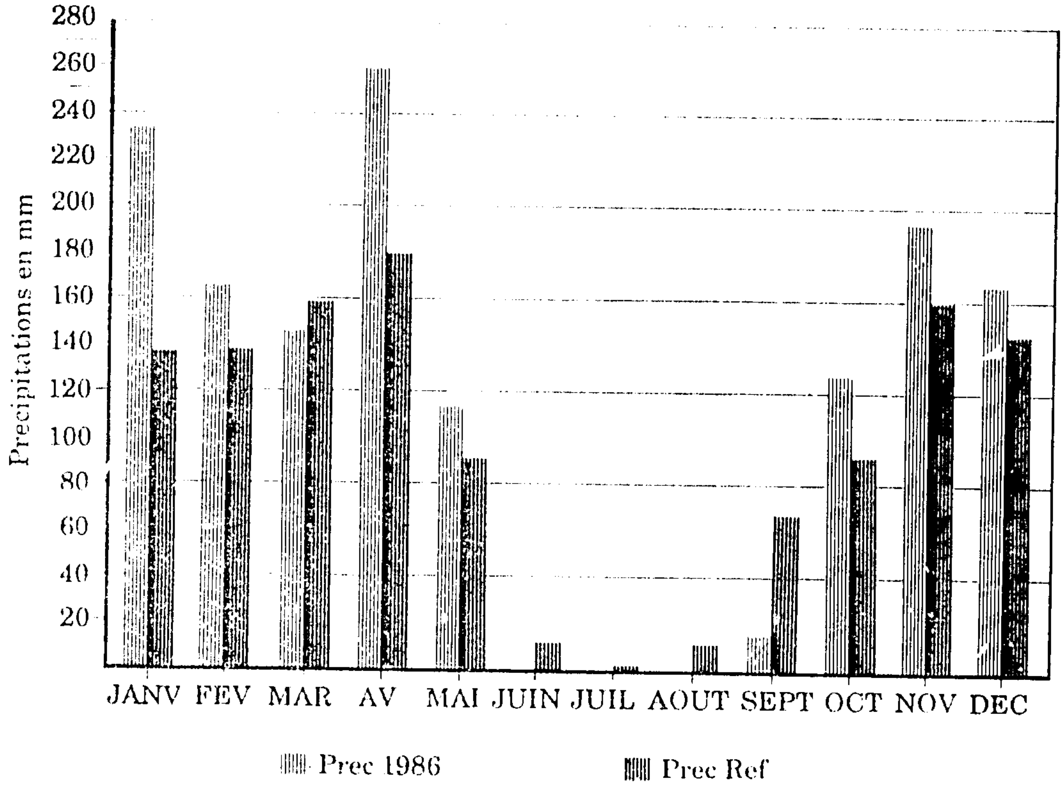
Graphique 2. Repartition des Precipitations en Fevrier 1985.



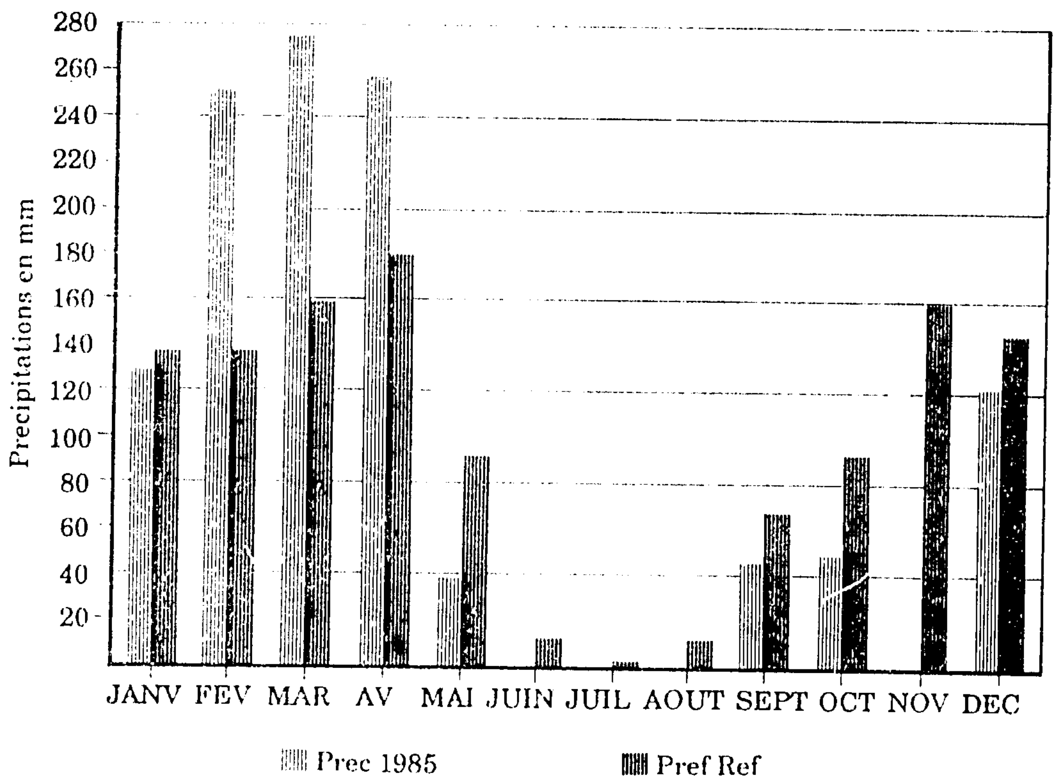
Repartition des Precipitations en Fevrier 1986.



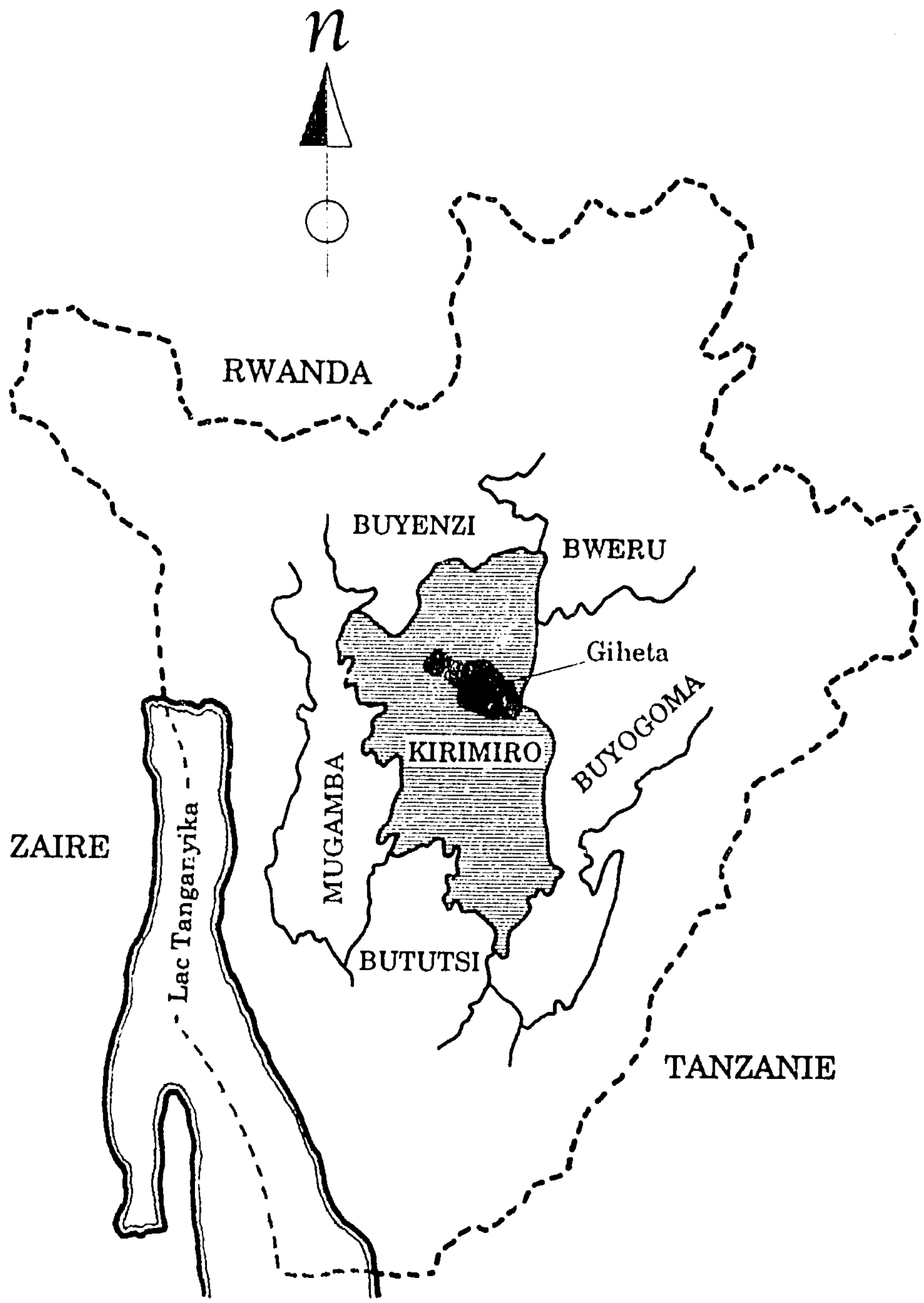
Graphique 3. Precipitations Mensuelles
Prec 1986 et Prec Annee de Ref



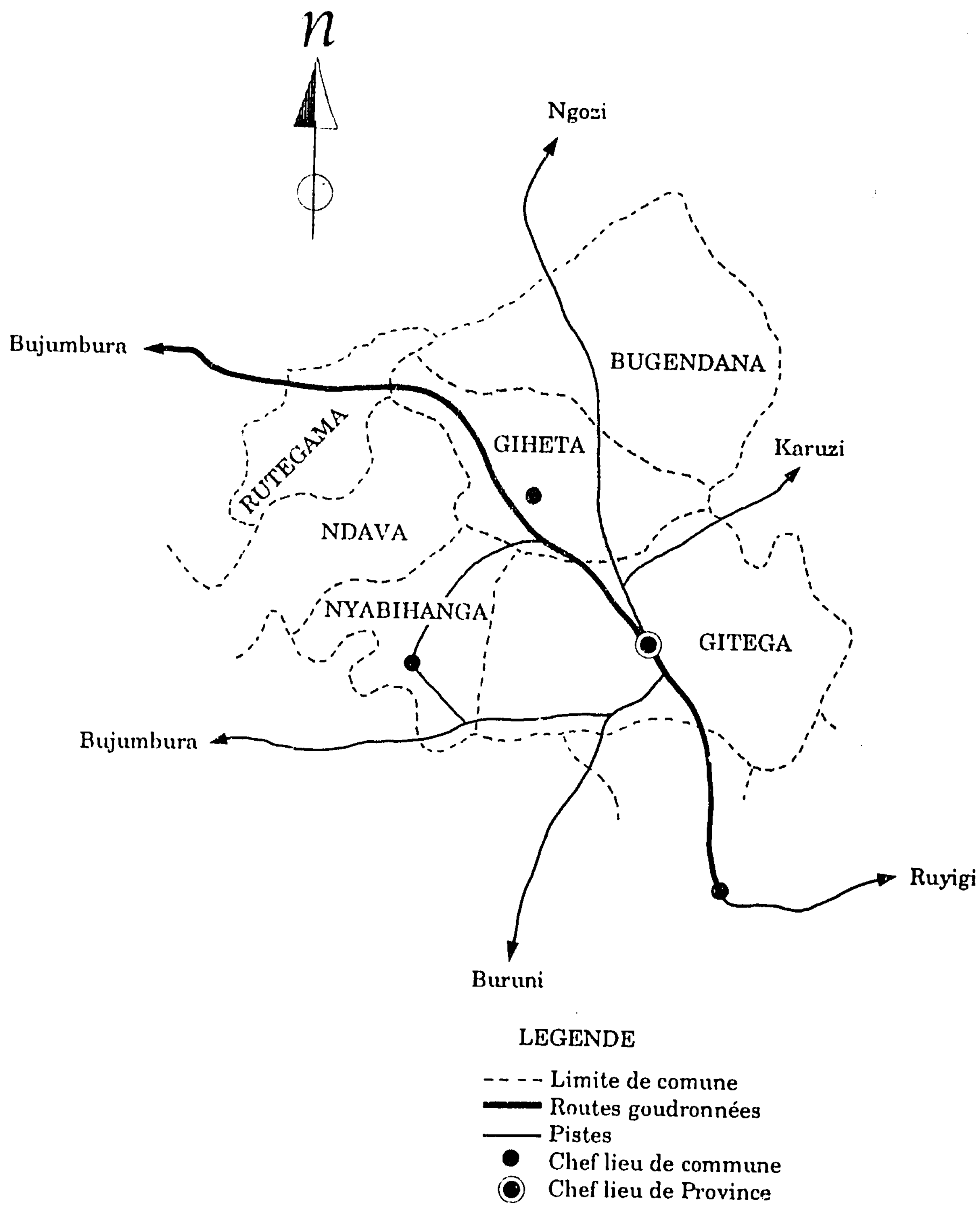
Graphique 4. Precipitations Mensuelles
Prec 1985 et prec annee de ref



Localisation de la région naturelle de KIRIMIRO



Localisation de la comune GIHETA



CROP AGRONOMY RESEARCH ON VERTISOLS IN THE CENTRAL HIGHLANDS OF ETHIOPIA: IAR'S EXPERIENCE

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Abstract

Barley is a major food crop around the district of Sheno in Ethiopia. Its production is associated with soil burning or "guie" and a long period of fallowing. Fairly high yields are obtained in the first crop season of "guie" but yields decline dramatically after the second crop season. Teff (Eragrostis abyssinica) and wheat are major food crops around Ginchi; they are planted late in the main rainy season and yields are quite low.

Crop agronomy research was conducted by the Institute of Agricultural Research at Sheno and Ginchi since 1986 and 1974, respectively. The major objective for undertaking research was to replace the inefficient traditional practices of crop production with improved drainage, fertilizer and crop management techniques.

Effects of "guie" were investigated at Sheno. Various drainage methods in association with N and P fertilizers were compared to alleviate waterlogging and increase fertilizer efficiency. Barley and wheat yields were substantially increased on 4-6 m wide cambered beds with application of 60-26 kg N-P/ha. Response to fertilizer was better with wheat than barley. Grain yields fluctuated with continuous barley production under improved management.

At Ginchi wheat yields were increased over 100% with improved drainage and application of 69-20 kg N-P/ha. Improved cultivars responded well to fertilizer application.

Introduction

Currently about 2 million ha of vertisols are cropped annually and about 6 million ha are left under native pasture because of severe drainage problems in the main rainy season (7). With the present trend of population growth in Ethiopia, estimated at 2.9%, there is a strong need for increased agricultural production which may be achieved by increasing productivity per unit area and/or opening new lands. Both options may be applied on vertisols in the highlands.

Some of the major limitations for crop production on vertisols are poor drainage, difficulty of seed bed preparation, and low soil fertility. In the high altitude areas the impact of low temperature complicates the soil problems.

Traditionally, farmers may cope with these problems by sowing crops late to mature on residual moisture, fallowing the land in the main rainy season, and by soil burning or "Guie" (1). Land that is plowed early for late planted crops is exposed to soil erosion due to high and intense rainfall, thereby diminishing soil fertility.

The Institute of Agricultural Research (IAR) has been conducting agronomy research at Sheno, about 70 km north-east of Addis Ababa, since 1968 and at Ginchi, 85 km west of Addis Ababa, since 1974. Crop production patterns and the research experiences at these locations shall be reviewed in this report. It is possible to increase crop productivity on Vertisols through improved drainage, fertilizer and crop management (5, 6, 7, 9, 10, 12).

Crops and Production Patterns

Sheno--Sheno is situated at an altitude of 2800. The surrounding area is a highland plain representing a large expanse of land in the central highlands. The soil is about 60% clay, pH slightly acid, with 0.2-0.3% total N and 7 ppm of available P (10). Annual rainfall is about 900 mm with excess rain in July and August. "Guie" is extensively practiced in the region. "Guie" plots are cropped to barley for 2-3 seasons and then left fallow for 10-20 years.

The predominant crop is barley with some faba beans, wheat, fieldpeas, and oats and a limited area of lentils and linseed. Average yields of crops around Debre Berhan are 856 kg/ha for barley, 1295 for faba bean, 964 for wheat, and 846 for field peas (2). Crop intensity is high on the hillsides and low on the bottom lands which are flooded in the main rainy season. Faba beans and wheat are mostly produced on the hillsides which have better drainage and less frost hazard; barley is produced on the flatter lands (2). "Belg" or off-season barley is mainly produced on bottom lands.

Tillage operations may start in September or October for "Belg" season production and "Guie" fields with repeated plowings in the short rainy season. "Guie" fields are planted in June. With the exception of wheat, early sowing is practiced for all crops. Barley may be sown in late June to escape aphid infestation.

Ginchi--The research site is at an altitude of 2200 m. Average annual rainfall is about 1083 mm about 65% of which falls between June and September. The soil is heavy clay with 0.91-1.32% OM, 0.09-0.14% N, and 4.2-9.9 available P (11); the pH is about 6.4 (4).

The major food crops are teff (*Eragrostis abyssinica*), wheat, niger seed and chickpeas. Sorghum, roughpea, and barley also are grown to some extent. Estimates of yields of major crops are 500 kg/ha for teff and chickpeas, 600 for wheat, and 300 for niger seed (Agricultural Economics and Farming Systems Research Division, Survey data, 1986).

Frequency of plowing varies for crops: 3-4 times before planting for teff, 3 times for wheat, 1-2 times for pulses, niger seed and sorghum. Plowing starts in March for cereals and niger seed. First plowing for pulses may be done in May. The small grains and pulses are sown late in the main rainy season and mature on residual moisture, sorghum is sown in March or April and niger seed towards the end of May. A pulse - cereal rotation is a common practice. Teff follows chickpeas in most cases, or rough pea and niger seed. Niger seed may follow sorghum for weed suppression.

Review of Research Results

Sheno testing site--The major objective for agronomy research was to replace the inefficient traditional practice of "Guie" crop culture with improved drainage, fertilizer and crop management techniques for continuous crop production.

About 1.5 t/ha of barley grain yield is obtained on "Guie" fields in the first crop season (12). The high yield is due to improved soil structure and increased availability of ammonium nitrogen and phosphorus; on the other hand, there is a high loss of organic carbon, organic matter, and total nitrogen with detrimental consequences on the cation exchange capacity and microbial activity (1, 9, 10, 12). "Guie" plots respond to fertilizer application and efficiency is better than on regularly plowed plots (12). Yields on "Guie" plots decline dramatically after the second season of barley production (9, 12).

In the early years, research on soil and fertilizer management was directed towards comparing the efficiency of tractor-drawn plows (such as disc, moldboard, and chisel) with narrow and wide cambered beds (prepared with mechanized operation) and using different rates of N and P fertilizers. The assumptions were that deep plowing and/or surface drainage prepared by tractor drawn plows would improve drainage. Higher yield advantages of narrow cambered beds with application of N and P fertilizers were realized. In 1970, about 2.5 t/ha of barley grain yield was obtained on a 6m - wide cambered bed with application of 60/13 (N/P) kg/ha (9). Grain yields of barley, wheat and oats were also better on narrow cambered beds than on "Guie" plots (9). Fertilizer efficiency was high on narrow cambered beds for barley and wheat.

The higher yield advantages of narrow cambered beds over local plowed and moldboard plowed plots were further confirmed in later years on barley and wheat. Best yields were obtained on cambered beds due to improved drainage (Table 1). However, efficiency of fertilizer with local barley was nearly similar on local plowed and cambered bed (10, 12).

Fertilizer efficiency with wheat was much better with improved drainage; wheat also responded better to additional P application than barley at a standard level of 60 kg N/ha (Table 2).

Grain yields of continuous barley production fluctuated over years; it was difficult to maintain stable yields with improved drainage and optimum fertilizer application (Table 3). Rotation with pulses may be essential to sustain grain yields.

Ginchi testing site--In 1971 a testing site was established at Wollencomi, 74 km west of Addis Ababa, to conduct research on drainage and fertilizer management and selection of high yielding crops and cultivars for early sowing on vertisols. The Ginchi site, 11 km further west, was selected in 1974 for better representation of the surrounding areas.

From 1975-1977 different methods of drainage systems-cambered beds, open trenches, and sub-surface trenches filled with wooden poles and branches at 4, 6, and 8 m intervals were compared on improved and local varieties of wheat, teff, and chickpeas at zero and optimum fertilizer levels. Grain yields were not different due to drainage systems; improved drainage had a significant effect on grain yields of crops especially wheat whose yields were increased over 100% compared to undrained plots (Table 4).

Wheat and teff gave better yields with narrow interval drainage methods; chickpeas performed better with wider intervals (5). Fertilizer efficiency was highest for wheat with improved drainage, while chickpeas responded poorly (Table 5). Between the wheat varieties, Enkoy responded better to fertilizers and improved drainage giving 1.8 t/ha while Bahir Seded yielded 0.65 t/ha; there was no difference between varieties of teff or chickpeas (5).

Results of sowing date studies on three cultivars of wheat - Enkoy, Cocorit 71 and Bahir Seded covering the period from the end of June to the third week of August showed no significant differences on 8m wide cambered beds (6). Average grain yields were 2.11 t/ha on cambered beds and 1.25 t/ha on flat beds; improved drainage gave about 68.8% yield increase over undrained plots (6). The cultivars Enkoy, Cocorit 71, and Bahir Seded yielded 2.4, 2.1 and 1.9 t/ha, respectively on combered beds; Enkoy was significantly better yielder than the other cultivars (6).

Undersowing wheat simultaneously with barrel medic, snail medic and *Trifolium* were found promising with 2-3 t/ha grain yields of wheat, comparable to sole crops, and dry matter forage yields of over 2 t/ha from the forage crops (8).

The major direction on cereal breeding is to select high yielding, late maturing cultivars for sole cropping to utilize the whole growing season. Long season wheat cultivars giving about 3.2 t/ha are identified for Ginchi (3).

Research Direction

Current research on vertisols is strengthened by collaborative work involving ILCA, ICRISAT, IAR, Agricultural University of Alemaya and the Ministry of Agriculture. The sharing of experiences among the institutions helps to streamline the research direction. Applied agronomic research based on animal drawn implements would have more relevance to the highly subsistence-oriented nature of crop production on highland vertisols. For high altitude areas, it may be worthwhile to consider alternative cropping systems for small grain-based production, appropriate tillage methods, and proper seeding and fertilizer application.

Cropping systems--Crop productivity on Vertisols can be increased through early planting and improved surface drainage. Appropriate cropping systems are required for efficient utilization of the whole growing season. Some forage legumes are known to benefit food crop production by enhancing soil fertility when planted in association or rotation with a major food crop. Most of the available information is relevant to maize and sorghum production in the mid-altitude areas, such as Debre Zeit. In the higher altitude areas, small grains are major food crops, so cropping systems based on such crops would be more appropriate. Some *Vicia*, *Trifolium* and *Medicago* species have high potential for sequential cropping with cereals. Some useful cropping systems may include: 1) forage legume-cereal sequence in the off-seasons and main rainy seasons and 2) cereal-pulse sequences in the main season.

Tillage--Timeliness of tillage with respect to soil moisture content is important to work the soil properly for effective control of weeds. The local plow is not effective for weed control; hence, better implements are needed. Reduced tillage with shallow cultivation and the use of glyphosate for weed control may be important (13).

Proper seeding and fertilizer application--There is a high waste of fertilizer on Vertisols due to the broadcast method of sowing and denitrification due to waterlogging. Proper methods of seeding, and method and time of application of fertilizers are important for efficient fertilizer use.

Conclusion

At Sheno relatively high grain yields are obtained with "Guie" in the first crop season due to improved soil structure and availability of substantial amounts of ammonium nitrate and phosphorus. Yields decline dramatically after the second crop season. Better grain yields can be obtained with improved drainage using 4- to 6-m wide cambered beds. There is good response to NP fertilizer with improved drainage especially with bread wheat. Yields fluctuate with continuous barley production even with improved drainage and optimum fertilizer application. Rotation with pulses may be essential to sustain grain yields.

At Ginchi improved drainage also gives a favorable impact on grain yields of crops, especially wheat. Teff and wheat perform best with 4- to 6-m wide drainage methods. Wheat responds well to NP fertilizer with improved drainage. Chickpeas have low response.

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Résumé

L'orge et l'une des principales cultures dans le District de Sheno en Ethiopie. Sa production est associée à la pratique du brûlage ou "guie" et à de longues périodes de jachère. Au cours de la première saison culturale, après le "guie", des rendements assez élevés sont enrégistrés. Cependant, les rendements chutent brutalement après la deuxième culture. A Ginchi, les principales cultures vivrières sont le teff (Ergrostis abyssinica) et le blé; elles sont semées vers la fin de la saison des pluies et leurs rendements sont assez faibles.

L'Institut de Recherche Agricole réalise des travaux depuis 1968 à Sheno et depuis 1974 à Ginchi. Son objectif principal est de mettre au point des techniques améliorées de drainage, de fertilisation et de gestion des cultures pour remplacer les pratiques traditionnelles peu efficientes. Les effets du "guie" ont été étudiés à Sheno. Diverses méthodes de drainage, conjuguées à l'épandage d'engrais (N/P), ont été comparées afin de pallier à l'engorgement en eau et d'accroître l'efficacité de la fertilisation. Une augmentation substantielle des rendements de l'orge et du blé a été observée sur des plates-bandes de 4 à 5 m de largeur avec l'apport de 60/26 kg/ha d'N/P. A Sheno, la production de l'orge cultivée de façon continue avec une gestion améliorée fut irrégulière.

A Ginchi, grâce au drainage amélioré et à l'épandage de 69/20 kg/ha d'N/P, les rendements du blé ont augmenté de plus de 100%. Les cultivars améliorés ont bien répondu aux engrais.

Table 1. **Mean grain yields of barley at different methods of seed-bed preparation and NP fertilizer rates, Sheno, 1979-84**

N/P rate kg/ha	Grain yields (kg/ha) LP[a]	MP[a]	CB[a]	Mean
0/0	200	400	780	460
30/13	630	690	1200	840
60/26	870	1230	1670	1257
90/40	1090	1410	1990	1497
Mean	698	933	1410	

[a] LP = Local plow; MP = Moldboard plow; CB = 6-m wide cambered bed.
Source: Taye (12).

Table 2. **Effects of seed-bed preparation methods and NP fertilizer rates on grain yields of wheat and barley, Sheno 1976**

N/P rate	Grain yield (kg/ha) Wheat CV. Enkoy				Barley CV. Local Sheno			
kg/ha	LP[a]	MP[a]	CB	Mean	LP	MP	CB	Mean
0/0	119	387	559	355	82	316	565	321
60/13	395	1267	1561	1074	909	1277	1385	1190
60/26	385	1318	1877	1193	1055	1246	1598	1300
60/40	657	1452	1996	1368	1079	1194	1692	1322
Mean	389	1106	1498	--	781	1008	1310	--

[a] LP = Local plow, MP = Moldboard plow; CB = 4-m wide cambered bed.
Source: Mesfin (10).

Table 3. **Response of barley to different methods of seedbed preparation at optimum level of fertilizer application (60-26 kg N-P/ha), Sheno, 1979-84**

Year	Grain yields (kg/ha) LP[a]	MP[a]	CB[a]	Mean
1979	1510	1930	2490	1997
1980	870	1940	2270	1693
1981	470	410	700	527
1982	690	1470	2050	1403
1983	300	520	850	557
1984	1350	1020	1650	1340
Mean	865	1225	1668	--

[a] LP = Local plow; MP = Moldboard plow; CB = 6-m wide cambered bed.
Source: Taye (12).

Table 4. Influence of drainage methods on grain yield of wheat, teff, and chickpeas, Ginchi, 1975-77

Drainage Methods	Grain yields (kg/ha)		
	Wheat	Teff	chickpeas
Cambered bed	1150	1280	1250
Open trench	1150	1180	1200
Subsurface drain	1100	1000	1480
Control	520	940	870
Mean	980	1100	1200

Source: Hiruy (5).

Table 5. Influence of drainage and fertilizers on the grain yields of wheat, teff, and chickpea, Ginchi, 1975-77

Crops	Grain Yields (kg/ha)			
	Undrained		Drained	
	F0[a]	F1[a]	F0	F1
Wheat	360	670	720	1530
Teff	740	1140	840	1470
Chickpeas	850	900	1220	1400

[a] F0 = No fertilizer, F1 = 69-20 kg N-P/ha for wheat and teff; 27-30 kg N-P/ha for chickpeas.
Source: Hiruy (5).

INCREASING WHEAT PRODUCTION IN ETHIOPIA BY INTRODUCING DOUBLE CROPPING UNDER IRRIGATION

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Abstract

Ethiopia is not self-sufficient in cereal grains even though it has 4.7 million ha of land under cereal production at present. Yields for most cereals in general are low and production is exclusively under rainfed conditions. Irrigated agriculture is in its infancy to date, even though the country has 3.3 million ha of irrigable land. Of these only 100,000 ha or about 3.0% is under cultivation. More than half of the presently irrigated area in Ethiopia is in the Awash Valley where 70% of the country's cotton requirement is produced during the warm season (May-October). An acceptable crop is required for the cool season (November-March) to optimize land use efficiency in the Awash River Basin. Hence, field experiments in irrigated wheat were conducted for three years at Melka Werer Research Center and results revealed that wheat is a very good potential cool season crop in the Awash Valley. Four cultivars with about 30 q / ha grain yield potential were identified.

Introduction

At present, about 4.7 million ha of land is under cereal production in Ethiopia. Wheat occupies 13.3% of this area and production is exclusively in the highlands (1800-2800 masl) under rainfed conditions. Even though the state farms produce bread wheat on about 80,000 ha, the major producers are still the small farmers. The national average yield is less than 1.4 t/ha for all cereals except for maize which is 1.8 t/ha (3). As a result, total production falls short of the country's requirement despite the large area under cultivation. Hence, Ethiopia imported about 1.4 million tons of cereal grains through direct purchase and relief aid from different countries during 1984/85. This was 28.8% of total grain supply for the year (4).

The government of Ethiopia is aware of the above mentioned facts and different attempts are being made to make the country self sufficient in food grains in the shortest possible time. The first and most dependable way is believed to be the improvement of the productivity of small farmers thereby increasing the yield per unit area. The second way to grain self sufficiency is to bring more land under cultivation. The third possible way is to intensify production under irrigation.

Even though Ethiopia has 3.3 million ha of irrigable land in its numerous fertile river valleys, irrigated agriculture is in its infant stage. Of the above mentioned irrigable land, only 100,000 ha or 3.0% is in use under irrigation.

Most of the large scale irrigated farms are in the Awash Valley (8). The Awash River Basin is the most utilized of the available fertile river valleys. A reconnaissance soil survey indicate that the gross area of potentially irrigable land in the Awash Valley is approximately 175,000 ha (1). Of this area about 70,000 ha are cultivated, of which 42,000 ha are put under cotton. The Ministry of State Farms Development produces 70% of the annual cotton production of the country in this valley (5). The area under cotton production is rapidly increasing without a decrease in yield (2).

Research carried out a Melka Werrer Research Center during the last 20 years have established recommended management practices for cotton in the Awash Valley. According to the present production practice, cotton is planted in May and needs 150-175 days from sowing to last harvest. This practice makes the same land available to grow an additional crop for about 5 months (November-March), using available land, labor, machinery and irrigation water (5).

The land use efficiency of irrigated regions in Ethiopia is very low compared to other countries which grow more than one crop per year on the same area. To optimize the land use efficiency of the irrigable lowlands in Ethiopia, some other crops could be grown during the cool season without interfering with the cotton production in the warm season. Preliminary results indicated that more research was required. Hence this paper summarizes the results of research into bread wheat as an alternative cool season crop.

Materials and Methods

The wheat cultivars used in this study were 10 selections made from the national bread wheat program and nurseries of different origin e.g., CIMMYT, ICARDA and the Kenyan National Program. During the cool seasons of 1981-1983, cultivars listed in Table 1 were grown under irrigation at Melka Werrer on black clay soil. Melka Werrer Research Center is located at an altitude of 750 m above sea level. It has a mean minimum temperature range of 14.0-18.0°C during the cool season (November - February). The mean maximum temperature range during the same period is 31.0-34.0°C. The pH of the soil in the area ranges from 7-8. The center is a representative research center for irrigated lowlands of Ethiopia in general and the Awash Valley in particular.

The varieties were arranged in a randomized complete block design with four replications during each season. Plot size was 15 m^2 at planting and harvest was made from 12 m^2 during each season. Planting was on both sides of 60 cm ridges. Seeding dates were December 15 during 1981 and 1982 and November 4 during 1983. All plots were fertilized with urea at the rate of 46 kg N/ha during the 1983 growing season only. Seed rate was 125 kg/ha and sowing was done manually. About 150 mm of water was applied every 10-14 days. The trials were hand weeded as required during each season. Plant height, days to heading and days to maturity were recorded for each variety. Thousand grain weight for each variety was determined from a composite sample during all growing seasons. Straw yield was also determined from composite samples in each season. Grain yield from each plot was weighed during each growing season and analysis of variance was performed.

Results and Discussion

A summary of grain yield for the three seasons is given in Table 1. There were no significant differences amongst varieties during all seasons.

Mean grain yields were 17.0, 19.1, and 28.4 q/ha for 1981, 1982, and 1983 growing seasons, respectively. The relatively high yield in 1983 was due to the adjustments in some agronomic practices, sowing date and irrigation frequency, in particular. There is room for improvement in yield as more knowledge in agronomic practices such as sowing date, seed rate, fertilizer rate, irrigation frequency and amount and sowing method is gained (6). In agronomic trials in 1985, yields as high as 60 q/ha were recorded. (Jamal M. unpublished data).

Unlike the experiences in the highlands of Ethiopia, diseases were of lower economic importance than insect pests in general. This was mainly due to the low relative humidity (about 40-60%) and high temperature in particular, which favour rapid multiplication of insects. Aphids and termites were of particular importance.

The summary of agronomic data for the 1983 trial is given in Table 2. All varieties tested headed in 50-63 days after planting and matured within 100 days.

This contrasts with the highland varieties in Ethiopia which need up to 160 days to mature. These varieties have a 30- to 40-day grain filling period at Melka Werrer and this relatively short grain filling period can impose a limitation on the yield potential of the cultivars. Plant height ranged from 75 to 105 cm and lodging was not a problem in any of the varieties. Thousand grain weight ranged from 29.5 to 39.0 g. The grains were plump and well filled similar to that of the wheat grains produced in the major production regions of Ethiopia.

Considering the large number of animals in the valley, straw yield becomes an important factor to be considered. It can be baled and fed to animals during feed shortage periods (5). Straw yield ranged from 4.9 to 6.1 t/ha during the 1983-84 growing season. Taking into consideration all these factors, wheat appears to be a good potential cool season crop in the Awash Valley. Varieties Bluejay"S", Chenab 70, Pavon 76 and Hazira are the most promising of the ten tested cultivars.

Since cotton is produced only during the warm season (May-October) and wheat can be produced during the cool season (November-February) in the Middle Awash Valley, doubling the cropping intensity of the irrigable land in this valley is possible. This, however, requires intensive machinery use, since the time left for land preparation is short. It is concluded that Ethiopia can increase its wheat production by double cropping wheat after cotton in its irrigated lowlands.

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Résumé

L'Ethiopie n'arrive pas à réaliser l'autosuffisance en céréales alors que celles-ci couvrent actuellement 4,7 millions d'hectares. Les rendements de la plupart des céréales sont généralement faibles et la production repose exclusivement sur la culture pluviale. Actuellement, la culture irriguée en est à ses débuts. Sur les 3,3 millions d'hectares irrigables, seulement 100 000 hectares, soit environ 3%, sont cultivés. Plus de la moitié des superficies actuellement irriguées en Ethiopie est située dans la vallée de l'Awash où la culture du coton durant la saison chaude (mai-octobre) permet de satisfaire 70% des besoins du pays. L'exploitation optimale du potentiel de production des terres du bassin de l'Awash nécessite de trouver une autre culture adaptée à la saison froide (novembre-mars). Dans cette optique, la culture irriguée du blé a été expérimentée pendant trois ans au Centre de Recherches de Melka Werer. Les résultats des travaux ont montré que le blé y offre de très bonnes perspectives comme culture de saison froide. Quatre cultivars avec un potentiel de rendement en grains d'environ 30 q/ha ont été identifiés.

Table 1. Summary of grain yield (q/ha) of 10 bread wheat cultivars grown under irrigation at Melka Werrer, 1981-1983

Variety	Year 1981	1982	1983	Mean
Hazira	18.8	19.3	24.4	20.8
Abughriab No. 3	17.0	18.5	31.3	22 3
Pichihuila"S"	16.8	15.2	--[a]	16.0
Pavon 76	18.9	17.5	31.0	22.5
Bluejay"S"	19.4	21.7	30.6	23.9
Chenab 70	17.7	23.5	31.9	24.4
Nacozari 76	14.2	22.2	28.7	21.7
Ku-75-11-53	14.9	15.4	22.9	17.7
Mayo 74	17.3	18.8	28.0	21.4
Cno-7CxCc-Tob	15.2	17.7	28.0	20.3
Mean	17.0	19.1	28.4	21.5
S.E.	2.5	2.3	2.4	
L.S.D. at 5%	NS	NS	NS	

[a] Not tested in 1983.

Table 2. Summary of agronomic data of wheat cultivars grown under irrigation at Melka Werrer in 1983-84

Variety	Days to Head	Days to Mature	Plant Height (cm)	Straw Weight (t/ha)	1000 Kernel Weight (gm)
Hazira	51	95	80	5.0	36.7
Abughriab No.3	51	95	87	6.1	29.5
Pavon 76	54	98	95	5.4	37.6
Bluejay"S"	51	95	80	5.7	35.4
Chenab 70	62	100	85	4.9	37.6
Nacozari 76	50	95	80	5.8	35.3
Ku-75-11-53	52	95	75	5.3	39.0
Mayo 74	51	95	91	6.1	36.5
CNO-7CxCc-Tob	63	100	105	5.4	30.5
Location Mean	54	96	86	5.5	35.5

THE STATUS OF WHEAT RESEARCH AND PRODUCTION IN SOMALIA

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Abstract

The government of Somalia is investigating the feasibility of domestic irrigated wheat production to substitute for the current high level of wheat product importation. The results of recent screening trials suggest that it may be possible to obtain heat-tolerant and disease-resistant varieties with economic yield levels, but little information on appropriate agronomic practices has been generated yet. The results of the most recent research trials are presented.

Introduction

Somalia, like many other tropical countries, is not self-sufficient in wheat. However, its population consumes wheat products in the form of bread, pasta and cakes (see Table 1). Some of the wheat flour and spaghetti is purchased with scarce foreign exchange while the rest is provided through food aid. Eighty percent of the imports are flour, with grain and pasta accounting for the remaining 20%.

The demand for wheat products is rising due to an increase in the urban population and associated changes in dietary behavior. This contributes to the country's serious problem with the balance of payments and trade. Alternative solutions are to limit importation or to explore the wheat growing potential of the country.

Rainfed Wheat Growing Area

Wheat has been grown historically in the north west region of Somalia, where its production was favored by the higher altitude (1500 masl), under a unimodal rainfall distribution with an average of 500 mm/year. Previously, an area of 3000 ha (1) was cropped annually to wheat with an average production of 1200 t of grain. Varieties grown in this region are similar to the older materials from the Ethiopian highlands and are characterized by low yield (4 q/ha) and late maturity, which subjects the crop to a high risk of failure due to extremely variable rainfall. To avoid this, farmers have opted to grow sorghum, which is more drought resistant and more reliable. Thus, over the last decade, the area under rainfed wheat production has been reduced. At present, the effort to develop and improve dryland agriculture is receiving funds from the IBDR and IFAD.

Research on Irrigated Wheat

In the 1970s, limited research on irrigated wheat was conducted at the Central Agricultural Research Station (CARS) in Afgoi by staff of the Agricultural Research Institute (ARI). Varieties for screening were introduced from the USSR, CIMMYT (Mexico), Egypt, and Kenya. Results were reported to be satisfactory, although none of the varieties had been described as heat tolerant. An average of 12 q/ha was obtained from the best varieties using high levels of inputs. Poor grain filling was mentioned among the major constraints to achieving acceptable wheat yields in lowland areas (2). From this group of trials, June was suggested as the most suitable date of planting.

In 1985, research on irrigated wheat resumed with the following objectives:

1) To obtain wheat varieties, both durum and bread wheat, which possess the characteristics of early maturity, disease resistance, heat tolerance and high productivity.

2) To identify agronomic practices that could be adopted by farmers and are feasible within the present cropping system.

An interdisciplinary team has been established under ARI coordination and wheat trials have been conducted in Jenale, Afgoi, Baidoa and Labagaras (in the latter 2 sites, screening has been conducted under rainfed conditions). At Jenale, wheat nurseries were planted on four different dates with the objective of observing the adaptability of the wheat varieties received from FAO in 1985. Screening of varieties received in the 9th SNACWYT from CIMMYT (East Africa) was also conducted and several entries were retained for further testing. Another trial was conducted to compare the effectiveness of pre- and post-emergence herbicides with hand weeding. The climatic characteristics of Jenale are reported in Table 2.

Variety screening--Haramoun, Mexipak, Belbec, Super X, Sannine and F. aurora were introduced by FAO in 1985, and Jori 69 (durum wheat) in 1986. With the exception of Belbec and F. aurora, all of these cultivars originated from CIMMYT crosses and were first released in various countries over the period 1965-75. Four observation nurseries were planted during September and November of 1985 and May and September of 1986. Data on the days to heading and maturity, plant height, grain yields and 1000 kernel weight are reported in Table 3. The management of the nurseries consisted of three irrigations, four hand weedings, carbofuran seed dressing, and 50 kg N/ha at the heading stage.

Yields of these varieties were quite variable depending on the date of planting. The highest yields were obtained from the November planting, probably because the plants were exposed to the lowest yearly minimum temperatures which occur in December and January. In general, Belbec possesses the best tillering capacity and has given the highest yields.

Thirty-four varieties were introduced from CIMMYT's East Africa wheat program (9th SNACWYT) for observation and were planted in October 1986. Preliminary selections were made on the basis of early maturity, good grain production and filling, and adequate resistance to *H. sativum*. On the basis of these criteria, 16 entries (2, 3, 6, 7, 22, 23, 24, 25, 26, 27, 28, 30, 31, 32, 33 and 34) seemed promising (Table 4), and further screening will be conducted in order to select the best three or four varieties for yield testing. It may be interesting to note that 6 of the retained entries were Veery "S" selections; none of the triticales were retained.

Weed control trial--An experiment was conducted to compare the effectiveness of the herbicides Stomp (pre-emergent) and Buctril MC (post-emergent) with hand weeding on the variety Haramoun planted on the 4th of November 1986, using two different row spacings: 20 and 30 cm. The results of this experiment are reported in Table 5. There were no significant differences at the 5% level of probability amongst any of the weed control treatments but all differed significantly from the check (0 control). Although the weed control trial has been modified for the future, it appears that the use of the relatively inexpensive phenoxy broadleaf herbicides, such as Buctril MC, may provide an economical means of controlling the predominantly broadleaf weed species occurring in irrigated wheat in Somalia.

Conclusions

In the past, the research on wheat was characterized by discontinuity, and the few researchers involved often reached pessimistic conclusions (3) on the basis of a single trial. The most recent trials provide us with some optimism for wheat production in lowland irrigated areas. The acquisition of varieties with greater heat tolerance and disease resistance will further improve the possibilities; such germplasm is being assembled by CIMMYT at present and will be tested in Somalia.

In addition to continued variety screening, the research plans for 1987 include a fertilizer response trial, a modified weed control trial and an economic assessment of a potential cropping pattern.

The government's decision to support more extensive research on wheat creates the institutional environment needed to guarantee the continuity of such research. The presence of CIMMYT's East Africa wheat program, which is already assisting the ARI with advice, support for staff training, equipment and germplasm, will increase our probability of success.

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Résumé

Le Gouvernement somalien étudie la faisabilité de la production de blé irrigué pour la substituer aux importations actuellement élevées de produits céréaliers. Les résultats des récents essais de triage laissent entrevoir la possibilité d'obtenir des variétés tolérantes à la chaleur, tolérantes aux maladies et rentables. Toutefois, il n'existe encore que peu d'informations sur les pratiques agronomiques appropriées. Les résultats des essais les plus récents sont présentés.

Table 1. Wheat, flour and pasta imports (in 1000 tons)

1980	1981	1982	1983	1984	1985
91.1	200.0	180.5	125.0	155.0	96.0

Source: Ministry of Commerce and Industry.

Table 2. Climatic Data for Jenale (average 1929-48)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Year
Mean monthly maximum temperature (°C)	32.3	32.7	33.5	33.1	31.5	29.6	28.6	28.9	29.5	30.5	[illegible]	31.0	31.1
Mean monthly minimum temperature (°C)	21.0	21.6	9	23.6	23.3	21.8	21.4	21.2	22.1	22.7	22.2	21.6	22.2
Mean monthly temperature (°C)	26.6	27.2	28.2	28.3	27.4	25.7	24.9	25.1	25.8	26.6	26.6	26.6	26.6
Absolute maximum temperature by months (°C)	38.0	38.0	39.0	39.0	38.0	35.0	34.0	35.0	36.0	35.0	35.0	36.0	39.0
Absolute minimum temperature by months (°C)	13.0	17.0	18.0	20.0	19.0	18.0	17.2	17.0	18.0	19.5	19.0	15.0	13.0
Relative humidity (%)	76	74	76	77	81	82	82	82	31	81	82	80	79
Wind speed at 2 m (mean monthly) (m/s)	1.4	1.6	1.4	1.2	1.8	2.2	2.4	2.4	2.5	1.8	0.9	1.2	1.7
Mean monthly total sunshine hours	290.7	264.6	292.2	246.4	239.9	198.1	194.8	235.2	255.6	237.1	219.9	255.8	2930.7
Monthly mean rainfall (mm)	1.5	0.1	3.9	75.9	73.9	80.5	54.8	47.4	21.5	32.7	52.6	26.2	471.0
Mean number of rainy days	0.7	0.0	0.4	6.0	8.5	10.4	11.6	9.6	3.5	3.4	5.7	3.0	62.8

Table 3. Wheat observation plot results (Jenale, 1985-86)

Planting date	Height (cm)	Days to maturity	Kernels/ spike	1000 KW	Yield (kg/ha)
Sept. 85					
Belbec	57	94	12.5	38.5	546
Haramoun	58	78	23.6	25.0	478
Mexipak	53	78	28.7	27.0	500
Super X	51	73	23.7	25.0	597
Sannine	45	82	13.0	24.5	555
F. aurora	60	89	16.0	39.8	916
Nov. 85					
Belbec	54	98	14.2	36.0	3153
Haramoun	44	74	22.2	34.1	1517
Mexipak	45	71	24.5	33.0	442
Super X	47	73	23.4	30.2	373
Sannine	62	72	12.5	28.0	585
May 86					
Belbec	69	90	15.0	36.0	1536
Haramoun	66	78	32.5	31.4	847
Super X	52	71	26.0	32.0	726
Sannine	60	76	24.5	30.0	1105
F. aurora	75	85	9.0	46.3	1470
Sept. 86					
Belbec	65	89	12.0	31.0	430
Haramoun	60	75	14.0	29.2	390
Sannine	70	85	30.0	31.0	520
F. aurora	95	85	11.5	40.0	779
Jori 69	-	100	-	37.0	715

Table 4. Selections from 9th SNACWYT (Jenale, 1986)

Entry No.	Variety or Cross and Pedigree	
2	Vee#5"S" = Ser182	CM 33027-F-15M-500Y-OM-87B-OY
3	Bow"S"	CM 33203-K-10M-7Y-3M-2Y-1M-OY
6	Chilero"S"	CM 66684-B-1M-6Y-2M-2Y-OY
7	Bye/Tc//Z/Bw/3/Cpista/6a /4/GioVZ374	CD 1045-2Bs-1Bs-OGs
22	Vee#5"S"	CM 33027-F-15M-500Y-OM-89B-OY
23	Vee#5"S"	CM 33027-F-15M-500Y-OM-110B-OY
24	Vee#5"S"	CM 33027-F-15M-500Y-1M-OY-OPtz-O'
25	II 58.57/4/Maya 74"S"/Cn /3/CC/Inia//Cal	CM 40742-27M-1Y-2M-3-Y-3M-1Y-OB
26	Lira"S"	CM 43903-H-2Y-1M-3Y-1Y-OB
27	Skh8/4/RRV68/WW15/3/Bj"S" /On*2//Bon	ICW 77117-K-1Ap-OAp-OAp-4Ap-2Ap-OAp
28	Fink"S"	CM 41860-A-5M-2Y-2M-1Y-OM
29	LAJ2484 = Kvz//Cno/Pj	
31	Vee#3 = Genaro81	CM 33027-F-12M-1Y-6M-OY
32	Vee#2 = Ures81	CM 33027-F-12M-1Y-4M-2Y-2M-OY
33	Maya/Mon//Kvz/Trm	CM 44033-N-2Y-2M-1Y-1M-1Y-2M-OY
34	Koel"S"	CM 34574-F-1M-5M-1M-1Y-OM

Table 5. Results of weed control trial (Jenale, 1986)

Treatments	Yield (kg/ha)
2 handweedings (at 15 and 30 days)	1600 a
Stomp plus 2 handweedings	1538 a
Stomp plus Buctril MC (1x)	1378 a
Buctril MC (2x)	1267 a
4 handweedings (at 10, 30, 50 + days)	943 a
No weed control (check)	77 b

Treatment means followed by the same letter do not differ significantly at the 5% level of the DMRT.

STATUS OF WHEAT PRODUCTION RESEARCH IN ZAIRE

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Abstract

Introduced in Zaire during the 1920s, wheat production has been threatened by many constraints. Yellow rust (Puccinia striiformis), common bunt (Tilletia caries) and Helminthosporium spp. are the principal diseases limiting wheat production in the country. Selection of varieties adapted to the ecological conditions and acid soils of the humid highlands (above 2000 m) and the promotion of erosion control practices are the principal objectives pursued to stimulate and intensify wheat production.

Introduction

Wheat was introduced in Zaire (then the Belgian Congo) at the beginning of the 20th century, initially in mission institutions (1). First attempts were described as unpromising during the early years in the mountainous region southeast of Lake Tanganyika (2).

In 1923, the Service d'Agriculture began showing interest in maize for cultivation in some highlands of the Nioka region (Haut-Zaire). An important number of varieties were then tested, most of which were destroyed by leaf rust. The same happened during seed multiplication attempts of in the Mahagi and Djugu regions, still in Haut Zaire (1800 m and above).

Trials were also made in the Lubero Region (Kivu) starting from the coast. Results here were more promising despite the fact that a number of lines succumbed to leaf rust. Hence, later work was oriented towards the selection of rust-tolerant species.

Starting in 1937, further experiments were conducted on wheat--including numerous introductions, breeding, crossing, local trials, etc. During the 1939-45 period, wheat cultivation started to attract more interest. Wheat was included in the "War Effort" Plan, along with cotton, rice, peanuts, maize, palm nuts, wild rubber plants, raphia and fuel wood. The aim of this plan here was to determine what the Belgian Congo could contribute to the allied countries.

Between the end of World War II and 1960, wheat cultivation was highly developed in Nord-Kivu. However, all research efforts on wheat ceased after Zaire became independent, because of political unrest in the country and also because of the lack of qualified staff to take over from the Belgian researchers. From 1960 to 1977, only irregular and uncontrolled research was conducted.

Cultivation Area (see map)

In Zaire, wheat is not included in the major feed crops which are rice, maize, cassava and legumes. However, following the most promising results obtained in the field by MIDEMA (4), government authorities engaged in agriculture are showing more interest in this crop.

Moreover, there is a general phenomenon where bread consumption is increasing at a rate proportionally faster than that of population growth. Hence, the amount of foreign exchange allocated to wheat imports is increasing every year.

Without full knowledge of the general status of wheat cultivation throughout Zaire, we can nevertheless say that it is practiced in Shaba, Kivu, Haut-Zaire and eastern Zaire.

Development and Objectives of the MIDEMA Wheat Project

The milling plant of Matadi (Minoterie de Matadi-MIDEMA) is a government-owned company with limited responsibility based in Kinshasa with exploitation sites in Kinshasa and Matadi. MIDEMA was created on February 25, 1969, and production started in April 1973 in a modern milling plant at the international harbor of Matadi. The milling capacity has been expanded several times; in 1986, 600 tons of wheat were processed per day. Flour and milling by-products, such as semolina and bran, are distributed throughout the Republic.

In view of the need to reduce the country's dependence on wheat imports, encouragement of local production has been considered. To this end, the "Project Ble de la MIDEMA au Kivu" was launched in November 1978.

For the launching of the Project, MIDEMA was asked by the Agriculture Department of Zaire to engage in research that would revitalize wheat cultivation. From 1978 until now, MIDEMA has operated the Project by allocating a special reserve fund from its own profits.

The objectives of the Project are:

1) Identify the best bread wheat varieties for the region.

2) Acquire a core stock of seed of promising varieties and ensure the multiplication of this seed.

3) Ensure the distribution of improved seed in rural areas.

4) Organize wheat production by training farmers.

5) Ensure wheat purchases.

6) Produce wheat flour for local consumption in Northeastern Zaire.

The Cultivation Zone in Northern Kivu

Wheat is cultivated from 1700 to 2500 masl. The hill soils of the area are favorable for wheat cultivation, under the following categories:

1) Soils with a high proportion of silty clays and rich in humid.

2) Soils with low to very low and insufficient levels of phosphate.

3) Soils with high pH (acid soils).

4) Soils with mineral contents from low to very low.

5) Bottomland soils that have been used for many years for intensive and productive vegetable production.

Status of Wheat Cultivation in Kivu

For the foreseeable future, the hoe and machete will be the main instruments used in the farmers' agricultural practices. Hence, all work will continue to be done by hand--from plowing and sowing through harvest.

There are two cultivation periods each year. The first is from March (sowing) to July-August (harvest); the second is from September (sowing) to January-February (harvest).

In the southern sector (from Kipese to Busekera), farmers open new fields each year by clearing high grass with machetes and scythes and plow with a hoe. Here, many farmers do not understand the importance of plowing and usually resort to the easier practice of burning and directly sowing without plowing, especially for maize and cassava cultivation. However, in the northern sector (from Masereka to Vuhovi), the farmers now understand the importance of plowing and use it to eliminate weeds and incorporate debris from the previous harvest.

Random sowing is still widespread among many farmers. Project agronomists are presently promoting the adoption of line sowing. It will take time for the farmers to understand the importance of this practice for wheat cultivation and to adopt it. With line sowing, farmers use a hoe, a strong rope and 1-m high wooden pegs. Sowing is done behind the rope after 4- to 5-cm deep furrows are made with the hoe. The hoe is used again to cover the seeds. Sowing is continuous on the same row and the spacing between rows is 25 to 30 cm.

Farmers do not extensively weed their fields. However, weeding is currently part of the extension package in rural areas. At seed production stations and among a number of progressive farmers, weeding is done with a small worn out hoe. Since weeds usually grow very quickly, three to four weedings are necessary from sowing to harvest.

Women collectively do the harvesting, using only knives. Threshing is men's work, which is also done collectively. The heads are beaten on the ground to separate the grains. Threshing is done during the day or at night under moonlight. Women use locally made instruments to do the winnowing, either individually or collectively.

Grains are kept either in large jugs made of baked clay or in traditional granaries made of young bamboo stems or in big baskets or in raffia sacks. The number one enemy of stored grain is the corn worm against which there is yet no efficient means of control.

Limiting factors--Major factors limiting wheat production in Kivu include:

1) Fungal diseases

2) Weather disturbances

3) Late sowing

4) Abandonment or little use of traditional techniques

5) Abandonment of erosion control measures (mountainous Kivu)

6) Difficulties in imposing improved varieties

7) Over-exploited and over-used soils

8) Deterioration of available genetic material, lack of improved seeds and few funds for research

9) Collapse of the agricultural training and extension services

10) Lack of secondary rural connecting roads

11) Damages due to rats and birds

Major pests--Major pests of wheat in Kivu include:

1) Fungi. As stated before fungal diseases are the main constraints to wheat production in Kivu. They can be classified as follows on the basis of their incidence.

Yellow rust (*Puccinia striiformis*) is very severe infection in the high altitude and humid regions.

Common wheat bunt (*Tilletia caries*) can reduce harvests by 50%. Many farmers place this disease as their number one constraint.

Helminthosporium (*Helminthosporium* spp.) is the third most important disease.

Black rust (*Puccina graminis*) and brown rust (*Puccina recondita*) exchange fourth and fifth place, depending on the season.

2) Insects. A number of insects do considerable damage.

Epilachana hirta, a coleopter of the coccinelidae family, produces larvae which feed on the epidermal tissues of wheat leaves that causes serious damage, mainly between tillering and the wax-ripe stage. So far, good results have been obtained using insecticides such as Folidol E605, Malath and Basodin 600EC.

Aphids attacks also occur during each crop season. Methods of control are the same as for *E. hirta*.

Caladra oryzae, the grain weevil, is a dangerous pest attacking stocks in storage. So far, we have obtained very good results with "Thioral". This product, which is both a fungicide and an insecticide, is made of 25% TMT (fungicide), 25% Heptachlore (insecticide) and a red dye mix. The proportion used is of 20 g per 10 kg of seed.

3) Mammals, mainly rats. In the fields, the most dangerous one is *Lemnysomys striatus*, the striped rat. In storage facilities, the most common species are *Rattus rattus* and *Mastomys ugandae*. Satisfactory results are obtained in storage with raticides mixed with bait such as grilled salted fish or grilled, very soft maize. However, in the field, traps and collective catching organized by young boys are not very effective.

4) Birds. Small birds flying in groups of hundreds cause serious damage in wheat fields. Manual scare tactics and block cereal cultivation (regrouping of fields) are costly and not very successful.

Wheat Cultivation Progress, 1980-1986

Data covering the whole country are not available. Even for Nord-Kivu, there are no reliable statistics. However, following work conducted among farmers for several years, our extension service has made the wheat production estimates in Table 1.

In 1980, the area cultivated with wheat (old seed varieties totalled 2500 ha manned by 8500 farmers. Yield did not exceed 500 kg/ha. More farmers began planting wheat starting in 1984, essentially due to an intensive extension program. However, wheat cultivation was seriously affected by an extended drought in 1984.

Concerning wheat purchases, the milling industry (Minoterie du Kivu-Minoki) established within "Projet Ble" had bought only 13 t, in 1984, which grew to 1261 tons by late 1986. This proves that local farmers are really interested in wheat cultivation. Moreover, the area under wheat cultivation is continuously expanding season after season.

Seed Production

The best varieties identified during trials are first multiplied at the Ndihira station before being distributed or sold to farmers. The first improved varieties were made available in August 1982. Main varieties released to date include: Musala, DZ-1, Kinglet, Ballilo, Buck Buck and recently, since March 1986, Ald, Musinga II and Buhimba Ex-Fink"S" Pc485.

From 1982 to 1985, Projet Ble was selling seed to farmers on credit, payable after the harvest. This policy motivated the increase in wheat production. However, since 1986, due to difficulties regarding credit repayments, it has been decided that available seed will be sold only on a cash basis. So far, no difficulties have been encountered with this system.

On the other hand, more advanced farmers, after harvesting, are now providing seed for their neighbors. We are encouraging this seed distribution system called "concentric circles," because of the lack of any related service responsible for seed multiplication.

The Use of Wheat in Kivu

Presently, wheat is used in Kivu in the following proportions:

* 50% is farmer-consumption, which means that at least half of the total production is consumed in the cultivation zone or its surrounding areas.

* 15% is kept for seed for future sowing.

* 35% is marketed (purchased by Minoki).

Wheat is consumed as porridge, dough and bread.

Herbicide Trials

Some years ago, mineral exploitation was opened up and one of the immediate consequences of this policy was that nearly all the strong young people completely abandoned the agricultural sector, leaving behind only the elderly to do agricultural tasks including wheat cultivation. Hence, it is very difficult to find labor for the maintenance of the farms. This is why we have launched herbicide trials, with the following objectives:

1) To compare the efficiency and the residual effects of products tested against weeds in Kivu.

2) To determine the appropriate products and adequate levels of application for weed control in wheat fields.

3) To characterize the toxicity of the products tested on wheat.

Two types of trials have been conducted: 1) post-sowing application and pre-sampling of weeds and crops and 2) post-sampling of weeds and crops.

Igran is very efficient as an herbicide even at low levels of application. The mixture, Igran + Dicuran, is equally efficient. Dicuran alone is inefficient.

Research Objectives

After some years of field experiments, MIDEMA thinks that, in order to stimulate and intensify wheat cultivation, the main objectives of the research program should be:

1) Breeding of varieties adapted to ecological conditions in high altitude, humid zones and to acid soils as well as highly resistant to the major plant diseases discussed above. Equally important is the capacity of the wheat plants to grow faster in the fields.

2) To find a good fertilization formula, since for this aspect has been neglected to date, while it is an important issue in Kivu (economic advantages of fertilization).

3) To determine the best seeding dates for wheat.

4) To carry out trials on cropping systems and methods, i.e., to determine, develop and disseminate new technologies and research results. It is possible, for example, to consider wheat cultivation in association with the farmers' major traditional crops such as potatoes, maize, beans, pick peas, etc.

5) To determine the place of wheat in the crop rotation.

Future Prospects

In Nord-Kivu, large-scale wheat production is limited by the very irregular profile of the land, which is an impediment to mechanized agriculture, and the over-exploited status of the soil. Population density is high, hence, fields are small. However, there is no doubt that there are possibilities to intensify wheat cultivation and to increase production. Erosion control and breeding of improved varieties offer some hope. It is obvious that the development of physical, financial and human resources is a must.

The real future for large-scale wheat production in Zaire is most likely in the Shaba region. Preliminary trial results are very promising. In addition, mechanized agriculture can be introduced in the highly fertile lands of the area if varieties adapted to the soils and the climate can be obtained.

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Résumé

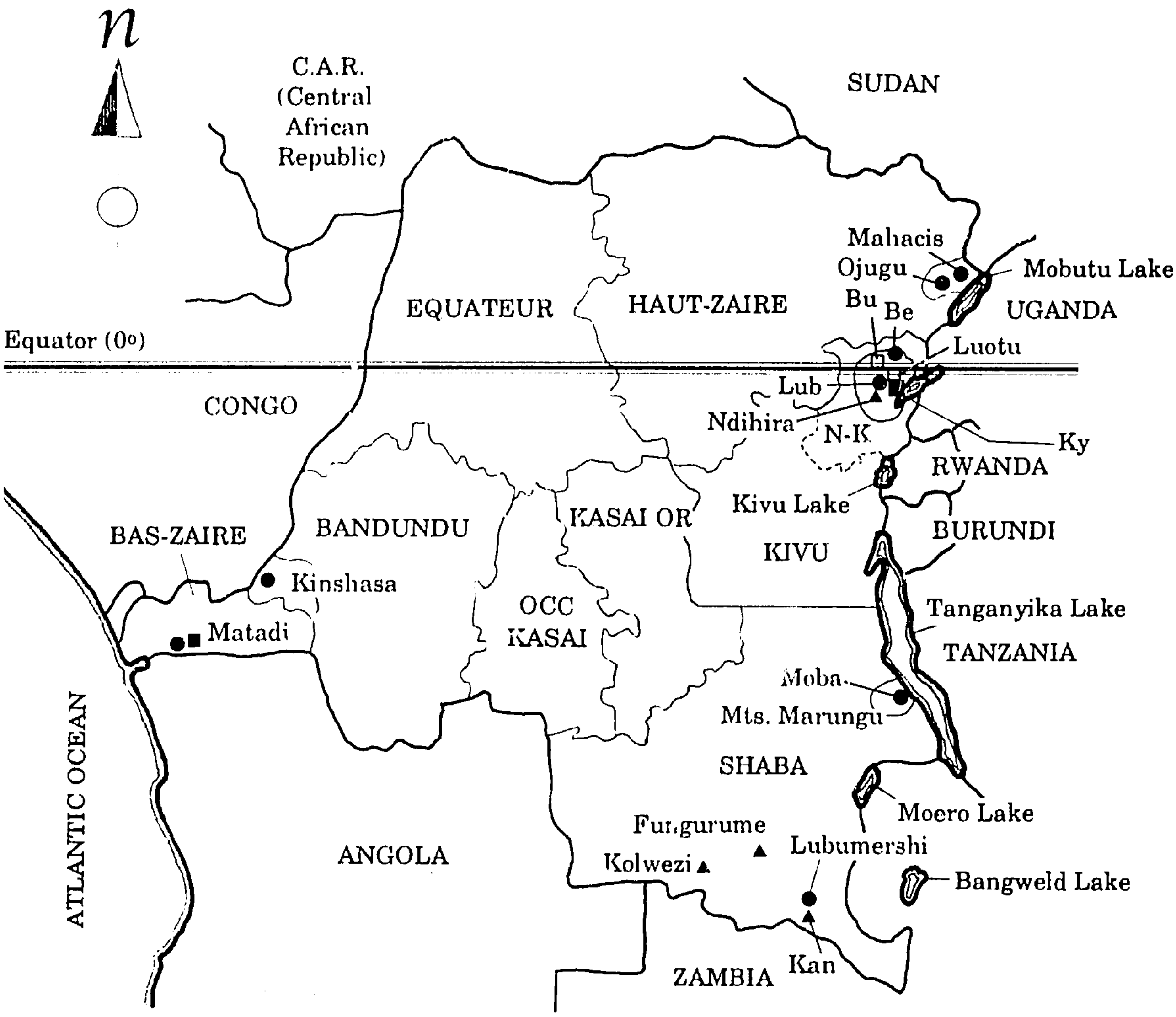
Introduite au Zaïre vers les années 1920, la culture de blé a toujours été fortement menacée par de multiples facteurs d'adversité. La rouille jaune (Puccinia striiformis), la carie commune (Tilletia caries), ainsi que l'helminthosporiose (Helminthosporium spp.) sont les principales maladies du blé au Zaïre.

La sélection de variétés adaptées aux conditions écologiques de la haute altitude humide (plus de 2000 m) et aux sols acides, renforcée par la lutte contre l'érosion dans le Kivu montagneux, reste le principal objectif à poursuivre pour stimuler et intensifier la culture du blé.

Table 1. Estimated wheat production figures for Nord-Kivu

	1980	1981	1982	1983	1984	1985	1986
No. of farmers	8500	8700	8700	9300	10,000	12,000	15,000
Area (ha)	2550	2600	2600	2800	3,000	3,700	5,000
Production (t)	1300	1450	1450	1700	900	2,300	3,400
Yield (kg/ha)	500	550	550	600	300	620	680

Cultivation Area of Zaire



WHEAT SEED PRODUCTION: THE KENYAN EXPERIENCE

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Abstract

In Kenya production of cereal seeds is a responsibility of Kenya Seed Co. Ltd. The functional parts of a seed industry are now well developed in Kenya.

1) Breeding: this is mainly done by the Kenya government research station (NPBS).

2) Seed multiplication: this is done by contracting with experienced farmers in the wheat growing highland.

3) Seed conditioning/processing: this done by the company in a centralized promises for ease of administration.

4) Seed quality control: it is enforced by an independent government agency; the National Seed Quality Control Service.

5) Seed distribution/marketing: this is done by the company through the farmers Union-Kenya Grain Growers Cooperative Union Ltd. The union has a network of shops all over the country where they stock other farm inputs besides seed.

In addition the farming community has access to crop seasonal credit scheme administered by the Agricultural Finance Corporation. In order to contain risks of disease attack on cereals, farmers are advised to grow more than one variety on a 20 ha or more holding. Seed availability has had an impact on increasing food production in the country where the wheat seed covers about 45% of the 110,000 ha under wheat production annually.

Experiences in Practical Seed Production

Kenya lies in the tropical zone of Africa with the equator passing through the middle of the country. The country stretches between 4 1/2°N and 4 1/2°S. The elevation ranges from sea-level to high mountains of about 5200 m. Due to the varying land elevation, the climate differs dramatically in various zones. The amount of rainfall also varies with altitude and is dependent upon inland water masses, and monsoon winds. Most of the soils are loamy-sandy and of volcanic origin.

Wheat is grown in the highlands with elevations ranging between 1700 and 2800 masl. The area has two rainy seasons, the main one extending from mid-March to the end of May (at times to mid-June) and the short rainy season from September to mid-November. Wheat is grown mainly in the long rains of March-May although certain areas also grow wheat in the September-November rains. The rains are generally moderate ranging between 750 to 1000 mm per year. The national wheat harvest in a good year is 2.6 90-kg million bags to date. Taking an average yield of 25 bags/ha (or 10 bags/acre) the national acreage under wheat per year ranges between 104,000 ha and 112,000 ha. All the wheat grown is rainfed and therefore this zone has very high competition with other enterprises like maize, beans, tea, pyrethrum and livestock.

Kenya Seed Company (KSC) has its headquarters in Kitale town some 360 km northwest of Nairobi. It has branches in Nakuru and Nairobi. Kenya Seed Company was formed in 1956 with the initial objectives of multiplying grass seeds for farmers. In the 1960s, the Company diversified into sunflower and hybrid maize production and distribution. In the early 1970s, the Company started a Cereals branch in Nakuru to deal with certified seed wheat and seed barley. Kenya Seed Company is mainly owned by the Agricultural Development Corporation holding majority shares of 53%. The second largest share holder is Kenya Grain Growers Cooperative Union, holding some 28% shares. This Cooperative Union has a network of shops all over the country and stocks other farm inputs besides seeds. The remaining shares are owned by individuals.

This report describes the stages undertaken by Kenya Seed Company as they relate to Wheat Seed Production.

KSC Activities in Wheat Seed Production

Research-breeding--In Ken all the basic wheat research is done by the Government Research station (National Plant Breeding Station-Njoro). After the research station releases a cultivar, Kenya Seed Company undertakes to multiply it. The research station also does seed maintenance of the varieties already released. Kenya Seed Company also does some maintenance of the varieties released to assist the breeders.

Contracting farms for seed multiplication--Kenya Seed Company depends on the services of experienced farmers to multiply all the basic and certified seed. The Company contracts with farmers for some 4000 ha. annually for seed wheat production. The land to grow such crops must be suitable and acceptable to the National Seed Quality Control services, the agency that formulates and enforces the rules governing the seed industry in Kenya.

Among other qualities, the land to grow the seed crop must be free from norious weeds, (eg., *Avena* spp. *Datura stramonioum*) or such land as ex-maize, ex-pyrethrum, ex-sunflower, ex-grass ley or ex-same variety and certified crop. The land must also be within 70 km. of Kenya Seed Company operations and of adequate size (e.g., 20 ha. or more). Currently, Kenya Seed Company multiplies some fourteen varieties of wheat.

Although the land under wheat in Kenya is about 112,000 ha. currently only half of the hectarage is planted with certified seed. Agricultural

Development Corporation farms contribute about one third of the 4,000 ha. grown to certified seed wheat annually.

The production and sales (Table 1) indicate a rather static situation of seed wheat for the last 7 years. Surpluses may be caused by official efforts to collect and store large quantities of the grains as seed or by farmers finding it difficult to obtain credit.

Field advisory services--The Field Advisory Services consist of agriculturally trained officers who liaise between the farmer, Kenya Seed Company and the Quality Control body. Every one of them is issued with a vehicle which becomes a tool for their work. The field officers job includes:-

1) recruiting seed growers,

2) inspecting fields under application to verify their acceptability and suitability,

3) helping in crop registration and forwarding the registration forms to the National Seed Quality Control Services,

4) constantly visiting the farms to assess crop development and to advise in event of pest or disease outbreaks, timeliness of herbicide application and suitable herbicides,

5) advising the farmers on roguing and isolation requirements,

6) inspecting all the combine harvesters before any seed crop is harvested,

7) sampling the harvested crops in the farms and forwarding the samples to the Kenya Seed Company laboratory for moisture testing,

8) coordinating all seed deliveries from farms and informing farmers of the outcome of any samples from their farms.

Quality control laboratory--There are two separate bodies that deal with seed quality control.

1) National Seed Quality Control Services (NSQCS). This is a government arm that ensures that seed produced and offered to the general farmer is of high quality and meets official standards. NSQCS does both field and factory inspections. The body could approve or reject a crop in the field. If a crop is approved in the field and upon processing it is found to be impure, or lacking or wanting in terms of purity, grade, sprouting, insect damage, etc., the crop could be rejected. For example, after a crop has been processed and dressed and germination falls below 85%, that lot will not be marketed.

2) Quality Control Unit. Kenya Seed Company's internal Quality Control Unit tests all the material presented to them. The control actually starts from the field where the field officers on their own reject portions of fields if found mixed or not conforming with the accepted standards.

Seed drying and storage--In principle, the calendar of the wheat crop aims at harvesting to be done during the dry spell. This does not always happen and it calls for preparation against any odds that may appear.

We have adequate and efficient driers to cope with any wet seed that is delivered to us. Our standard is 13.0% moisture content and any seed that is delivered containing higher moisture must be dried. We normally dry about one third of the wheat and barley seed. In some cases the seed could have as much as 25% moisture due to sudden rain that may come a harvesting time. We do require that farmers have their own stores so that they may keep a dry crop for a while before the arrangement is made for collection of the seed.

We have stores constructed specifically for seed with adequate ventilation. The stores also have high ceilings to maintain constant cool temperatures. They are large enough to contain the contracted crops before and after processing. The stores should be without any leaks whatsoever.

Conditioning plants--Although the seed is approved in the field by NSQCS to ensure variety purity and absence of noxious weeds, it is important to condition the same seed to ensure that all the quality aspects are met. We have processing plants that clean seed by:-

1) Size and shape--by use of screens of either slot or round in both pre- and fine cleaners,

2) Length--by use of indented cylinders that would remove the very long or very short materials,

3) Weight--by use of a gravity table that would separate the heavy or light materials from the rest,

4) Pressure--by air blowing, the light material is separated from the normal seeds.

All this, leads to very satisfactory results. After the seed is cleaned, it is dressed with the desired chemical (insecticide/fungicide /nutrient or all as the demand may be). We use both liquid and slurry in the Mist-O-Matic seed treaters or in the auger chamber for the slurry. We use insecticide, fungicide and about half of the seed is treated with Copper Oxychloride as a nutrient.

Seed distribution and marketing--Almost all our seed is distributed through KGGCU. A few other sub-agents assist in the seed distribution and marketing. The agricultural agents stock other farm inputs such as fertilizers, pesticides and livestock feeds, veterinary drugs etc. and the farmers find it easy to deal with such firms that stock more or less all the farming requirements. Also these agricultural agents act as agricultural credit facilitators. They facilitate loans given by the government through the

Agricultural Finance Corporation (AFC). In this manner the loanees collect their credit in kind from these firms and then the firms deal with AFC.

Problems

Like any other business, a seed merchant has some problems.

1) If the basic seed is solely to come from another (government) body, the merchant is not able to program his production well. It is very important for the merchant to maintain his varieties.

2) Land fragmentation makes it un-economical to produce seed in the very small holdings. It forces the merchant to go further afield in search of larger and more suitable fields. The further you go from your plant the higher the cost of production.

3) High cost and inadequate availability of spare parts for the seed processing machines. Some machines could be 15 or 20 years old. If the machine breaks down, the spare parts must come from where the machine was bought (abroad). At times the machine could be obsolete and spare parts must be made at very high cost and it may take much time to reach the seed merchant. Thus, cost in money and time is quite high.

4) Use of certified seed could be seen as a costly unit or farm inputs and thereby the merchant realizes very low sales and hence returns in a year. This can force the firm out of business.

5) Lack of farmers' seasonal credit scheme could also affect adversely the use of certified seed.

6) Government directives to the effect that the merchant should stock much higher stocks than the merchant's projection affect the business adversely.

7) Unfair competition from un-registered merchants who do not even pay taxes on their business also may have adverse effects.

8) Lack of knowledge by farmers of the advantages of using certified seed affect the seed merchant.

9) Stringent price control by the government on the seed affect the seed merchant.

10) Diseases attacking certain varieties will render those varieties unpopular and a merchant will be left with huge stocks of seed.

Conclusion

Despite having been beset by some of the problems enumerated above, the seed industry in Kenya has had a great impact on increasing food production. This has come about in terms of higher yields per unit area of land and opening of new land with an assurance that seed is available in time and within reach.

Résumé

Au Kenya, les semences de céréales sont produites sous la responsabilité de la Kenya Seed Co. Ltd (KSC). La partie opérationnelle d'une industrie semencière y est maintenant bien dévelopéc:

1) l'amélioration variétale est confiée principalement à une station de recherche gouvernementale: la National Plant Breeding Station;

2) la multiplication des semences est realisée sous contrat par des fermiers experimentés dans les regions à blé de haute altitude;

3) le conditionnement des semences est centralisé par la K.S.C. pour plus de facilités administratives;

4) le contrôle de la qualité des semences est confiée à une agence gouvernementale indépendante: le National Seed Quality Control Service;

5) la distribution et la commercialisation des semences sont effectuées par l'intermédiaire d'une association paysanne: la Kenya Grain Growers Cooperative Union Ltd. Les établissements de cette association, répartis dans tout le pays, emmagasinent les semences, ainsi que d'autres intrants agricoles.

En outre, la communauté paysanne a accès au crédit agricole saisonnier par l'intermédiaire de l'Agricultural Finance Corporation. Afin de limiter les risques liés aux maladies des céréales, les fermiers sont invités à cultiver plus d'une variété lorsque leur superficie dépasse 20 ha. La disponibilité en semences a contribué à augmenter la production vivrière dans le pays où les semences de la K.S.C. couvrent environ 45% des 110 000 ha consacrés annuellement à la production du blé.

Table 1. Wheat seed production and sales

Year	Clean Seed Production (t)	Sales (t)
1972/73	1,033	1,033
1973/74	2,876	2,876
1974/75	4,289	4,289
1975/76	5,724	4,994
1976/77	7,285	6,232
1977/78	9,009	5,449
1978/79	7,996	2,541
1979/80	6,020	4,310
1980/81	6,456	6,656
1981/82	14,209	5,480
1982/83	6,319	5,885
1983/84	6,808	5,491
1984/85	14,691	4,436
1985/86	5,350	6,286

PRELIMINARY INDICATIONS ON THE IMPORTANCE OF YIELD LIMITING FACTORS ON WHEAT

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Abstract

Wheat is one of the major food crops around Holetta. Its production may be limited by a range of physical and biotic factors. In this experiment the effects of three factors, namely, variety, weed competition, and fertilizer on grain yields of wheat were investigated. Two levels of each factor, local and recommended practice, were considered.

There were significant yield differences due to use of fertilizer, weeding, and variety. Application of 60-20 kg N-P/ha increased grain yield by 749.25 kg/ha. One hand weeding increased grain yield by 556.75 kg/ha. Enkoy was superior to Dashen especially under conditions of low soil fertility and high weed competition, where it gave 49% better yield. The most common and aggressive weeds were Polygonum nepalense, Plantago lanceslata, and Corrigiola chittoralis.

The results of the experiment indicate that soil fertility is a major yield constraint, followed by weed competition, then variety for production of wheat.

Introduction

A particular region has its own potential grain yield which may be affected among other factors by climate, topography, and soil type. The difference between the potential and actual yields may be due to agronomic constraints. In a high yield environment (where water is not limiting), the yield constraints are variety, weed control, nitrogen fertilizer, seed bed preparation method and stand establishment, seeding date and rate, row spacing, and plant nutrients such as P, S, and micronutrients (1). Nilson and Juhnke (3)in Montana identified inappropriate variety selection inadequate fertility, plant diseases, insect damage, weed competition, and herbicide damage as major yield limiting factors (3). At Holetta, grain yields of wheat may be largely affected by soil fertility, weeds variety, diseases, and pests. Fertilizer studies clearly show the importance of amending soil fertility to obtain high yields. Weed competition may reduce yield by 36.4% of wheat (4). When susceptible varieties are planted in early June, leaf blotch of wheat may reduce yield by 82% (2). Several high yielding varieties have been released from the wheat improvement programme. The cultivar Enkoy was released in 1974 and currently occupies a large hectarage. Dashen is one of the most recently released varieties which is now being multiplied.

The impacts of the various yield limiting factors were studied at Holetta as single factors. The interaction of the factors and hence, their order of importance, is not clearly known. In addition, yield loss assessment studies on diseases were conducted using susceptible varieties and unfavorable planting dates. Thus, the available information indicates mainly potential yield losses. In this experiment, yield losses due to variety, soil fertility, and weed competition were studied on adapted varieties on the basis of optimum practices to understand the practical yield losses and potential yields.

Materials and Methods

The trial was conducted in 1986 at Holetta Research Center on red soil examining three major factors affecting yield: variety, soil fertility and weed competition. The treatments were two-bread wheat varieties, Enkoy and Dashen, two fertilizer levels, 0/0 and 60/26 kg N and P/ha, and two weeding levels, no weeding and one hand weeding. The experimental design used was 2^3 factorial in randomized complete block with three replications. A plot size of 2.2m x 5m (= 11 m^2) with 40 cm spacing between plots was used, seed rate was 150 kg/ha. Fertilizer types used were urea and DAP. Seeds and fertilizers were applied in rows which were made manually by a row marker, spaced at 20 cm apart. Fertilizers were mixed with soils, then seeds were sown and covered with soil. Seeds and fertilizers were applied on June 21 while soil was moderately moist. Weed populations were counted on July 24 using a quadrant
(25cm x 25cm) to estimate the abundance of major weeds. Handweeded plots were weeded 27 days after sowing. The *Septoria tritici* score was recorded using both a 0-5 and a 0-9 scale The variety Enkoy was harvested on Nov. 25 while Dashen was harvested on Dec. 18. The crop was harvested close to the soil surface for the determination of straw yield. Whole plots (11 m^2) were used for grain yield calculations.

Results and Discussion

Availability of moisture plays an important role in crop production. At Holetta, the 1986 main rainy season was suitable for optimum crop growth and development. Both the amount and distribution of rainfall were satisfactory (Table 1).

There was a highly significant yield difference due to the application of fertilizers. Fertilizer increased yield by 51.0% (749.25 kg/ha) as compared to unfertilized treatments (Table 2). Application of fertilizer also increased straw yield, plant height and slightly hastened maturity (Table 3).

Grain yields also were highly significantly different due to weeding treatments. One handweeding increased grain yield by 36.0% (556.75 kg/ha) (Table 2). Grain yields were significantly different due to varieties. Enkoy was superior to Dashen by 18.7% (312.25 kg/ha) (Table 2). Enkoy gave 49% better grain yields than Dashen under low soil fertility and high weed competition. It also had better response to fertilizer under weedy conditions.

Dashen performed well under weed-free conditions and with application of the optimum rate of fertilizer.

Weed counts indicating high infestations on unweeded and unfertilized plots is given in Table 4. The most common and aggressive weeds were *Polygonum nepalense*, *Plantago lanceolata* and *Corrigiola chittoralis*.

There were no statistically significant yield differences due to first and second order interactions. The results of the experiments indicate that poor soil fertility is a major yield constraint, followed by weed competition, then variety for production of wheat.

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Résumé

Dans les environs de Holetta, le blé constitue l'une des principales cultures vivrières. Une série de facteurs physiques et biotiques en limite la production. Dans la présente expérimentation, l'incidence de trois de ces facteurs sur le rendement en grains du blé est evaluée: la variété, la concurrence des adventices et la fertilisation. Pour chacun de ces facteurs, deux niveaux ont été considérés: la pratique locale et la pratique recommandée.

La fertilisation, le désherbage et la variété utilisée ont eu une incidence significative sur le rendement. L'apport de 60/26 kg/ha de N/P a augmenté la production de 749 kg/ha et un seul désherbage manuel a procuré un supplément en grains de 557 kg/ha. La variété Enkoy fut supérieure à la variété Dashen, particulièrement dans les sols peu fertiles et en présence d'une végétation adventice importante. Dans de telles conditions de culture, la différence de rendement fut de 49% en faveur de la variété Enkoy. Les adventices les plus communes et les plus agressives furent Pohygonum nepalense, Plantago laneeslata et Carrigiola chittoralis.

Les résultats de l'expérimentation montrent que la principale contrainte à la production du blé est constituée par la pauvrété des sols, suivie par la concurrence des adventices et enfin par la variété utilisée.

Table 1. Rainfall by decade (10-day interval), June-Sept., 1986, Holetta

	Total Rainfall (mm)			
Month	1st decade	2nd decade	3rd decade	Total
June	34.6	69.3	54.0	157.9
July	69.5	59.2	115.2	243.9
August	111.2	119.1	49.1	279.4
September	111.8	24.4	7.8	144.0
				825.2

Table 2. Main effects of yield limiting factors on wheat, Holetta, 1986

Treatment[a]	Mean Yields, kg/ha	% change
F_0	1452.00	
F_1	2201.25	
Main effect	749.25	51.6
W_0	1548.25	
W_1	2105.00	
Main effect	556.76	26.0
V_0	1982.75	
V_1	1670.50	
Main effect	312.25	18.7

[a] Fertilizer: F_0 = No fertilizer, F_1 = 60-26 kg N-P/ha fertilizer; Weeding: W_0 = No weeding, W_1 = Weeding once; Variety: V_0 = Enkoy V_1 = Dashen.

Table 3. Mean agronomic, disease and yield data for treatments in the yield limiting factors trial on wheat (Holetta, 1986)

Treatments	Days To Em[a]	Hd[a]	Mt[a]	Hr[a]	Plant height (cm)	Septoria disease score (0-9/0-5)	Straw yield (t/ha)	Grain yield (kg/ha)	1000 Kernel weight (g)
V_0 F_0 W_0	7	66	123	158	91	5/2.3	1.9	1317	32
V_0 F_0 W_1	7	68	122	158	96	5/2.6	2.6	1859	33
V_0 F_1 W_0	7	63	120	158	103	5/3 5	3.2	2316	36
V_0 F_1 W_1	7	64	125	158	107	4/2.5	4.6	2439	35
V_1 F_0 W_0	7	80	133	181	81	5/2.3	1.1	882	38
V_1 F_0 W_1	7	81	133	178	88	5/2.7	2.0	1750	39
V_1 F_1 W_0	7	70	133	181	95	5/1.9	2.0	1678	40
V_1 F_1 W_1	7	81	133	181	95	5/2.8	3.1	2372	39

[a] Em = Emergence, Hd = Heading, Mt = Maturity, Hr = Harvest.

Table 4. Weed count for the treatments in the yield limiting factors trial, (Holetta, 1986)

Treatments	Weed count per m^2: Polygonum nepalense	Corrigiola chittoralis	Plantago lanceolata	Galium spurium	Oxalus spp	broad[a] leaf weeds	grassy[b] weeds
V_0 F_0 W_0	270	112	114	0	64	160	125
V_0 F_0 W_1	96	64	128	0	112	256	80
V_0 F_1 W_0	224	82	26	16	48	144	96
V_0 F_1 W_1	64	80	144	0	80	176	96
V_1 F_0 W_0	208	96	160	0	48	192	80
V_1 F_0 W_1	144	80	128	0	96	192	80
V_1 F_1 W_0	24	64	144	16	32	80	80
V_1 F_1 W_1	80	64	128	0	96	176	64
Mean	139	80	125	--	72	172	88

[a] Broadleaf weeds = *Guizotia scabra*, *Spergula arvensis*, *Galinsoga parviflora*, *Caylusea* spp., *Commelina* spp., *Rumex abyssinica*, *Solanum* spp., *Erucastrum arabicum*, *Polygonum pleuneum*, *Splantis moriteana*.

[b] Grassy weeds = *Panicum* spp., *Phalaris paradoxa*, *Setaria pallidefusca*, *Cynodon dactylon*, *Digitaria* spp., *Avena fatua*.

SOME AGRONOMIC ASPECTS OF RAINFED WHEAT PRODUCTION IN NORTHERN ZAMBIA

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Abstract

Rainfed wheat production in northern Zambia, characterized by >1000 mm rainfall, is limited by crop diseases, uneven rainfall distribution, soil acidity and low inherent soil fertility. Trials to evaluate the time of planting, weed control, tillage methods, and the use of lime and fertilizers have been undertaken to develop production recommendations and make rainfed wheat an agronomically viable crop in northern Zambia. This report summarizes results from some of the trials conducted at the Zambia Canada Wheat Project Research Farm at Mbala, Northern Province, Zambia.

Introduction

In Zambia rainfed wheat production is primarily limited by weather and crop disease. High temperatures and the common occurrence of droughty periods make the low rainfall regions of Zambia unsuitable for rainfed wheat production. Over the past 9 years efforts have been made to establish rainfed wheat in Northern Zambia where temperatures are generally cooler and rainfall is better distributed. A significant constraint for rainfed wheat production in this region are soils characterized by acidic phs and low inherent fertility.

The Zambian rainfed wheat breeding program has released varieties which are better adapted to the environment. These varieties have better disease resistance and greater tolerance to soil acidity. Their yields varied between 1.5 and 2 t/ha on commercial farms, during the1986/87 rainfed season an advanced selection yielded 2.7 t/ha over 40 ha. In order to maintain economically viable yields, soil constraints and the incidence of crop disease must be overcome.

Research findings obtained during the past three cropping seasons at the Zambia Canada Wheat Project Research Farm, Research Branch, Ministry of Agriculture and Water Development, on some aspects of the rainfed wheat production are summarized below.

Time of Planting

Early planted (December) crop usually develops greater levels of *Helminthosporium sativum* (spot blotch) as the crop grows under very wet conditions, which favour disease development. Low soil pH below the top 15cm layer prevents deeper root penetration due to aluminium toxicity which renders the late planted (February) crop very susceptible to drought even though moisture may be available in deeper layers. If the rains finish early (mid-April), the late planted crop is likely to suffer from water stress whereas the early planted crop will produce a reasonable yield.

Trials were conducted at Mbala on soil with pH between 3.9 to 4.1 ($CaCl_2$). Since the first cropping season, 1979, a total amount of 5.5 t/ha lime have been added. Data in table I show that rainfed wheat (var. Whydah) produced higher mean yields when planted from mid January to late January. The different yield pattern of the 1986/87 compared to the other two seasons was the result of a heavy rainstorm during late March 1987, which caused lodging at the grain filling stage of the late December and mid January planting. Mid December planting invariably had higher disease scores than later planting. Consequently, the optimum time of planting rainfed wheat will have to be a compromise between the level of *H. sativum* development and water stress at the end of the rainy season. The newer wheat lines under development, with greater resistance to *H. sativum* and better Al^{3+} tolerance will possibly provide more flexibility in planting rainfed wheat to obtain optimum yield.

Weed Control

Main weed species present in the area are *Eleusine indica*, *Achyranthes aspera*, *Bidens pilosa*, *Bothriocline laxa* and *Tagetes minuta*. Results presented in Table 2 obtained during the past three seasons (5) showed that some of the herbicides studied as well as hand weeding provided good weed control in comparison to no weeding. Modown 4F caused considerable crop damage in 1984/85. Tribunil Combi, although causing slight crop damage during 1985/86 did not show any effect on overall yield. Two hand weedings (3 weeks and 5 weeks after seeding) gave the highest yield. Based on these results, hand weeding, Stomp (50% E.C. at 3.0 l/ha or 33% E.C at 4.5 l/ha) or Hoegrass (2.5 l/ha) plus 2,4-D Amine (2.0 l/ha) are recommended weed control practices for rainfed wheat production. Although Tribunil Combi and Modown 4F appears promising the associated cost/ha is very high and in addition these herbicides are not readily available in Zambia. Use of hand weeding by commercial farmers, may not be feasible due to labour constraints.

Tillage Methods

Tillage studies were conducted over a period of three seasons to study the effects of zero, minimum, conventional, deep ploughing, deep chiseling, late and straw removed treatments (1). Parameters studied were grain yield, thousand grain weight (TGW) and plant height (PH) of the rainfed wheat and bulk density (Db) of soil. Only grain yield was significantly influenced by the tillage treatments. Higher grain yield under zero tillage treatment was closely followed by that under deep chiseling and minimum tillage all of which being significantly higher than the conventional tillage. Higher yields in non conventional treatments were probably due to the maintenance of crop residue on the soil surface.

Mean Db under zero tillage was not significantly different than the two deep tillage treatments but was significantly lower from the conventional and straw removed treatments. The surface 10cm soil had lowest Db values under zero tillage. Deep tillage treatments (20-25 cm) did not reduce the Db significantly compared to shallow tillage (10-12 cm) treatments. The tillage treatments which had higher soil Db gave lowest grain yields probably due to reduced infiltration of rain water into the soil and increased soil resistance to the growth of plant roots.

It was concluded that for the type of soils used in this study, maintenance of crop residue on top of the soil is crucial in avoiding soil compaction and obtaining higher grain yields. If weeds are not a problem or are controlled by other means, no tillage is necessary for rainfed wheat production.

Soil Acidity

Soil acidity has been identified as a major constraint for wheat and other crops in Northern Zambia (3). Sub-soil acidity limits root development and exacerbates the effects of droughty periods. While low pH levels are of common occurrence in these soils, it is primarily Al^{3+} toxicity which limits crop yield.

The yield of wheat variety Jupateco has been observed to be fairly well correlated ($r^2 = -0.85$) with 1N KCL extracted Al^{3+} in the top 15 cm of soil (5). Yields of almost 3 t/ha associated with Al^{3+} levels of 13ppm were in sharp contrast to yields of 0.4 t/ha associated with 100ppm Al^{3+}. The primary methods of dealing with soil acidity include the planting of tolerant cultivars and soil liming.

Tolerant Varieties

The breeding program has resulted in the development of varieties and lines with greater aluminum tolerance than the earlier recommended variety Jupateco. Figure 1 gives the response (in 1987) of 3 released varieties and 2 advanced selections from the breeding program to 0, 3, 6 and 9 t/ha of lime applied prior to the 1982 season. All lines responded to lime treatments. However, there were differences to Al^{3+} tolerance as shown by the relative yield of various line, grown under the zero lime treatments.

Liming

The present liming recommendations are based on soil pH. For soils with a pH of less than 4.5 ($CaCl_2$), wheat has not been observed to be immediately responsive to lime applications greater than 2 t/ha. As shown in Figure 1, the residual effect of higher application rates becomes very significant after several years. To refine liming recommendations, trials to determine critical Al^{3+} levels for recommended wheat varieties have been recently started.

Nitrogen Fertilization

The present N recommendation is 18 kg/ha as basal and 69 kg/ha as top dressing four weeks after planting (5). Figure 2 gives the response of wheat variety Whydah to urea top dressing at two locations during the 1986/87 season. All treatments received 18 kg/ha N basal dressing. The trial site had been under a maize-soybean-wheat rotation for 9 years receiving 120-30-120 kg N/ha, respectively. The build-up of residual N is reflected in the relatively high yield at the 0 kg/ha N treatment. To account for a yield of 1200 kg/ha the soil supplied 35-40 kg N/ha. A positive correlation between N treatments and lodging at this particular site accounts for the yield decrease at the higher rates of N

Figure 3 illustrates the beneficial effect on wheat yield of a soybean-wheat rotation versus a maize-wheat rotation at the lower rates of N application. catalog

Phosphorus Fertilization

The present recommendation is 54 kg P_2O_5/ha for rainfed wheat (5). Long term monitoring of commercial farmers fields under constant maize cultivation shows an increase in soil P levels with the annual application of 80 kg P_2O_5/ha. As a result there are seldom responses to P fertilization on these fields. Virgin Zambian soils generally contain low levels of available phosphorus. Crops grown on such soils generally respond to P fertilizer in the first or second crop depending on levels of organic P.

Figure 4 illustrates the results for the second year of a study to evaluate the residual effects of various rates of P_2O_5. The curves correspond to 0, 189, 248, 327 and 385 kg/ha of P_2O_5 broadcast prior to the first planting. These values correspond to the amounts of P_2O_5 required to give 0, 0.05, 0.1, 0.2 and 0.3 ppm P in the soil solution (as determined by P-isotherms). The yield response to maintenance levels of banded P_2O_5 applied at planting was greatest where no P_2O_5 was initially applied and least where over 300 kg P_2O_5/ha was initially applied. Although the study is only in its 2nd year, it suggests the following P management strategies: 1) large initial broadcast applications; 2) moderate annual banded applications; and 3) a combination of 1 and 2.

Potassium Fertilization

The present K recommendation is approximately 30 kg K/ha for rainfed wheat (5). Generally, North Zambian soils range from moderate to deficient in K levels. A preliminary study indicates that the critical level (i.e. the level required to obtain a response) of exchangeable K is close to 0.14 meq/100g. In many soils low in exchangeable K, levels of exchangeable Al^{3+} must be decreased and levels of available P increased before any response to K is observed.

Micronutrients

Effects of micronutrients especially Boron (B), Copper (Cu) and Molybdenum (Mo) on rainfed wheat production were studied over a period of three seasons (i.e., 1982/83, 1983/84 and 1984/85). During the first two seasons, non-significant yield differences were observed but in 1984/85 B gave significantly higher yield than the Mo, Cu and check treatment. A deficiency of B is known to affect yield (2) by causing head sterility in irrigated and rainfed wheat (4). The present recommendation is to use Compound "C" fertilizer which contains 0.1% B as a basal dressing .

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Résumé

Dans le nord de la Zambie, la production du blé pluvial bénéficiant de précipitations supérieures à 1000 mm est limitée par les maladies, la distribution irrégulière des précipitations, l'acidité et la faible fertilité naturelle des sols. Des essais concernant l'époque de semis, le contrôle des adventices, le travail du sol, le chaulage et la fertilisation minérale ont été entrepris afin de mettre au point des recommandations faisant du blé pluvial une culture agronomiquement viable dans le nord de la Zambie. Le présent rapport résume les résultats d'essais conduits par le Projet Blé Zambo-Canadien à la ferme expérimentale de Mbala située dans la province Nord de la Zambie.

Table 1. Yield (kg/ha) of rainfed wheat variety Whydah in time of planting trials at Mbala, Zambia

Dates	Yield (kg/ha) 1984/85	1985/86	1986/87	Mean
Mid-December	1034	1822	840	1232
Late December	1526	1657	738	1307
Mid-January	1505	1466	1192	1388
Late January	1351	1366	1606	1441
Mid-February	966	893	*	930

* Not planted in 1986/87

Table 2. Yield (kg/ha) of rainfed wheat in the herbicide trial at Mbala

Treatments		1984/85 kg/ha	%Control	1985/86 kg/ha	%Control	1986/87 kg/ha	%Control
Stomp 50% E.C. or 33% E.C.	3.0l/ha 4.5l/ha	2632	135	1419	170	2174	115
Modown 4F	5.0l/ha	2660	134	1437	172	2076	110
Glean	20g	*		1341	161	2161	114
Tribunil Combi	4.0kg/ha	2339	118	1500	180	2178	115
Hoegrass + 2,4-D Amine	2.5l/ha 2.0l/ha	2186	110	1430	171	2289	121
Hand weeding	(3 & 5 weeks)	*		1571	188	2312	122
Control (no weeding, no chemicals)		1981	100	834	100	1891	100

* Treatments not included in trial

Figure 1. Response of wheat cultivars grown in 1987 to applied lime January, 1982, Mbala.

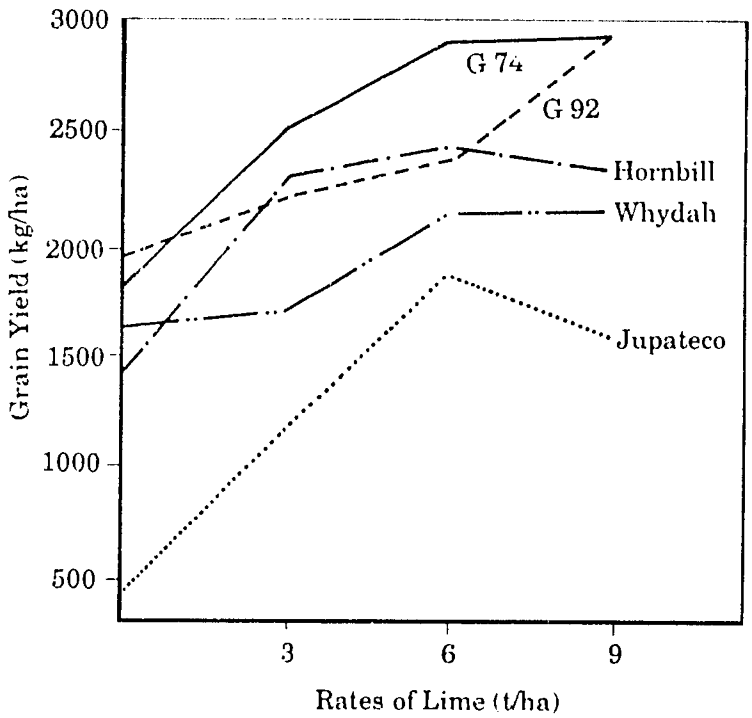


Figure 2. Response of Wheat (Var. Whydah) to rates of urea topdressing, Mbala and Mpika 1986.

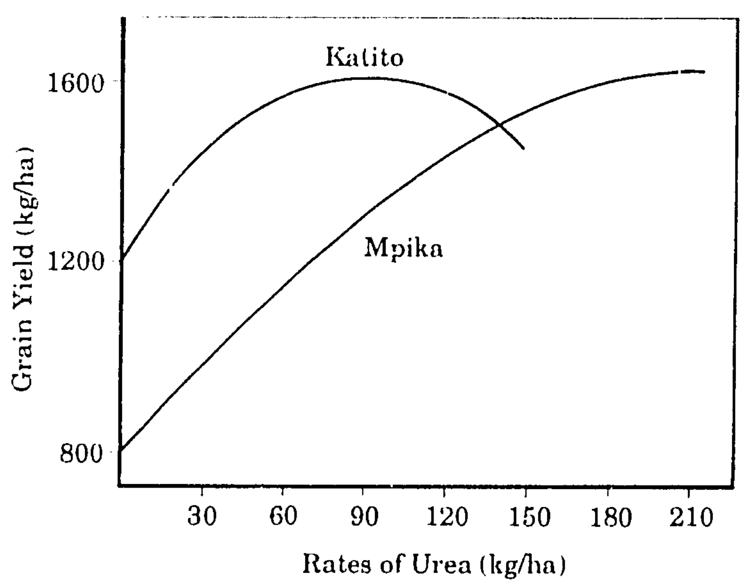


Figure 3. Response of wheat (Var. Hornbill) to rates of urea (20% basal, 80% top dressing) after soybeans and maize.

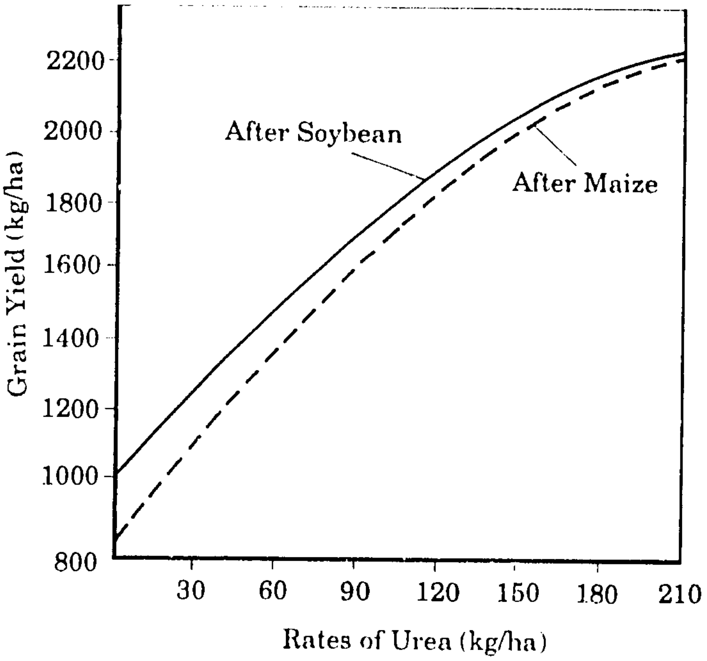
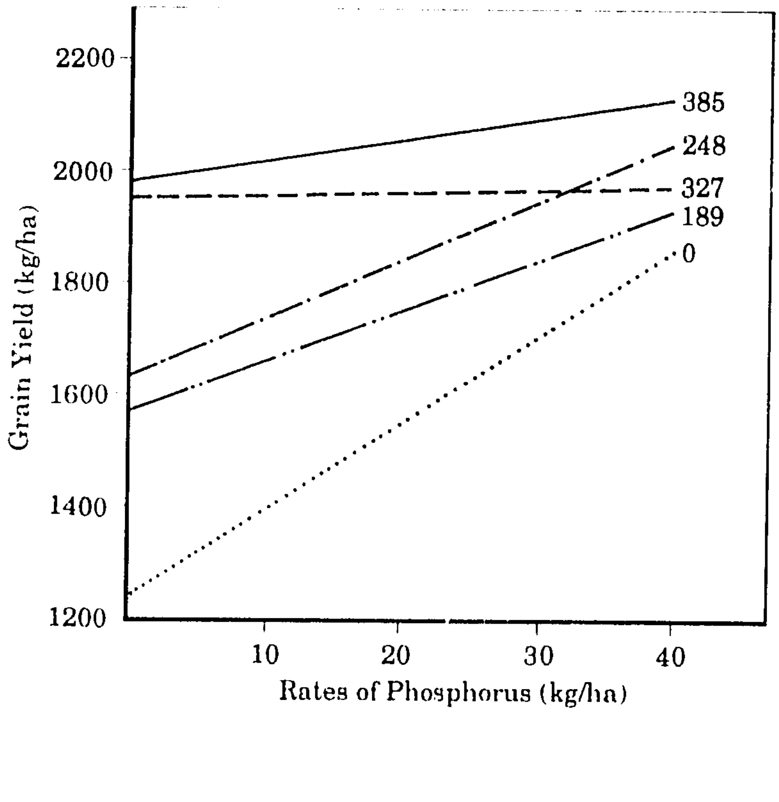


Figure 4. Response of wheat (Var. Hornbill) to P_2O_5 applied in January 1986 (0, 189, 248, 327) superimposed prior to the 1987 cropping season.



PERFORMANCE OF FOUR IMPROVED WHEAT VARIETIES AND ONE TRITICALE VARIETY UNDER FARMERS' CONDITIONS IN RWANDA

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Abstract

This work was conducted in Rwanda's Buberuka Highland area with an average altitude of more than 2000 m, and a bimodal annual rainfall of about 1400 mm. Approximately one-half of Rwanda's 4000 ha under wheat is located in this area where the average yield is only about 850 kg/ha. In contrast, at the ISAR (Institut des Sciences Agronomiques du Rwanda) station at Rwerere, located in the same work area, the average yield of wheat is over 3000 kg/ha.

We tested four of ISAR's improved wheat varieties and one triticale variety under farmers' production conditions. The purpose was to compare these varieties with the farmer's own variety, and to learn farmer practices by closely working with them so that appropriate interventions could be proposed at a future date.

Preliminary results indicate that poor soil fertility and traditional cultural practices are the principal factors that limit wheat yield under farmers' conditions. Other problems and possibilities in relation to wheat production by area farmers are also discussed.

Introduction

Rwanda is a small country of 26,300 sq km, located in Central Africa, just south of the equator. With a population of more than 6 million, it is Africa's most densely populated country. About 95% of the population are engaged in subsistence farming, in very hilly terrains.

Rwanda's National Agricultural Research Institute (ISAR) has a substation in Rwerere, located in the Buberuka Highlands region, one of Rwanda's 12 major agroclimatic zones. This station is specifically charged with research on wheat/triticale, beans, peas, and to a lesser extent on corn and sorghum. As members of a Farming Systems team attached to this station, our role is to determine farmer problems, search and/or develop appropriate technology to address a specific problem, and to test it on the farmers' fields in collaboration with the farmer and the extension workers. A successful technology coming out of this process must be biologically sound, economically feasible and socially acceptable (3). We work on the high altitude area around Rwerere, and only since February 1987, this work on wheat was begun.

Wheat is not a major crop in Rwanda, and is not a staple in Rwandan diet. Presently, only 4000 ha are planted annually in wheat, and one-half of that is located in the Buberuka Highlands area. Yield is only 850 kg/ha. To meet increasing demands of bread in the rapidly growing urban centers, the Government of Rwanda has decided that by the year 2000, wheat hectarage in the country should be increased to 10,000, and yield to 1500 kg/ha. Again, under the Government's regionalization policy, wheat has been identified as a major crop for this zone.

In the project area, wheat is normally grown above 2200 masl. It is grown in both seasons, but season B (March-August) is more important for wheat production. Rainfall is bimodally distributed with a total annual rainfall of about 1200 mm. Temperature generally varies between 5 and 25°C. Soil is lateritic, and the pH is about 5 or less.

Materials and Methods

We conducted a survey amongst the wheat growers to learn the problems and the prospects of wheat production from their point of view (2). To learn their actual production practices, we selected 16 farmer-collaborators, and worked with them during the entire season (1987 B).

We brought to them four of ISAR's wheat and one of triticale varieties and planted these side by side with the farmers' own variety in 3- x 5-m plots. To maintain some uniformity, we requested the farmers to prepare the land once and to weed the wheat crop once.

The seeding was done by broadcasting at the rate of 120 kg/ha, which was the normal farmers' practice in the region. We visited each farm 4-5 times during the season accompanied by the farmer to gather data and to seek his/her opinion. Harvesting was done by clipping at maturity, the harvest from each plot was placed in separate bags and taken to the compound (rugo). Manually threshed grains were subsequently weighed by us.

We provided the farmers with seeds, and helped a little during sowing and harvesting; all other operations were carried out by the farmers themselves. The harvest, of course, was for them to keep.

Results and Discussion

The number of seeds sown for the five wheat and one triticale varieties, and the number of seedlings emerged are presented in Table 1. The emergence of all the four improved wheat varieties was less than 50%, with Sesa being the lowest (30%); the percentage emergence for the local variety was much higher (63%), followed by the triticale variety used in this study. The seeds were sown traditionally on poorly prepared seed beds and were covered in most parts with large clods of soil. Apparently, the local varieties are better adapted to this type of seeding practice. One would assume that the larger seeded varieties (Musama, in this case) would be able to emerge better from a greater depth, but this was not so. Other determining factors, such as seedling vigor, coleoptile length and strength, might also be involved. In order to have a good stand, good seed bed preparation and shallow planting would be more important for the improved than the local varieties.

Table 2 shows the characteristics of the test varieties. The number of tillers per plant varied between 1.5 and 2.5, and the number of grains per head ranged from 32 for the local to 41 for the triticale variety. Triticale produced the highest yield. The yields for varieties Musama and Rugezi were in the same range as the local, while the yields of Sesa and Mpinga were considerably lower. The grain sizes of Musama and Rugezi were much larger than the other varieties.

The yield data presented in Table 2 are the averages of 16 farms. Table 3 shows individual farm yields of three selected varieties. For the local variety five out of 16 farms produced yields lower than 1000 kg. The corresponding numbers for Rugezi and the triticale variety were seven and one. In general, on most farms, the performance of triticale was superior to all the wheat varieties tested in the present study. This simply confirms the results of many others that triticale is better adapted than wheat under less than optimum production conditions.

An effort was made to determine as to why the yields on certain farms were much higher, and on other farms much lower than the median yields. As has been presented in Table 4, we selected four farms where the yields of the local wheat variety were 1600 kg/ha or more, and a second set of three farms where the yields were less than 800 kg/ha. Our objective was to find out what these two groups of farmers did differently. Aside from the soil fertility factor, some farmers are just better managers than others and it would be worthwhile to tap into their expertise.

As we see them, three things were done differently: a) previous crop and its management; b) seed bed preparation, and c) weed control; and all these have a major bearing on many other parameters.

Potatoes and beans are planted in fields not too far from the rugo. Land is well-prepared for these crops, and if available, manure is applied to the bean crop. Both potato and bean fields are kept relatively weed-free. When the potatoes are harvested, the soil is left into well-worked conditions. One more hoeing of these fields is adequate for an acceptable seedbed preparation.

Wheat sown on this soil on time should emerge well, and one more weeding should be enough to keep the crop relatively weed-free.

Most of our farmer-collaborators had sown wheat after beans or potatoes, but the differences was that some had properly managed the previous crop while the others did not. This latter group had allowed the weeds to multiply and compete with both bean and wheat crops.

Pea is grown in Rwanda by broadcasting the seeds on land without cultivation, and then the seeds and the weeds are buried under by turning over clods of soil. The pea crop is not weeded. Therefore, after pea or fallow, the land is left under poor physical conditions with a high weed population. If wheat is seeded in these fields after one hoeing, and no subsequent weeding is done, the wheat crop will run into a multitude of problems, and consequently, the yield will be reduced. The importance of weed control in wheat production has been adequately discussed by others (1, 4).

There are of course certain factors on which the farmers have little control. In season B, normal planting time for wheat is early to mid-April in our area, and April is also the month of heaviest rainfall. Sometimes the farmers have to seed in the rain, thus causing soil compaction; heavy rainfall following seeding on steep slopes also washes away seeds. Both of these factors seriously affect the subsequent stand establishment.

Farmer opinion--Almost all the collaborators thought that the varieties Musama and Rugezi were quite good. They yield well, have larger grain size, and are easier to thresh.

The farmers, most of whom saw triticale for the first time, were impressed with its yield, but did not like its smaller grain size, and the "pate" made from the triticale flour. Although there is no market for triticale in Rwanda at the present time, all the farmer-collaborators will plant it again on their own. They are looking into other uses of triticale.

Conclusions

1) Even with the existing varieties, wheat yield could be substantially increased by making minor changes in the cultural practices. It would be advantageous to sow wheat after beans or potatoes than after peas or fallow. Good seedbed preparation, planting on time, good weed control would all add to increased yield. We should show the farmers how to do things, on which they have control, better before giving them something new, such as fertilizer or pesticide.

2) Triticale appears to be a potential crop for our area.

3) All technologies generated on the research stations that are destined for the small farms should be tested for appropriateness under farmers' conditions before recommendations are made.

Acknowledgments

Funding for this study was provided by the United States Agency for International Development (USAID) through a grant to ISAR (Contract No. 696-0110-C-00-5016-00). The authors wish to acknowledge the contribution of Mr. Jerome Habukwizera, Field Technician, to this study.

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Résumé

Le présent travail a été realisé au Rwanda dans la région de haute altitude de Buberuka, où l'altitude moyenne est supérieure à 2000 m. Le régime pluvial y est bimodal et la moyenne des précipitations annuelles d'environ 1400 mm. Près de la moitié des 4000 hectares de blé du Rwanda est située dans cette région où le rendement moyen est d'environ 0,85 t/ha. Par contre, à la station de l'ISAR (Institut des Sciences Agronomiques du Rwanda) basée à Rwerere, dans la même région, le rendement moyen du blé est approximativement de 3 t/ha.

Quatre variétés de blé et une variété de triticale, sélectionnées à l'ISAR, ont été comparées en milieu rural en utilisant les pratiques locales de production. Cette expérimentation avait pour objectifs de comparer ces variétés à la variété de l'agriculteur et d'étudier les pratiques des agriculteurs en travaillant étroitement avec eux de sorte que des interventions appropriées puissent être proposées dans le futur.

Les résultats préliminaires font ressortir que les principales contraintes à la base des faibles rendements des exploitations locales sont la faible fertilité des sols et les pratiques culturales traditionnelles. D'autres problèmes et possibilités liés à la production du blé dans les exploitations de la région sont discutés.

Table 1. Emergence of wheat varieties under farmers' conditions (1987 B)[a]

Varieties	No. of seeds sown/m²[b]	No. of seedlings/m²	Percentage emergence
Musama	186	72	38
Rugezi	210	102	48
Sesa	255	83	33
Mpinga	260	124	48
Local	280	175	63
Triticale (Delfina)	260	131	50

[a] Average of 16 farms
[b] Based on a seed rate of 120 kg/ha

Table 2. Yield characteristics of selected wheat varieties under farmers' conditions (1987 B)[a]

Varieties	No. of tillers per plant	No. of grains per head	Yield kg/ha	Wt (g) per 1000 grains
Musama	2.5	36	1314	65
Rugezi	1.5	37	1229	57
Sesa	2.5	34	831	47
Mpinga	1.5	38	972	46
Local	1.7	32	1223	43
Triticale (Delfina)	2.5	41	1738	46

[a] Average of 16 farms

Table 3. Yield distribution of selected wheat and triticale varieties in on-farm trials (1987 B)

Farm ranking[a]	Yield kg/ha		
	Local	Rugezi	Triticale
1	2400	2200	2567
2	1833	2333	1800
3	1667	1267	1467
4	1600	1300	2100
5	1467	1267	2533
6	1450	1033	1117
7	1333	1733	2467
8	1333	1233	1733
9	1167	800	1400
10	1167	700	1333
11	1000	1000	3250
12	967	867	1433
13	933	767	1200
14	667	900	1600
15	500	600	1033
16	500	667	767
Average	1223	1229	1738

[a] Ranking of farms as per yield of the local variety.

Table 4. Factors influencing the yields of local variety under farmers' conditions (1987 B)

Factors	Farms with higher yields	Farms with lower yields
1. Yield (kg/ha)	> 1600 (4 farms)	< 300 (3 farms)
2. Previous crop & its management	Potato or bean; properly managed	Bean, pea or fallow; poorly managed
3. Hoeing, once	Yes	Yes
4. Seed-bed preparation	Adequate	Poor
5. Time of planting	Early to mid April	Early to late April
6. Stand establishment	Good	Poor
7. Weeding, once	Yes	No
8. Soil fertility and pH[a]	To be determined	To be determined
9. Manure/compost	Added to last crop	None
10. Disease/insect	Mild	Mild
11. Bird damage	Slight	Severe
12. Soil erosion	Slight	Moderate

[a] Soil pH in the work area in general is about 5.0 or less.

WEED POPULATIONS AND CULTURAL PRACTICES ON WHEAT FARMS OF THE HANANG COMPLEX IN TANZANIA

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Abstract

Mechanized wheat production in a monoculture began on the Hanang plains in northern Tanzania in 1968 at the Basotu farm. In 1986, wheat was seeded on 24,200 ha at seven farms. The main cultural method for weed control is to delay seeding until the middle of the rainy season. Herbicides are used when foreign exchange is available for both broad leaf and grassy weed control. In 1986, the dominant weeds were Setaria spp., mainly lovegrass (Setaria verticillata L.). The Setaria spp. population ranged from 0 to 420 shoots/m2 on fields in the two oldest farms while the average Setaria spp. density on farms established since 1980 was less than 3 shoots/m2. The densities of the other weed species on the Hanang complex were not influenced by the number of years (1 to 15) that wheat had been grown in monoculture. Several weeds were identified that are resistant to 2,4-D which is currently used for broadleaf weed control, but there was no indication that these weeds were becoming a serious problem.

History of Wheat Production Practices at Hanang

Mechanized wheat production was started by the Tanzania Ministry of Agriculture on the Basotu farm on the Hanang plains in northern Tanzania (4° 24'S, 35° 10'E) at an elevation of 1700 m in 1968. Prior to the initiation of the wheat production scheme there were a few intermediate sized farms covering less than 5 percent of the present Hanang complex. Most of the land was used for grazing cattle by nomadic Barbaig and Iraqw people (4). The natural vegetation was grassland dominated by *Cynodon dactylon* (L.) Pers (star grass), *Pennisetum mezianum* Leeke (bamboo grass), *Themeda triandra* Forssk. (Red oat grass), other tall grasses and small trees (*Acacia* spp.) (1). Since the establishment of the farms, wheat has been grown primarily in monoculture with small areas devoted to workers' maize shambas and barley production. These other crops have covered less than 5% of the cultivated area in all years.

New farms were initiated in 1976, 1980, 1981, 1982, and 1984. In 1986, wheat was seeded on 24,200 ha at seven farms. The complex receives an average of 631 mm of rainfall between November and April (3). Temperatures are usually between 10-15°C (at night) and rise to 21-23°C (during the day) with little seasonal variation (3).

Initially, cultural practices included the use of a disc plow or double disc type implement for land preparation prior to seeding in November or December at the beginning of the rainy season. Cultural practices were changed prior to the initiation of the second farm in 1976 to the use of a chisel plow with spike tines for initial cultivation and with sweep tines for the final cultivation. Three to five cultivation operations were done before seeding in the middle of the rainy season (usually seeding is done in February). The initial practice of seeding in November and December usually resulted in thin wheat stands and severe weed infestation. Initially, broadleaf weeds were dominant; however, in the mid-1970s the main weed problem on the oldest farm (Basotu) changed from broadleaf weeds to *Setaria verticillata* L. Delaying seeding from November/December to February, increased wheat yields by 94% (based on average yields for the complex for 1968 to 1975 and 1976 to 1983). The increase in yield corresponded with a large decrease in weed infestation. In experiments, wheat seeded in early December was normally heavily invested with weeds (up to 100% of the vegetation was weeds) while wheat seeded in the middle of the rainy season normally has a light weed infestation.

2,4-D has been used on a large percentage of the cultivated land at the Hanang complex for weed control from 1968 to the present time. Diclofop or isoproturon have been used for annual grass control on less than 30% of the complex in each year since 1983. These herbicides have not been effective in controlling weeds in early seeded wheat. They control the early germinating broadleaf weeds and grasses but the thin wheat stands were not capable of competing with latter germinating weeds.

Weeds Survey Conducted in 1986

In 1986 the farms were surveyed to determine which weed species are present in the wheat fields at Hanang and to relate differences in cultural practices, soil types, and years of monoculture wheat production to weed species composition and densities. The weed survey was conducted in May of 1986 just prior to harvest; thus, the counts represent the final weed population in the mature crop. One field or seeding unit was sampled for every 615 ha of seeded land. The fields which received the same cultivations, herbicides, and seeding treatment had an average size of 65 ha. The fields on each farm were numbered and random numbers were used to select fields (sampling sites) on each farm. At each sampling site the surveyors travelled 100 paces from a field corner along the edge of the field, turned at a right angle to the edge of the field and walked 100 paces into the field. A "W" shaped sampling pattern was walked in the field and weeds were identified and counted on 0.18 m^2 areas after every 20 paces. Five counts were made on each arm of the "W" pattern for a total of 20 counts per field. The count data were converted into number of weeds per m^2 and then the percentage of fields where each weed was observed was calculated. In addition to weed counts, soil typed, cultivation operations, type of seeder used, variety of wheat seeded, seeding date, moisture conditions in the surface layer of soil, and herbicide applications were recorded on a questionnaire for each farm.

Analysis of variance, one-way classification with unequal replication or "t" tests (5) were used to determine which factors were influencing populations of specific weed species. Differences in populations of specific weed species among farms were analyzed first. Then, differences between soils in farms with similar densities of a particular weed species were considered, followed by analysis of differences in densities caused by various cultural practices within soils with similar densities of a particular weed. To correct for heterogeneous variances among levels of individual factors, as determined by the Chi square test (5), a logarithmic transformation of the count data was used prior to analysis of variance.

The wheat yield for each field was recorded by each farm manager and the effect of the major weed (*Setaria* spp.) on wheat yield was tested by regression analysis.

Weed Species and Densities

The most frequently occurring weeds were *Setaria* spp., mainly *Setaria verticillata* L. (Lovegrass) and *Amaranthus* spp. mainly *Amaranthus retroflexus* L. (redroot pigweed) (Table 1). *Setaria* spp. occurred in much greater densities than the other grasses and broadleaf weeds, with *Setaria* spp. densities as high as 420 shoots/m^2 occurring in some fields on the oldest farms. *Amaranthus* spp. occurred in almost all fields but their density was much lower than that of *Setaria* spp. *Galinsoga parviflora* cav. appeared in almost half of the fields at an average density of about 2 plants/m^2. The remaining weeds listed on Table 1 occurred at densities of less than 1 plant or shoot/m^2. Thirty-four additional broadleaf weed species were identified on the wheat farms but the total average density of these weeds was 0.7 plants/m^2.

The most abundant grass, *Setaria* spp. is susceptible to the currently used herbicides, diclofop and isoproturon. The less-frequently occurring grasses are either resistant to diclofop and isoproturon or only susceptible at a very early stage (Table 1). Similarly, the most abundant broadleaf weed, *Amaranthus* spp., is susceptible to 2,4-D but the second and third most abundant broadleaf weeds have little susceptibility to 2,4-D. There is little information available about the susceptibility of the 34 rarely occurring broadleaf weeds to 2,4-D.

Factors Influencing Weed Densities

The oldest farms Basotu, Setchet, and Mulbadow had significantly greater *Setaria* spp. densities (P=.05) than the remaining farms (Table 2). With the other grasses and broadleaf weeds, there were no significant differences (P=.05) among farms. Thus, only the density of *Setaria* spp. seems to be influenced by the number of years of monoculture wheat production.

On the Basotu farm (oldest farm) there was a significant difference, by "t" test (P=0.05), in *Setaria* spp. density between the upland soils (Mollisols and sloping Vertisols) and the depressional Vertisols. The *Setaria* spp. densities were 149 and 13 shoots/m^2 for upland soils and depressional Vertisols respectively. Soil type did not have a significant effect on *Setaria* densities on the other farms or on the densities of the other weeds on any of the farms.

In 1986, 2,4-D was applied to 69% of the sampled fields on the Hanang complex. *Amaranthus* spp., which were the dominant broadleaf weeds, occurred at densities of 16 and 1.1 plants/m^2 on fields that were not sprayed with 2,4-D and those that were sprayed respectively. The densities for sprayed and unsprayed fields were significantly different by the "t" test ($P=0.05$). There was no significant difference ($P=0.05$), due to 2,4-D in the total density of the weeds other than *Amaranthus* spp. listed in Table 1. The average density of these weeds in 2,4-D treated fields was influenced by the lack of control of *Argemone mexicana* and *Galinsoga parviflora* Cav. in a few 2,4-D treated fields.

In 1986 the number of fields treated with diclofop or isoproturon for grass control, within soils with similar *Setaria* spp. densities, was too small to assess the efficacy of these chemicals.

Additional environmental factors and cultural practices such as wheat varieties, cultivation operations, or surface soil moisture conditions at seeding time did not seem to influence weed populations in 1986.

Effect of Weeds on Wheat Yield

On the upland soils at Basotu and Setchet farms (Mollisols, Inceptisols, and Alfisols), there was a good correlation between wheat yield and *Setaria* spp. density ($r^2=-0.68$). The relationship between yield loss and *Setaria* spp. density was linear and equal to about a 1% yield loss for every 10 *Setaria* spp. shoots/m^2. No attempt was made to relate *Setaria* spp. density to yield on the rest of the Hanang complex where the *Setaria* spp. density was low, or to relate populations of other weeds which occurred at much lower densities to wheat yields.

Conclusions

1) Seeding in the middle of the rainy season after several cultivations greatly reduced weed populations and increased wheat yields compared to seeding at the beginning of the rainy season.

2) Post-emergence applications of nonresidual herbicides were not effective in controlling weeds in wheat seeded at the beginning of the rainy season.

3) The dominant weed species on the Hanang complex is *Setaria verticillata* L. (lovegrass).

4) On the oldest farm *Setaria* spp. populations are much greater on the upland soils than on the depressional vertisols.

5) The density of *Setaria* spp. is greatest on the farms where wheat has been grown in a monoculture for the longest period of time.

6) There is no indication that the densities of the other weed species are increasing due to monoculture wheat production.

7) 2,4-D is effective for controlling the dominant broadleaf weed (*Amaranthus retroflexus* L.) but there are several broadleaf weeds present that are not susceptible to 2,4-D.

8) *Setaria* spp., mainly *Setaria verticillata* L., is causing a wheat yield loss in the order of 1% for every 10 setaria shoots/m^2. Estimated average yield loss due to *Setaria* spp. for the Hanang wheat farms was 90 kg/ha in 1986. Based on the total acreage seeded and wheat price in 1986, the loss due to *Setaria* spp. was 371,428.57 U.S. Dollars.

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Résumé

La monoculture mécanisée du blé a été lancée en 1968 dans les plaines du Hanang dans la ferme du Basotu (nord de la Tanzanie). En 1986, un total de 24 200 ha ont été emblavés dans sept exploitations. La principale pratique culturale pour lutter contre les adventices consiste à reporter les semailles jusqu'au milieu de la saison des pluies. L'utilisation d'herbicides pour maîtriser les adventices, aussi bien à larges feuilles qu'herbacées, est liée à la disponibilité en devises. En 1986, les principales espèces d'adventices appartenaient au genre Setaria dont surtout le Setaria verticillata L. La population de Setaria spp variait de 0 à 420 pousses/m^2 dans les champs des deux plus anciennes exploitations, alors que la population moyenne était de moins de 3 pousses/m^2 dans les exploitations établies depuis 1980. On n'a pas trouvé de rélation entre la densité de population des autres adventices et le nombre d'années (1 à 15) pendant lesquelles la monoculture a été adoptée. On a identifié plusieurs espèces d'adventices résistantes au 2,4-D utilisé actuellement contre les adventices à feuilles larges, mais rien n'indiquait que ces plantes pourraient poser un sérieux problème.

Table 1. Major weeds present on the Hanang wheat farms

Weed	Common Name	Density (number/m^2)	Frequency of fields where weed observed (%)	Susceptibility[a] to Diclofop	Isoproturon
Grasses and Sedges					
Setaria spp.	Lovegrass (mostly)	58.1	78	S	S
Eragrostis spp.	Stink lovegrass	0.8	25	S	S
Eleusine indica L. Gaertn	Wild finger millet	0.8	30	S (seedlings)	R
Digitaria abyssinica (A. Rich.) Stapf.	Couch grass	0.6	26	R	R
Cynodon spp.	Stargrass	0.3	17	R	R
Cyperus esculentus L.	Yellow nutgrass	0.3	18	R	R
Broadleaf Weeds				2,4-D	
Amaranthus spp.	Pigweed	3.3	90	S	
Galinsoga parviflora Cav.	Gallant soldier	1.8	43	S[b]	
Argemone mexicana L.	Mexican poppy	0.4	6	MS	
Hibiscus spp.	Flower-of-an-hour	0.2	22	S	
Crotalaria spp.	Rattlepod	0.2	28	S	
Commelina spp.	Wandering Jew	0.2	18	R	
Euphorbia hirta and E. heterophylla L.	Asthma Weed	0.1	8	S	

[a] S = Weed susceptible or controlled by herbicide; R = Weed resistant to herbicide. Rating for grasses are based on unpublished results from experiments conducted by Tanzania Agricultural Research Organization (TARO). 2,4-D ratings are from Ivens (1975); MS = Moderately susceptible.

[b] Ivens (2) indicated Galinsoga parviflora Cav. is susceptible to 2,4-D; however, research experiments in Tanzania and CIMMYT/Mexico (Personal communications, B.R. Makoko, Tanzania Agricultural Research Organization, Arusha) indicate this weed is not controlled with 2,4-D. It is susceptible to herbicide mixtures containing bromoxynil.

Table 2. Setaria spp. density on wheat farms

Farm	Age of farms in years	Average Setaria spp. density No./m^2
Basotu	18	67a
Setchet	10	54a
Mulbadow	6	26a
Gawal	4	3b
Gidagamowd	4	2b
Murjanda	5	2b

Weed densities followed by a common letter are not significantly different by Duncan's multiple range test (P = 0.05).

NUTRITION OF WHEAT ON THE HANANG PLATEAU IN TANZANIA

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Abstract

Continuous wheat has been produced for up to 17 years on parastatal farms occupying 25,000 ha of predominantly vertisols (50%) and mollisols (42%) with some alfisol-inceptisols (8%) developed in calcareous volcanic ash on the relatively cool (20C) Hanang Plateau (1700m) in Tanzania. The area receives 630 mm of precipitation falling primarily from December through April, so that wheat is seeded in February to be harvested during the totally dry months of June through September.

Response to 50 kg N/ha as ammonium sulfate drilled in 18 experiments was significantly related (5% level) to soil NO_3-N to 60 cm according to the equation % yield=32.2 + 14.1 (ln kg NO_3-N to 60 cm). The average yield increase resulting from N fertilization in experiments for which the soil NO_3-N level was less than the critical level of 35 kg NO_3-N/ha to 60 cm (according to the Cate-Nelson Analyses of Variance Method) was 0.97 t/ha. However, 55% and 45% of the soils in 72 fields on the Hanang Plateau sampled in a survey from 1982-1985 contained 35 to 85 and greater than 85 kg NO_3-N/ha upon which the average expected yield increases from N fertilization would be only 0.28 and 0 t/ha, respectively.

Response to 20 kg P/ha as triple superphosphate (TSP) drilled in 26 experiments was significantly related (1% level) to 0.5 M $NaHCO_3$ extractable P to 15 cm according to the equation % yield = 64.9 + 9.6 (ln ppm 0.5 M $NaHCO_3$ extract P to 15 cm). The average yield increase in experiments in which the extractable P level was below 10 ppm (the critical level determined by the Cate Nelson Method) was 0.39 t/ha. The survey of extractable soil nutrient levels suggested that only 4% of the land area (1000 ha of mostly alfisol-inceptisols) contains less than 10 ppm $NaHCO_3$ extractable P. Since the extractable soil P levels did not vary among years, it is recommended that a maximum of 20 kg P/ha as TSP be drilled with the seed of wheat on those 1000 ha of alfisol-inceptisol soils.

Application of K, S, Mo, Cu, Mn, or Zn did not increase wheat grain yields on the Hanang Plateau in Tanzania.

Introduction

Research concerning the nutrition of wheat in the highlands of Northern Tanzania up until the early 1970s was concentrated primarily in the major wheat growing areas, Mbulu and West Kilimanjaro. The research emphasized N since the soils appeared to supply adequate amounts of P and

K to wheat. Nitrogen fertilizer recommendations were based mainly upon the previous cropping history and/or weather conditions that prevailed before and after seeding (1).

Parastatal wheat farms were established on the Hanang Plateau in northern Tanzania in the late 1960s and were expanded rapidly during the late 1970s and early 1980s to the present land area of 25,000 ha under continuous wheat production. The Hanang plateau produces 40,000 to 50,000 tons of wheat each year, one third of Tanzania's total demand and one half of its total production. The mean annual precipitation of 630 mm falls primarily within the months of December through April such that February becomes the optimal planting time. Vertisols, Mollisols and Alfisol-Inceptisols, occupying 50%, 42%, and 8% of the land area, respectively, have developed in calcareous volcanic tuff (3).

Very little was known about the nutrient levels of soils on the Hanang Plateau, necessitating additional fertility research to determine the nutrient requirements of wheat. Emphasis was placed upon the macro-nutrients, N, P and K, the nutrients which are often deficient in many parts of Tanzania (1, 7, 13). Nevertheless, some research concerning micronutrients was conducted since some soils in Tanzania are deficient in micronutrients, particularly Cu and Mn (5, 6).

The specific objectives of the fertility research conducted on the Hanang Plateau from 1977 through 1985 were 1) to determine if wheat grain yields could be increased through application of N, P, K, S, Cu, Mn, Zn, Mo or B; 2) to determine the optimal rate as well as method of application for any nutrient which increased yields; 3) to describe the relationship between yield response to each deficient nutrient and the extractable soil nutrient level so as to establish the soil critical level; and 4) to determine extractable soil nutrient level over the entire Hanang Plateau in order to describe the extent and severity of nutrient deficiencies.

Material and Methods

N, P, K field studies--Twenty-nine field experiments were conducted on the Hanang Plateau from 1977 through 1985 in order to fulfill objectives 1, 2 and 3 for N, P and K. In the 18 experiments involving N, ammonium sulfate was drilled with the seed at rates of 0 to 60 kg N/ha or mixed with the surface 10 cm of soil just prior to seeding or surface broadcast 4 weeks after seeding at rates of 0 to 120 kg N/ha. In the 26 experiments involving P, triple superphosphate (TSP) was drilled with the seed at rates varying from 0 to 80 kg P/ha, but most often at 0, 20 or 40 kg P/ha. In some experiments, 80 kg P/ha as TSP mixed with the surface 10 cm of soil just prior to planting was compared to the same rate of P drilled with the seed. Similarly, in several experiments 80 kg P/ha as finely divided rock phosphate containing 15% P mined at Minjingu, Tanzania, was either drilled with the seed or mixed with the surface 10 10 cm of soil just prior to planting in order to compare its effectiveness with that of TSP. In the 8 experiments involving K, muriate of potash was drilled with the seed at the rate of 25 kg K/ha. The various treatments were replicated 4 to 6 times in randomized complete block designs.

Plots were seeded with the wheat variety Trophy (3503) (most of the N experiments and all K experiments) or Mbuni (T26-73) (most of the P experiments) at 110 kg seed/ha using either a four-row small plot cone seeder with double disc openers at 22.8 cm spacing (most of the N experiments) or a six-row small plot belt seeder with double disc openers at 17.8-cm spacing (most of the P experiments). Soils were sampled to at least 60 cm at seeding and analyzed as described under the section entitled "Soil Analyses". The plots were hand weeded and hand harvested by cutting at ground level.

Sulfur and macronutrient studies--Sulfur and/or micronutrients were applied to wheat on mollisols in eight experiments on the Hanang Plateau. In all eight experiments, Mo as $Na_2MoO_4.2H_2O$ was mixed with the surface 10 cm of soil at rates up to 40 kg Mo/ha, applied as a seed treatment at rates up to 0.8 kg Mo/ha, or foliar applied at rates up to 1 kg Mo/ha. Copper as $CuSO_4.5H_2O$ at 5 kg Cu/ha was mixed with the surface 10 cm of soil just prior to planting in 4 experiments. Manganese as $MnSO_4.4H_2O$ at 5 kg Mn/ha was drilled with the seed in 4 experiments. Boron as $Na_2B_4O_7$ at 2 kg B/ha was mixed with the surface soil in 2 experiments. Zinc as $ZnSO_4.7H_2O$ at 5 kg Zn/ha was also mixed with the surface soil in 1 experiment. Sulfur as Na_2SO_4 at 5 kg S/ha was drilled with seed in 1 experiment.

Survey of extractable nutrient levels in soils on the Hanang plateau--Beginning in 1982, fields covering approximately 8000 ha on the Hanang Plateau were randomly sampled shortly before seeding and subjected to the analyses described under "Soil Analyses" in order to fulfill objective 4. Each field was sampled at 15 locations to depths of 0 to 15 and 15 to 60 cm. For most fields all 15 samples for each of the two depths were composited before analysis. However, the 15 samples were kept separate for about 10 fields in order to estimate variation in fertility levels within fields. In addition, the 10 fields are being sampled periodically (every year from 1982-1985) and then every 3 years) to estimate changes in fertility levels with time. The survey has not been conducted long enough to interpret results concerning fertility level changes. All samples for this survey and from all fertility experiments were treated with toluene in the field to minimize nitrogen transformations and then placed moist into polyethylene bags. Several days later the samples were air dried and hand ground to pass a 30-mesh sieve.

Soil analyses--Available soil N was estimated by determining NO_3-N level to a depth of 60 cm according to Harper's (4) modified phenoldisulphonic acid method. The Cate-Nelson Analysis of Variance Method (7) was used to estimate the critical level of soil NO_3-N to 60 cm and P to 15 cm and P to 15 cm. Available soil P was estimated by extracting soil to 15 cm with 0.5M $NaHCO_3$ according to the method of Olsen and Dean (8). Available K, Ca, Mg and Na were estimated by determining exchangeable cation levels using 1 M NH_4OAc according to the Pratt modified procedure (10). Soil pH in 1:2, soil:0.01M $CaCl_2$ was determined electrometrically by the method described by Peech (9).

Results and Discussion

Nitrogen--Nitrogen fertilization significantly increased wheat grain yields on the Hanang Plateau in six of 18 experiments (Table 1). Percentage yield was significantly related (5% level) to the level of NO_3-N to 60cm according to the relationship % Yield = 32.3 + 14.1 (ln kg NO_3-N).

The critical soil NO_3-N to the 60-cm level according to this approach was 35 kg/ha. The average yield increase resulting from N fertilization in experiments for which the soil NO_3-N level was less than 35 kg/ha (or "low"), was 0.97 t/ha. The average yield increase in experiments for which the soil NO_3-N level was 35 to 86 kg/ha (or "medium"), was 0.28 t/ha. Application of N fertilizer on soils containing more than 86 kg NO_3-N/ha (or"high") had no influence upon wheat grain yield.

The average soil NO_3-N to 60 cm level for 72 randomly selected fields in the survey of extractable nutrient levels just prior to seeding in 1983, 1984 and 1985 was 86 kg/ha. None of the fields contained less than 35 kg NO_3-N/ha. Most of the fields contained 35-85 kg NO_3-N/ha and 85 kg/ha. The NO_3-N levels in those fields which were sampled every year from 1982 through 1985 varied greatly, likely resulting from variation in leaching, immobilization and/or denitrification resulting from variation in rainfall and/or weed and trash management.

In six experiments in which N significantly increased wheat yields, ammonium sulfate drilled with the seed at the rate of 45 kg N/ha increased yield by 0.84 t/ha (Table 2). Drilling 60 kg N/ha did not increase yields further.

In fact, in two experiments, yields with 60 kg N/ha drilled were lower than those with 45 kg N/ha drilled, perhaps because of seedling injury. Mixing 60 kg ammonium sulfate N/ha with the surface 10 cm prior to planting was nearly as effective as drilling with the seed, increasing yield by about 0.8 t/ha. Mixing 120 kg N/ha increased yield further, but by only 0.3 t/ha. Broadcasting ammonium sulfate 4 weeks after planting was not as effective in increasing yields as drilling or mixing with the soil prior to seeding.

Phosphorus--Approximately 20 kg P/ha as TSP drilled with the seed increased wheat grain yields significantly in 6 out of 26 experiments (Table 3). Percentage yield was significantly related (1% level to the level of 0.5 M $NaHCO_3$ extractable soil P according to the equation % Yield = 64.9 + 9.6 (ln ppm 0.5 M $NaHCO_3$ extrac. P).

The critical 0.5 M $NaHCO_3$ extractable soil P level in the surface 15 cm according to the Cate Nelson method was 11 ppm. The average yield increase resulting from P fertilization in experiments for which the soil P level was less than 11 ppm (or "low") was 0.39 t/ha. The average yield increase in experiments for which the soil contained 11 to 28 ppm P was only 0.08 t/ha. Application of P fertilizer on soils containing more than 28 ppm P decreased yields by an average of 0.19 t/ha.

The average soil 0.5 M $NaHCO_3$ extractable P level for 72 randomly selected fields in the survey of extractable nutrients just prior to seeding in 1983, 1984 and 1985 was 55 ppm. Only 4% of the fields, all occupied by Alfisol-Inceptisol soils, contained less than 10 ppm P (or "low"), whereas 25% of the fields contained between 10 and 30 ppm P and 71% contained more than 30 ppm P. It is surprising that soils on only 4% (1000 ha) of the land area on the

Hanang Plateau responded to P since 50% of the land area is mapped as being occupied by Vertisols which contain an average of 12.0 ppm 0.5 M $NaHCO_3$ extractable P. Perhaps the discrepancy can be explained by the extreme variation in soil P levels within fields which are mapped as including vertisols, likely as a result of inclusions of mollisols which contain considerably more P.

On this 1000 ha of land, drilled T.S.P. with the seed was more effective in increasing yields than T.S.P. mixed with the surface 10 cm prior to seeding. Triple superphosphate drilled with the seed increased yields up to 20 kg P/ha. Drilling of more than 20 kg P/ha as T.S.P. had no further influence upon wheat grain yield. Finely divided rock phosphate from Minjingu, Tanzania at 80 kg P/ha drilled with the seed or the same amount mixed with the surface 10 cm before seeding was not effective in increasing wheat grain yields.

Potassium--Potassium fertilization of wheat on the Hanang Plateau had no influence upon yields. This is not surprising since all exchangeable soil K levels were well above the critical level of 125 ppm suggested by Doll and Lucas (2).

The average exchangeable soil K level to 15 cm for 72 randomly selected fields in the survey of extractable nutrient levels just prior to seeding in 1983, 1984 and 1985 was 1220 ppm and the soils in all 72 fields contained at least 3 times the critical level of 125 ppm. Supplemental K is not needed for wheat production on the Hanang Plateau in Tanzania.

Sulfur and micronutrients--Application of S, Mo, CU, Mn, B or Zn had no influence upon wheat grain yields on the Hanang Plateau. Although the number of experiments, particularly for S and Zn, was not large enough to prove conclusively that these nutrients are not deficient, it seems quite unlikely that the supplies of these nutrients are significantly limiting yields. Molybdenum was applied in 8 experiments and did not increase yields. In addition, the levels of Cu, Mn, Fe, Zn (and in a few samples, B and Mo) in numerous wheat shoots sampled at early heading were well above the critical levels suggested in the literature (12). Also, it should be mentioned that since all soils on the Hanang Plateau are high in exchangeable bases, Mg and Ca deficiencies are not likely.

Conclusions

Since the average soil NO_3^--N level within each of the 72 representative fields covering 25,000 ha Hanang wheat farms was greater than the critical level of 35 kg/ha it can be concluded that N fertilizer would not be required soon. Also, it would not be practical to apply P fertilizers on the Hanang Plateau since the effected area is very minor. Other elements seem to be present in the soils in adequate amounts. However, it is suggested that periodic soil sampling and field fertilizer observation plots be conducted to monitor changes in fertility levels.

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Résumé

Le blé a été cultivé de manière continue pendant 17 ans dans des fermes para-étatiques s'étendant sur 25 000 ha de terres constituées essentiellement de vertisols (50%) et de mollisols (42%) avec quelques alfisols-inceptisols (8%) sur de la cendre volcanique calcaire dans l'environnement rélativement frais (20° C) du plateau du Hanang (1700 m). La pluviosité y est de 630 mm et les pluies tombent essentiellement de décembre à avril, de sorte que le blé est semé en février et récolté durant les mois secs allant de juin à septembre.

Après 18 expériences, on a trouvé une corrélation significative (au niveau de 5%) entre la réponse à l'épandage de 50 kg N/ha sous forme de sulphate d'ammoniaque et la teneur en NO_3-N à 60 cm, sur la base de l'équation de rendement (%) = 32,2 + 14,1 (1n kg NO_3-N à 60 cm). Un accroissement moyen des rendements de 0,97 t/ha a été obtenu grâce à l'épandage d'engrais à base de N dans les experiences pour lesquelles la teneur du sol en NO_3-N était inférieure au niveau critique de 35 kg NO_3-N/ha à 60 cm (en partant de la méthode d'analyse de variance Cate-Nelson). Cependant, sur 55% et 45% des 72 champs ayant servi d'échantillons pour une étude menée de 1982 à 1985, la teneur en NO_3-N était de 35 à 85 kg et plus, ce qui fait que les accroisements des rendements escomptés sur ces sols après fertilisation à base de N étaient seulement de 0,28 et 0 t/ha, respectivement.

Il y avait une corrélation significative (au niveau de 1%), dans le cadre de 26 expériences, entre la réponse à l'épandage de 20 kg P/ha sous forme de superphosphate triple (SPT) et un niveau de 0,5 M $NaHCO_3$ de P extractible à 15 cm, sur la base de l'équation de rendement (%) = 64,9 + 9,6 (1n ppm 0.5 M $NaCOH_3$ extrait de P à 15 cm).

L'accroissement moyen des rendements au cours des expériences pour lesquelles la teneur en P assimilable était inférieure à 10 ppm (niveau critique déterminé sur la base de la méthode de Cate-Nelson) était de 0,39 t/ha. L'étude des teneurs du sol en éléments nutritifs assimilables a montré que seulement 4% des terres de la zone avaient une teneur en P extractible inférieure à 10 ppm $NaHCO_3$. Puisqu'il n'y a pas de variations des teneurs du sol en P extractible au cours des années, il est recommandé l'enfouissage, avec les semences de blé, de 20 kg P/ha sur les 1000 ha de terres constituées d'alfisols-inceptisols.

Apport de K, S, Mo, Cu, Mn ou Zn n'a pas engendré d'accroissements des rendements de blé sur le plateau du Hanang en Tanzanie.

Table 1. Relationship[a] between response in wheat grain yield to fertilizer N and soil NO_3-N to 60 cm on the Hanang plateau in Tanzania, 1977-1984

Nitrate-N to 60 cm (kg/ha)	Year	Soil order	Fertilizer[b] N applied (kg/ha)	Grain Yield without N (t/ha)	Yield[c] Change with N (t/ha)	% Yield	R^2 [d]
10	1979	Mollisol	60	1.55	+ .51 S	75	0.040
19	1979	Mollisol	0	1.80	+ 1.23 S	59	0.206
20	1977	Mollisol	60	2.33	+ 1.05 NS	69	0.311
32	1980	Mollisol	60	2.04	+ 1.08 S	65	0.472
37	1979	Vertisol	60	2.83	+ .47 S	86	0.437
41	1980	Vertisol	60	3.72	- .14 NS	104	0.280
56	1977	Vertisol	60	3.38	+ .18 NS	95	0.225
66	1978	Mollisol	60	1.40	- .13 NS	110	0.110
72	1981	Mollisol	60	1.76	+ .31 NS	85	0.128
84	1984	Alfisol-Inceptisol	50	2.19	+ .54 S	80	0.176
86	1984	Alfisol-Inceptisol	50	1.67	+ .63 S	73	0.287
86	1981	Mollisol	60	1.71	+ .34 NS	83	0.356
87	1982	Alfisol-Inceptisol	50	2.40	+ .01 NS	100	0.304
97	1984	Alfisol-Inceptisol	50	1.76	- .04 NS	102	0.247
100	1982	Vertisol	50	1.46	- .09 NS	107	0.162
101	1978	Millisol	60	1.35	- .27 NS	125	0.013
142	1978	Vertisol	60	1.88	- 13 NS	107	0.008
143	1982	Altisol-Inceptisol	50	1.56	+ .31 NS	83	

[a] The relationship % yield = 32.2 + 14.1 (in kg NO_3-N) significant at 5% level and more significant than linear or polynomial relationship.

[b] N as ammonium sulfate was drilled with the seed. Sufficient P as T.S.P. was drilled with the seed to eliminate P deficiency.

[c] S-yield increase statistically significant at 5% level. NS-yield increase not statistically significant at 5% level.

[d] R^2 calculated according to Cate-Nelson Analysis of Variance Method (7) for determining critical NO_3-N level to the 60-cm soil. Critical level found to be about 35 kg/ha.

Table 2. The influence of rate and application method of ammonium sulfate upon wheat grain yield on the Hanang in Tanzania[a]

	Application method		
N Rate (kg N/ha)	Drilled with seed (t/ha)	Mixed with surface 10 cm just prior to seeding (t/ha)	Surface broadcast 4 weeks after seeding (t/ha)
0	2.06	2.06	2.06
15	2.42	2.34	--
30	2.58	2.59	2.48
45	2.90	2.77	--
60	2.08	2.85	2.53
90	--	3.07	2.62
120	--	3.17	2.74

[a] Average of 4 experiments in which N significantly increased yields (5% level) on Mollisols and Vertisols containing an average of 25 kg NO_3-N/ha to 60 cm.

Table 3. Relationship[a] between response in wheat grain yield to fertilizer P and 0,5 M $NaHCO_3$ extractable soil P on the Hanang plateau in Tanzania, 1977-1985

0.5 M $NaHCO_3$ Extractable P (ppm)	Year	Soil order	Fertilizer[b] P applied (kg/ha)	Grain Yield without P (t/ha)	Yield[c] Change with P (t/ha)	% Yield	R^{2d}
3.0	1983	Alfisol-Inceptisol	20	0.98	+ 0.62*	61	0.11
4.0	1984	Alfisol-Inceptisol	20	1.25	+ 0.18	87	0.07
4.2	1984	Alfisol-Inceptisol	20	1.36	+ 0.43	76	0.10
4.6	1984	Alfisol-Inceptisol	20	1.24	+ 0.40	76	0.13
4.9	1983	Alfisol-Inceptisol	20	1.06	+ 0.35*	75	0.17
5.0	1985	Alfisol-Inceptisol	20	2.53	+ 0.64	80	0.19
5.1	1985	Alfisol-Inceptisol	20	2.07	+ 0.69*	75	0.23
5.4	1984	Alfisol-Inceptisol	20	1.97	+ 0.26	88	0.22
5.6	1983	Alfisol-Inceptisol	20	1.50	- 0.05	103	0.15
5.8	1984	Alfisol-Inceptisol	20	2.23	+ 0.44*	84	0.16
6.0	1982	Alfisol-Inceptisol	20	1.69	+ 0.71	70	0.24
6.7	1984	Alfisol-Inceptisol	20	1.21	+ 0.96*	56	0.10
7.1	1984	Alfisol-Inceptisol	20	1.48	+ 0.02	99	0.34
10.6	1980	Vertisol	26	3.63	- 0.12	103	0.28
10.6	1983	Alfisol-Inceptisol	20	1.09	+ 0.55*	66	0.40
10.7	1982	Vertisol	20	1.30	+ 0.12	92	0.40
11.7	1978	Vertisol	26	1.79	0	100	0.35
12.1	1979	Vertisol	26	2.95	+ 0.07	98	0.32
14.0	1977	Vertisol	26	3.50	- 0.23	107	0.25
22.0	1985	Alfisol-Inceptisol	20	3.31	+ 0.10	97	0.23
28.0	1982	Alfisol-Inceptisol	20	1.53	+ 0.44	78	0.34
87.4	1979	Mollisol	26	2.03	+ 0.02	99	0.33
92.6	1977	Mollisol	26	3.11	- 0.20	107	0.27
115.0	1978	Mollisol	26	1.62	- 0.32	124	0.10
125.0	1979	Mollisol	17	3.34	- 0.47	118	0.01
132.0	1978	Mollisol	17	1.27	+ 0.02	98	0.01

[a] The relationship - % Yield = 64.9 + 9.6 (ln ppm P), significant at P = 0.01.

[b] P as triple superphosphate was drilled with the seed. Sufficient N was mixed with the surface 10 cm of soil prior to seeding to aliminate N deficiency.

[c] *-yield increase statistically significant P = 0.05.

[d] R^2 Calculated according to Cate-Nelson Analysis of Variance Method (7) fcrdetermining critical 0.5 M $NaHCO_3$ extractable P in surface 15 cm soil. Critical level found to be about 11 ppm.

TILLAGE EFFECTS ON RAINFED WHEAT PRODUCTION AND SOIL BULK DENSITY

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Abstract

Effects of zero, minimum, conventional, deep ploughing, deep chiseling, late and straw removed tillage treatments were investigated for three seasons, on the grain yield, thousand grain weight and plant height of rainfed wheat and bulk density (Db). Soil of the experimental site was clayey kaolinitic Rhodic Haplustox. Amongst crop parameters only the grain yield was significantly influenced by the tillage treatments. Whenever the crop residue was not maintained on the soil surface, compaction of the soil occurred and the grain yield declined. Maximum grain yield and minimum soil Db were achieved with zero tillage. In general, treatments which had higher soil Db produced lower grain yields. The presence of crop residue on top of the soil was crucial to avoid soil compaction and achieve higher grain yields.

Introduction

It has long been recognized that excessive soil manipulation, beyond what is required to provide suitable seed-zone conditions and weed control leads to deterioration of soil structure, accelerated soil erosion and consequently reduction in crop yield. In recent years, increasing awareness of these hazards has resulted in the development of radically new conservation tillage systems. These systems aim at conserving soil and water through minimization of soil manipulation and maintenance of organic residue on top of the soil surface. These organic residues shade the soil, serve as a vapor barrier for water losses from soil, slow surface runoff and increase infiltration (3). To control structural deterioration, perhaps the best management practice is to prevent compaction by protecting the soil surface with mulch or plant canopies which decrease the energy of raindrops and the rate of organic matter decomposition (19). Although there have been signifcant gains in the knowledge of how conservation tillage systems function (4) and all major field crops are adapted to conservation tillage, only limited information is available to identify the soil response.

The present study was undertaken to investigate the effects of tillage type and timing on rainfed wheat production and soil bulk density.

Material and Methods

Effects of the various tillage operations as given in Table 1, were studied from plots of 25- x 9-m dimensions, using a randomized complete block design with three replications. The wheat cultivars grown were Whydah (tolerant to soil acidity) during the 1984/85 and 1985/86 seasons and Hornbill (less tolerant to soil acidity) during the 1986/87 season. The experimental site was located in the Katito Wheat Scheme, Mbala, Zambia, situated approximately 9° 12'S and 31° 22'E. The rainfall distribution during the three seasons is given in Table 2.

Soil of the experimental area named as Katito Series is classified as clayey Kaolinitic isothermic family of the Rhodic Haplustox (24). It had sandy clay texture in the 0- to 27-cm depth and clay texture in the deeper layers. Its pH ($CaCl_2$) varied from 4.1 to 4.4 with base saturation of 15.6% in the 0-to 8-cm depth and between 4.0 and 7.0% in the deeper layers. The land after clearing in May/June 1978 has been used for growing wheat except for the 1981/82 (maize) and 1982/83 (fallow) seasons. Liming was done @ 2.0, 0.5 and 0.5 t/ha, respectively, at the beginning of the 1979, 1981 and 1982 rainy seasons. Lime was incorporated by discing of the top 10-12 cm soil.

Various tillage treatments (Table 1) were first imposed during the 1984/85 season on the soil undisturbed after harvest of the previous crop. Table 3 shows dates of significant operations undertaken during the three seasons. Seeding was done with Zero Tillage Drill in the T1, T2 and T3 treatments and with the Hoe Drill in rest of the treatments. Seed rate was 90 kg/ha and basal fertilizer dressing was 18:54:36:30:03 kg/ha of N:P:K:S:B. Rates of top dressing given 4 weeks after planting are shown in Table 3. Plant height (PH) was recorded at physiological maturity. At harvest, a 10- x 1.25-m strip was cut through the middle of the each plot using a Hege 125B combine. Grain yield and thousand grain weight (TGW) were recorded.

Soil bulk density (Db) towards the end of the third season (April 1987) was determined for the 0-5, 5-10, 10-15, 15-20, 20-25, 25-30 and 30-40 cm soil layers. Steel cores of 100 cc in volume (approx. 5 cm in diameter and 5 cm in height) were used to collect samples from sides of the soil pits. One pit was dug in each plot and for each soil layer a composite sample of 2 cores/pit was used to determine the soil Db.

Statistical analysis of the crop data was done considering seasons and tillage treatments as the two factors. Similarly the Db data were analyzed, considering the tillage treatments and soil depth as the two factors. As no tillage operation had its working depth deeper than 25 cm, only the 0-25 cm soil Db data was used for statistical analysis. The LSD values at 0.05 probability were used for mean separation.

Results and Discussion

Wheat performance--The effect of year was highly significant as values of all the crop variables declined with time. Probably a severe rainstorm at the time of grain filling in the 1985/86 season (Table 2) which caused intensive lodging, replacement of Whydah cultivar by Hornbill for the 1986/87 season and the reduced rate of top dressing (Table 3) was responsible for the

The lowest mean Db values from the T_1, T_2 and T_5 treatments were significantly lower than both the T_3 and T_7 treatments. The layerwise data also showed that Db values of the T_3 and T_7 treatments were always on the higher side of the range, for a given layer. In general, whenever crop residue was either removed (T_7) or incorporated into the soil (T_3), compaction of the soil occurred.

Mean Db under zero-tillage (T_1) treatment was not significantly different from either two deep tillage (T_4 and T_5) or the two shallow tillage (T_2 and T_6) treatments, but it was significantly lower than the conventional (T_3) and straw-removed (T_7) treatments. Actually, the surface 10 cm soil had lowest Db values under zero tillage treatment which indicated that maintenance of crop residue on top of the soil surface was able to avoid any compaction as a result of raindrops.

Deep tillage treatments (T_4 and T_5) did not significantly reduce the Db in relation to shallow tillage treatments (T_2 and T_6).

The occurrence of highest Db in the 5- to 15-cm soil layer was probably due to soil texture change from coarser to finer as a function of soil depth (5) and compaction of the soil layers most often disturbed as a result of repeated tillage operations.

Conclusions

In general, the tillage treatments which had higher soil Db gave lower grain yields. The negative effect of increase in soil Db on crop performance was probably due to reduced infiltration of rain water into the soil and increased soil resistance to the growth of plant roots. Both phenomena can cause reduced water and nutrient availability and, consequently, low crop yield. Earlier, increased Db and soil pulverization of a sandy clay soil as a result of severity of the tillage were considered to be the factors that contributed to high amounts of runoff and soil loss (2).

Our results showed that the presence of crop residue on top of the soil played a major role in crop production. As the rainfall data in Table 2 shows, rainfall during the months of April and May was unable to meet the crop water requirements. During these months, probably the crop residue on top of the soil surface improved the water availability to the crop through greater infiltration of rainwater and reduced evaporation of soil water.

From a review of previous results, it was illustrated that minimum or reduced tillage systems which maintain crop residue on the soil surface, usually result in crop yields equal to or higher than those attained with conventional or clean tillage systems through improved soil and water conservation (22). Earlier, increased soil water contents and crop yields with zero tillage were observed in years when rainfall was limited (12, 14, 17, 20, 25), and yields equal to or higher than those with other tillage methods when precipitation was adequate (7, 17). However, our results were at variance with some of the previous work (6), where increased crop yield resulted from loosening of a compacted soil through tillage. Previously yield reduction with minimum or reduced tillage was reported to occur at some locations (2) which decline in crop performance during the successive seasons. Only grain yield was significantly influenced by the tillage treatments whereas both the plant height and TGW were not (Table 3). During the 1984/85 season the highest grain yield under zero tillage treatments was closely followed by deep chiseling and minimum tillage, all of which were significantly higher than the T_3, T_6 and T_7 treatments. Results for the 1985/86 season were statistically non-significant. Lodging as a result of a severe rain storm during the grain filling period wiped out some of the possible treatment differences. However, deep chiseling which gave the highest grain yield seemed to perform better than the other treatments, which might have been a result of deeper root development and consequent reduced lodging in this case. For the 1986/87 season, the grain yield results were again statistically significant; however, only the lowest yield obtained from the conventional tillage was statistically different from the highest yield obtained under zero tillage. Grain yields of the remaining treatments were not significantly different either the conventional (lowest) or the zero (highest) tillage treatments.

Grain yield averaged over the three seasons showed significant differences due to tillage. The highest mean yield under the zero tillage treatment was closely followed by deep chiseling. Both of these treatments had significantly greater grain yield than the conventional, late and straw-removed treatments. It seems the mean grain yield was highly related to the amount of crop residue retained on top of the soil surface. The zero tillage treatment, where all the crop residue stayed on the top of the soil surface, gave the highest grain yield. In the case of the second highest yielder (T_5), both of its tillage operations (chiseling and cultivation) leave most of the crop residue on top of the soil surface. Therefore, it seems the beneficial effect of deep chiseling (T_5) treatment resulted from the combination of deeper loosening of the soil and the maintenance of crop residue at the soil surface. In the case of the deep ploughing and minimum tillage treatments, which were the next highest in terms of grain yield, November operations would have caused only partial mixing of the previous crop residue. Thus, part of the crop residue remaining on the soil surface might have benefited the crop. The treatments in the lowest group of grain yields, viz. conventional, late and straw-removed, were all devoid of any residue on top of the soil surface, although due to different reasons. In the conventional and late treatments, crop residue was mixed into the soil whereas it was taken away in the straw removed treatment.

Non-significant influence of the tillage treatments on the TGW and plant height indicated that neither of them was a factor in causing differences in wheat yield as a result of different tillage treatments.

Overall, lower wheat yield in all the treatments was probably due to the unfavorable temperatures which inhibited tillering, the water stress as rainfall during the later part of the growing period (April onward) was not enough to fully meet the crop water needs (Table 2), and the soil acidity as soil of the experimental site with inherent low pH was last limed in October, 1982.

Soil bulk density (Db)--The highest mean Db shown by the T_7 treatment was statistically higher than all the other treatments except the T_3 (Table 4).

were usually associated with a particular problem at the given location, viz compaction (6).

Higher grain yields as a result of deep chiseling were probably also due to the maintenance of crop residue on the surface of the soil. Deep chiseling has been reported to incorporate only 25% of the residue as compared to 90% and 50% incorporation by the disc ploughing and disc harrowing respectively (1).

Lower crop yields under conventional (T3) tillage seem to be a combined result of higher Db and lower soil water availability to the crop. Earlier reports indicated that clean tillage resulted in a general decline in soil organic matter content (9, 10, 23) which decreased aggregate stability (8; 13, 18) and caused a general decline of other soil physical conditions viz Db, infiltrability, permeability, water retention, compaction and porosity (8, 21, 26). In clean tilled soils, in addition to the soil compaction associated with decreased organic matter content, compaction also resulted from raindrop impact and soil dispersion (11) and from traffic on the soil surface (16).

Finally, it can be concluded that for the type of soil used for this investigation, maintenance of crop residue on top of the soil is crucial to avoid soil compaction and to achieve optimum crop yield. If weeds are not a problem or are controlled, no tillage is needed for crop production.

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Résumé

L'effet de sept traitements comprenant l'absence de labour, le labour minimum, le labour conventionnel, le labour profond, le hersage profond, le travail tardif du sol et l'exportation des pailles a été étudié durant trois saisons sur le rendement en grains, le poids de 1000 grains et la hauteur des plants du blé pluvial, ainsi que sur la densité apparente du sol. Le sol du site étudié était argileux et kaolinitique (Rhodic Haplustox). Parmi les paramètres agronomiques, seul le rendement en grains fut significativement influencé par les méthodes de labour. Lorsque les résidus de culture ne furent pas maintenus à la surface du sol, un compactage du sol fut observé, ainsi qu'une chute de production en grains. Le rendement maximal en grains, ainsi qu'un minimum de densité apparente du sol, furent observés en l'absence de labour. En général, les traitements avec une haute densité apparente du sol ont accusé un rendement en grains trop bas. La présence des résidus de culture sur la surface du sol fut déterminante pour empêcher le compactage du sol et permettre un rendement en grains plus élevé.

Table 1. Various tillage treatments and their timing in different treatments

Treatments	Tillage operations and their Timing[a]
T_1 (Zero)	No Tillage
T_2 (Minimum)	Disk harrowing
T_3 (Conventional)	Disk Harrowing - Nov + Cultivation Dec and Jan
T_4 (Deep ploughing)	Disk plowing - Nov + Cultivation - Jan
T_5 (Deep chiseling)	Chiseling - Nov + Cultivation - Jan
T_6 (Late)	Disk harrowing - Jan + Cultivation - Jan
T_7 (Straw removed)	1984/85 Season - Same as T6 1985/86 and 1986/87 Seasons - straw of previous crop removed at harvest + no tillage

[a] Approximate working depths where 10-12cm for the disk harrowing and cultivation and 20-25cm for the deep plowing and chiseling

Table 2. Rainfall distribution during the three seasons

Cropping Season	Rainfall(mm) for the months of Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Total
1984/85	25	87	190	207	155	168	87	4	928
1985/86	10	160	160	265	185	312	55	25	1272
1986/87	78	102	311	236	130	314	182	11	1364

Table 3. Important operations during the three seasons

Operations	Season 1984/85	1985/86	1986/87
Planting	17.01.85	14.01.86	22.10.87
Harvesting	22.05.85	28.05.86	21.15.87
Top Dressing N kg/ha	115	92	69
4 weeks after planting			
Weed control			
Roundup T1 & T2 & T7 in 1985/86	27.12.84 4dm3/ha	31.12.85 4dm3/ha	
Hoegrass (All Trt)	2.5dm3/ha 2-3 leaf		
Stomp (All Trt)		15.01.86 4dm3/ha	23.01.87 3dm3/ha

Table 4. Bulk density of the various soil layers as influenced by the tillage treatments

Tillage Treat.	Bulk Density (kg/m^3) of the soil layers in cm 0-5	5-10	10-15	15-20	20-25	Mean 0-25
T_1	1278 a	1475 a	1468 ab	1434 b	1423 bc	1416 a
T_2	1314 ab	1486 ab	1445 a	1425 a	1412 ab	1416 a
T_3	1343 bc	1510 ab	1451 ab	1460 b	1470 c	1447 bc
T_4	1298 ab	1487 ab	1500 b	1433 a	1406 ab	1425 ab
T_5	1282 a	1510 ab	1466 ab	1458 b	1369 a	1417 a
T_6	1334 bc	1488 ab	1456 ab	1474 a	1408 ab	1432 ab
T_7	1375 c	1528 b	1482 ab	1478 a	1338 bc	1460 c
Mean	1318	1498	1467	1451	1418	1430

ANOVA

Source	df	MS	LSD (kg/m^3)
Tillage (T)	6	4380^{xx}	22.9
Depth (D)	4	100780^{xx}	19.4
T x D	24	1414	15.2
Error	68	983	

POSSIBILITIES FOR GROWING WHEAT IN RELATION TO AGROECOLOGICAL CONDITIONS

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Abstract

In Madagascar, bread consumption increases every year but wheat production is not enough to meet the needs of the Malagasy population. Therefore, there is a need to increase the wheat production. The Vakinankaratra region remains the best wheat growing area but the wheat crop can be extended to other areas of Madagascar where the agro-ecological conditions are favorable. These areas are: the Malagasy high Plateau, the Alaotra region and some alluvial area in the south-western part of Madagascar.

Introduction

Wheat production in Madagascar is insufficient to meet the needs of the population. Madagascar had to import 33,000 tons of wheat in 1985 to meet the capacity of the flour mill. It is able to receive 60,000 tons of wheat per year and is built in the Andranomanelatra Antsirabe region (Table 1) (2). To avoid wheat importation, we need to produce more wheat by developing this crop in other areas than Vakinankaratra because the latter is not able to provide the wheat tonnage needed for the existing mill. However wheat can be grown only in those regions where the climatic conditions are favorable.

Ecological Wheat Requirements

Temperature

Emergence to flowering stage

1. Mean minimum temperature: 5-18oC
2. Mean maximum temperature: less than 30oC
3. Temperatures up to 30oC affect germination rates and may result in low yields.
4. Mean temperature flowering stage requirements: 16oC.

Ripening stage

1. Mean temperature dough grain stage: 13-25oC.
2. Heat in the presence of high humidity may promote fungal diseases.

Rainfall

1. The minimum requirement is 600 mm and a good distribution is needed.
2. 150 mm during each of the first 3 months.
3. 100 mm at least during the fourth month.

Irrigation is required when the amount of rainfall is less than 500 mm. Excess rain at the flowering stage results in poor filling of the grains. The wheat water requirement depends on the vegetative stage and the evapotranspiration intensity (Table 2) (3).

Light

The daily light requirement during the first month is 11 hours. It is needed to promote a sufficiently long vegetative phase to achieve high yields.

Progress Report on the Possibility of Wheat Culture in Relation to Ecological Wheat Requirements

Regions favorable to wheat culture can be chosen based on altitude and latitude. The best wheat growing area in Madagascar is located at altitudes higher than 1000 m but wheat can also grow well in lower areas if irrigation is available and temperatures are not too extreme.

In East Africa, wheat is largely grown in highland areas and under irrigation at some lower altitudes.

Berge and Collin (1) give the altitudes and latitudes of some stations chosen for wheat growing (Figure 1). It appears from Figure 1 that the stations chosen are located above 2000 m and at larger latitudes than 10°. However, wheat is found near the equator at high altitudes and, in tropical regions, it is found at both high and low altitudes.

Based on the results of this study, Madagascar, which is located between 12° and 25°S including various areas with altitudes of 0 to 1800 m, should have good potential for wheat production. Many new wheat lines distributed by CIMMYT for the intertropical region have been tested.

Promising Sites for Wheat Production in Madagascar

Soil fertility can be improved by good fertilization to meet the requirements of wheat. Climate factors will be the major criteria for choosing wheat growing areas in Madagascar.

Some climatic data of certain Malagasy regions are given in the Table 3. The following general temperature requirements hold for wheat at emergence to flowering stage:

1) Mean minimum temperature: 5-18°C.
2) Mean maximum temperature: less than 30°C.
3) Flowering to ripening stage--mean temperature: 13-25°C.

Based on the above requirements the following three regions were identified:

The Tulear region: Should be able to produce wheat from May to September. However, irrigation is required to meet the water needs because of insufficient rainfall.

The Morondava region: Shows the required characteristics and from May to August will additional irrigation wheat can be grown.

The Alaotra region and some areas in the Malagasy High Plateau: Especially in Fianarantsoa, Ambositra and some places near Antananarivo seem suited to grow wheat: Namely from January to May during the rainy season in the upland areas and from May to September during the dry season on rice fields after the rice harvest.

Earlier variety tests in some of these sites in the High Plateau region and in Tulear region showed good results (Table 4) (5).

Conclusions

The Vakinankaratra region remains the best wheat growing area. But additional suitable ecological environments exist in Madagascar. Some experiments conducted in these sites indicate this. However, prior to extension of wheat production to others areas than Vakinankaratra preliminary study on agro-economic constraints is required.

The agro-technical aspects especially the integration of this crop within the cropping system usually followed by the farmers in these regions has to be studied. Also to each peasant family or group of families a small hand craft mill which will allow them to mill wheat must be made available. Most villages do not have rice mills, and traditional mortar are used for grounding rice.

If wheat cultivation is to be expended into regions outside Vakinankaratra it is of utmost importance that the peasant are taught how to utilize wheat.

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Résumé

La production de blé à Madagascar n'a jamais atteint un volume considérable, alors que la consommation de farine augmente dans des proportions considérables. De telle situation ne peut être remédiée que par le développement de la culture du blé à Madagascar. La région du Vakinankaratra a été toujours considérée comme celle la plus favorable à la culture du blé, mais il existe des régions en dehors du Vakinankaratra susceptibles de répondre aux exigences écologiques du blé. Ceux sont les zones des Hauts Plateaux et de moyenne altitude et les zones alluvionnaires du Sud-Ouest. Les expérimentations ponctuelles réalisées en certaines de ces zones montrent que la culture de blé est possible.

Table 1. Local production and wheat importation, 1983 to 1985 (2)

	1983	1984	1985
Wheat importation ('000 tons)	30	35	33
Local production ('000 tons)	150	484	2860
Local production collected by KOBAMA ('000 tons)	50	421	850

Table 2. Wheat cultural coefficient value (K) (3)

Growth stage	Cultural coefficient (K)	Remarks
Emergence - tillering stage	0.5	
Tillering - booting stage	0.5	ETP <3 mm per day
	0.6	ETP >3 mm per day
Booting - panicle initiation	0.8	ETP <5 mm per day
	1.0	ETP >5 mm per day
Panicle initiation - flowering stage	1.0	
Flowering - grain formation	1.0	
Grain formation - milk grain	0.8	

Table 3. Climatic data in some regions of Malagasy (4)

Data	Altitude (m)	Latitude	J	F	M	A	M	J	J	A	S	O	N	D
Tulear	8	23° 33'S												
Mn			22°4	22°4	21°4	19°	15°8	15°9	13°	13°5	15°2	17°4	19°8	21°5
Mx			32°3	32°5	31°9	30°8	28°5	26°6	26°3	27°2	28°6	29°	30°3	31°4
M			27°3	27°4	26°6	27°9	22°2	20°2	19°9	20°3	21°9	23°2	25°	26°2
P			70	71	42	7	18	11	4	3	10	14	74	57
H			79	69	72.3	72	70	69	69	63	58	70.6	70	70.6
Morondava	8	20° 17'S												
Mn			23°7	23°5	23°1	20°9	17°4	14°9	14°5	15°5	18°	20°5	22°6	23°4
Mx			31°8	31°2	31°8	31°5	28°3	27°8	25°7	27°7	28°6	29°5	30°5	31°6
M			27°7	27°6	27°4	28°2	23°3	21°3	21°	21°6	23°3	25°	26°7	27°5
P			228	209	117	13	7	6	1	2	7	3	17	129
H			813	105	80.1	78.6	76.8	76	74.9	75.4	77.4	76.8	77.1	80
Alactra	767	17° 48'S												
Mn			18°3	18°	17°8	16°2	13°7	11°7	11°	11°1	11°3	13°3	15°6	17°2
Mx			28°5	28°3	28°	27°3	25°5	23°6	22°6	23°3	24°9	27°4	29°	29°1
M			23°4	23°1	22°7	21°7	19°6	17°6	18°3	17°2	18°4	20°3	22°3	23°1
P			307	267	206	36	10	8	10	7	3	20	92	211
H			74	74	76	73	71	72	71	68	64	62	64	68
Antananarivo	1381	18° 55'S												
Mn			15°8	15°4	15°6	13°8	11°6	10°1	9°1	8°9	10°	11°9	14°	15°6
Mx			25°2	26°	25°2	24°4	22°5	20°5	20°	20°4	22°3	25°6	26°6	26°2
M			20°5	20°7	20°4	19°1	17°1	15°3	14°6	14°7	16°4	18°8	20°3	20°9
P			305	235	221	47	16	9	9	9	14	49	154	292
H			82	82	83	81	77	79	79	78	73	69	71	78
Fianarantsoe	1106	21° 27'S												
Mn			16°	8°	16°3	14°7	12°	10°3	9°5	9°5	10°5	12°7	14°5	16°
Mx			26°	25°7	29°3	24°6	22°3	20°1	19°4	20°7	22°4	25°6	26°9	26°4
M			21°4	21°	20°8	19°7	17°2	15°2	14°5	15°1	16°5	19°2	20°8	21°2
P			291	206	172	44	27	20	19	17	24	34	131	237
H			83	86	84	83	82	82	88	82	80	76	77	81
Ambositra	1245	20° 32'S												
Mn			15°9	15°4	15°4	13°9	11°1	9°7	8°7	8°5	9°6	11°7	13°9	15°2
Mx			25°5	25°4	25°	24°3	22°	19°9	19°	20°	22°1	25°1	26°2	25°3
M			20°7	20°4	20°2	19°1	16°6	14°8	15°9	14°3	15°9	18°4	20°1	20°5
P			314	239	242	219	32	26	26	20	35	57	183	303
H			78	78	80	77	76	77	76	73	69	66	70	75

Mn = Mean minimum temperature
Mx = Mean maximum temperature
M = Mean temperature
P = Rainfall in mm
H = Relative humidity

Table 4. Yields (kg/ha) of varietal performance trials (5)

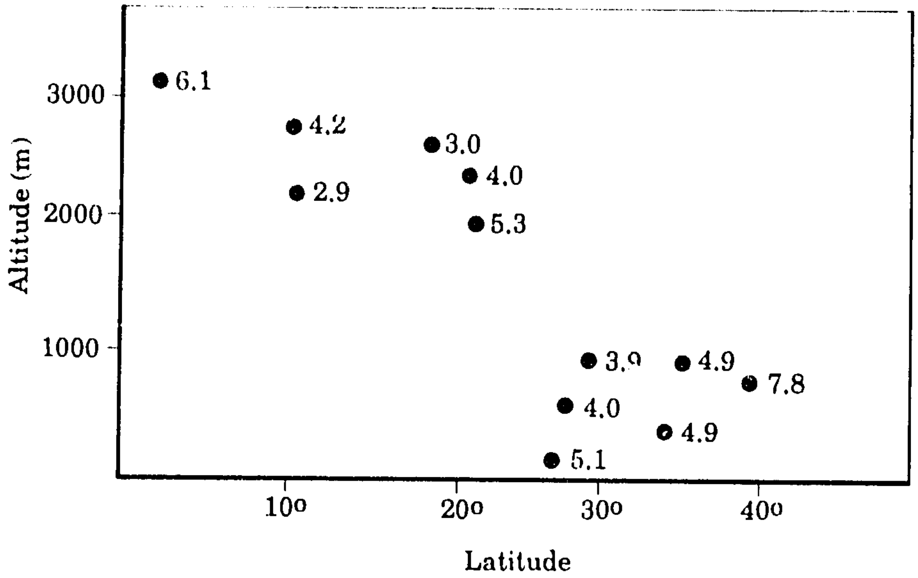
Varieties	Sites: Alaotra	Betafo	Monokely	Ambato lampy	Ambchi trakoho	Antsi-rabe	Manjak andriana	Fiana rantsoa	Bezaha Tulear
FIFA 2	2720	3125	2490	2142	1845	2000	782	1312	1650
FIFA 20 (a)	3127	2687	1535	1985	1620	1562	375	657	1330
FIFA 23...........	4250	3125	1877	2422	1730	1907	580	907	1250
FIFA 44 (b)	1907	3725	1622	2390	2240	1815	687	657	1150
AFRICA MAYO (c)	3407	3750	2147	1140	2135	1375	945	782	1210
LERMA ROJO (d)	2890	2137	2647	1485	1600	1532	1000	750	1240
PITIC 62..........	3782	3312	2140	2282	2055	2000	1095	812	1280
NAINARI (e)	4125	4062	2590	1360	2200	1612	830	815	1140
TOBARI 66 (f)	2375	2187	1597	2140	2070	1312	595	657	1100
SONORA 64 (g)	3250	3125	1990	1032	1835	1345	437	690	1060
TAICHUNG (h)	2940	2187	2435	1577	1802	2032	625	695	1050
763	3000	1812	1837	1890	1747	1595	595	532	1500
IBWSN-14 -83 (i)	3032	2812	2897	2467	1930	1720	1375	782	1050
IBWSN-14 -86 (j)	3782	3437	2560	2095	1702	1970	1532	750	1100
IBWSN-14 -95 (k)	3687	3125	1602	1047	1665	1812	345	720	1080
IBWSN-14 -108.....	3545	3000	2560	2672	1895	2312	1595	845	1350
IBWSN-14 -112.....	3032	3437	2102	2607	1607	1750	625	845	1150
IBWSN-14 -114.....	3562	3125	3757	2080	1985	2095	1062	970	1200
IBWSN-14 -120 (l)	3512	3312	3377	1515	1565	1782	875	687	1060
ROMANY............	2470	2812	3065	1202	1842	1437	1375	877	---[a]

[a] Not tested

In TULEAR: a = FIFA 3, b = FIFA 7, c = FIFA 49, d = IBWSN 14-88, e = IBWSN 14-58, f = IBWSN 14-21, g = IBWSN 14-59, h = KENYA LEOPARD, i = FIFA 86, j = FIFA 48, k = FIFA 44, l = IBWSN 92.

FIFA: Fifimanor Breeding Program

Figure 1. Yields (t/ha) at some stations chosen for growing wheat according to their altitude and latitude (1).



AN APPRAISAL OF WEED CONTROL METHODS IN WHEAT IN UGANDA

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(Presented by Gard Turyamureeba)

Abstract

The paper outlines the scope of wheat production in Uganda. The methods of cultivation, types of weeds and their control have been reviewed. In view of the importance the Government of Uganda is attaching to wheat, the paper proposes a number of research areas which could be exploited in order to reduce weed control problems and increase wheat production. The paper concludes by emphasizing the need for dissemination of both technical and advisory knowledge to farmers if increased production is to be achieved.

Introduction

Wheat production in Uganda is carried out both on mechanized large-scale and small-scale farms. In the former, wheat occupies a total of about 10,000 ha most of which is found in Kapchorwa District. Reported yields range from 2 to 3 t/ha. In the small-scale production areas, found in the highlands of Western Uganda and in Mbale District in the East, wheat is grown mainly for local consumption. On average, each farmer may have 0.25 ha of wheat yielding about 0.5 t/ha. in both production systems, heavy infestation of weeds have been observed, contributing to the low yields reported for this country.

The use of herbicides has been limited to the large-scale farms. On the small-scale farms, herbicide use is unknown and the peasants resort to hand weeding if they weed at all.

The Major Weed Species

Table 1 gives the most common weeds that have been observed in Ugandan wheat fields.

The occurrence of these weeds varies. In the non-mechanized field, both the broadleaf and grass weeds occur. In the mechanized ones, the most problematic species are the grasses. This shift has been caused by herbicide application which has controlled or eradicated the broadleaf species. In some cases, perhaps due to improper herbicide application, broadleaf weeds have been observed in the mechanized fields.

Present Control Methods

Small-scale farming--Land preparation is by hand hoeing, which normally results in poor seed bed preparation. In most cases, the weeds are not controlled as the hoeing is limited to an average of about 10 cm. in depth. Sowing is by broadcasting which can result in variable seed rates. Since the main method of weeding is pulling by hand, movement within the field is rather difficult and may result in mechanical damage to the crop. Low seed rates may create favorable conditions for weed growth and weeding becomes more tedious.

Depending on the intensity of weed infestation, weeding may be done as early as at tillering or as late as at grain filling. These farmers usually give priority to weeding other more traditional crops such as beans, sorghum and millet. Also, labour on small scale fields is mainly provided by the farmer's family as they cannot afford to hire labor. Consequently, the area that can be weeded is influenced by family size.

In some cases, late seeding is practiced in the hope that weed infestation will be lower due to drier weather conditions. However, the crop may suffer drought stress and as a result reduced yields will occur.

The use of herbicides by small-scale farmers is rare as in most cases they lack knowledge of herbicide utility, also the high costs involved are prohibitive.

Large-scale farming--On large-scale farms, most operations are mechanized. Cultivation methods (i.e., moldboard, disc ploughing and harrowing are applied). A drill may be used for seeding or in a few cases the seed is broadcast and covered by disc harrowing. These operations, where timely, ensure better weed control. But due to the high cost of maintenance tractor numbers have been greatly reduced, leading to some farmers receiving tractor service late if at all. The tractor operations like many other farm provisions in Kapchorwa are handled by Sebei-Elgon Co-operative Union. This Union, like many others in the country is struggling with the problem of obtaining foreign exchange for the purchase of spare parts, herbicides and seed. This has understandably influenced the timing of farm operations. In general, it has led to a reductions in tillage, resulting in increased weed infestation.

Where before, they had used herbicides like 2,4-D at 0.7 l/ha (chemical company recommendation) they were having only a problem of broadleaf weeds. Now where they have resorted to reduced tillage, they are experiencing an infestation of both grass and broadleaf weeds.

Research on Weed Control in Wheat

The Uganda Government is now putting emphasis on increasing production of "non-traditional cash crops", among which wheat is one. Accordingly, efforts are being made to solve some of the production problems such as those discussed above. For instance, many tractors are now being imported. Given such technological components, their applicability in the current cropping systems has to be established.

Secondly, a look at how to control weeds by rotations needs to be given due consideration. This is especially the case with small-scale farmers whose cropping systems could be improved in this context. For example the most common practice is: fallow-wheat-maize (+ beans)/millet-fallow-wheat.

Here, if another appropriate crop could be raised just before wheat, it is likely that weed infestation in the wheat would not be as high.

Conclusions

That weeds are a contributory factor to low yields is evident. It is also clear that the current weed control methods are not being exploited fully due to lack of the technological components and insufficient education of the farmers.

And now, given that the Government is taking an active role to boost wheat production, investigations using the "available inputs" need to be carried out. This should be accompanied by intensive dissemination of the weed control package if the farmers are to realize the benefits.

Résumé

L'auteur donne un aperçu général sur la production du blé en Ouganda: les méthodes de culture, les types d'adventices et les méthodes de lutte contre celles-ci. En raison de l'importance que le gouvernement ougandais attache à la production du blé, il est proposé un certain nombre de domaines de recherche pour permettre un meilleur contrôle des adventices et accroître la production. L'auteur conclue sur la nécessité de diffuser les connaissances techniques et les recommandations auprès des agriculteurs si l'on vise l'augmentation de la production.

Table 1. Weed species of wheat in Uganda

Grass Weeds	Broadleaf Weeds
Eleusine indica	*Galinsoga parviflora*
Digitaria scalarum	*Bidens pilosa*
Cynodon dactylon	*Achyranthes aspera*
Pennisetum clandestinum	*Amaranthus* spp.

CONTROL OF STEM AND LEAF RUSTS OF WHEAT

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Abstract

In spite of the concern about failures of specific resistances against wheat leaf and stem rust, a large number of resistant cultivars exist. As wheat production is increased in the subtropical and tropical areas, additional efforts will have to be expended on control of these diseases due to the effect of the environment on disease development. The durable resistance provided by Sr2 and Lr13 and 34 may be inadequate in these areas. New sources of resistance may be required and this may require new techniques for the evaluation of progenies. Additionally, it will be necessary to use cultural control practices to reduce the amount of disease that survives on volunteer plants between wheat growing seasons.

Introduction

The cereal rusts have been a major factor in reducing wheat yields on a worldwide basis (12, 16, 17). Losses due to stem rust are generally more severe in areas where wheat heads during the summer (rather than the spring). Leaf rust is often more severe where wheat grows during the winter (not in a dormant stage). Over the past 100 years it has been necessary to control the rust diseases in order to maintain a uniform quantity of high quality wheat. In some areas wheat can not be grown without rust control. In arid areas rust is only occasionally a problem, but even there devastating epidemics can occur. It would appear that the rusts will continue to be a major problem well into the 21st century. In fact, as wheat production is expanded into the subtropics and tropics the necessity of rust control increases. In the more traditional wheat growing areas a series of combinations of resistant genes currently use should provide for at least short-term disease control. There are essentially three ways used to control the rusts diseases of wheat, the use of fungicides, selection of cultural practises and the use of resistant cultivars.

Disease Control

Control with fungicides--Chemical control is often the most advertised. It has been effectively used in areas of high production with subsidized production costs. Chemical control shifts the cost and control decisions to the producer, often relieving the government of responsibility of disease control. The cost of developing fungicides is advanced by the chemical company which recovers it from the users. The advantages of disease control by fungicides are: the costs are borne by the producer, it is available when needed and it is often effective against the entire pathogen population over many years.

Disadvantages of chemical control are: the high cost to farmers who often lack means to pay the cost, and potentially disastrous environmental effects which often cannot be determined until after years of use. Economic and environmental sound use of fungicides requires a system for predicting the annual disease hazard so the fungicide is applied only when needed. Because of the need to monitor disease development and make quick decisions and responses chemical control has been most effective used by educated farmers. Periodic usage of fungicides creates a need to stockpile the chemical. In some years chemical usage and sales be a limited where as in other years all the farmers will need the fungicides and the equipment for application within a few days. Fungi have been able to develop resistance to some chemicals, thus a continual effort to develop new chemicals is required. Fungicides are most effective when used in conjunction with other control methods.

Cultural control practices--Cultural methods are often overlooked in the control of rust diseases. The barberry eradication programs of northern Europe and North America successfully reduced the frequency of stem rust epidemics. The eradication also delayed the annual diseases onset and number of pathogens types to the point where resistance can protect the crop in most years (7, 10). However, the importance of removing volunteer wheat plants to reduce the amount inoculum between seasons and to delay the establishment of epidemics is poorly documented (11, 13, 19).

Inoculum to generate epidemics must originate inside the area (endogenous) under consideration or outside the area (exogenous). It is commonly thought that in tropical and subtropical areas the inoculum source exogenous in origin. The misconception probably relates to the large amount of literature from North America, where wheat is spring planted at 40 to 50^{o} N latitude. In this area historically wheat is planted in the spring and harvested in the fall and winters are severe enough to eliminate volunteer plants and uredospores.

The distinction between inoculum sources is important for at least two reasons. Endogenous inoculum is generally produced on volunteer wheat whose resistance is similar to that of the crop to be seeded the following year. Thus, endogenous inoculum is most often virulent on the seeded crop. Additionally, endogenous inoculum is present at seeding time and can result in the early establishment of rust in the seeded crop providing the possibility for an early disease onset. Endogenous inoculum generally is characterized by the oldest infections being low in the canopy. Foci are common in a field and horizontal spread is about equal to vertical spread until uredia appear at the top of the canopy. Once the disease reaches the top of the canopy inoculum rapidly spreads both horizontally across the field and vertically where winds carry the spores to upwind fields.

Characteristically exogenous inoculum results in primary infections that are at a standard plant height and random in distribution. These infections generally occur on the portion or the plant which was at the top of the canopy when the inoculum was deposited by the scrubbing action of rain water passing through spore laden air. Secondary infections tend to be higher in the canopy. However, by the time the uredia resulting from the secondary infections sporulate they are usually within the canopy, due to plant growth. When exogenous inoculum results in the primary infection occurring on the flag leaf or when the disease spread reaches the flag leaf horizontal spread becomes very rapid.

Control by resistance--Resistance has and will continue to be the major means for control of the cereal rusts. Resistant cultivars have been developed, some of which proved to have durable resistance over a range of environments for many years (4, 13). However, many other cultivars were not as successful. The failures or disappointments have often been emphasized by both breeders and pathologists and have led plant pathologist to searches "new" and somehow magical resistance. This search for resistance led to a proliferation of terminology for resistance based on genetic, disease, epidemiological, pathogen and host characteristics. Each term describes a specific type of resistance and how it functioned. Unfortunately these "new" resistances were not adequately studied and many assumptions have been made. For example, it is often assumed that slow-rusting is due to a combination of several to many genes that individually have little effect. Although this may be true in some cases in others it is apparently due to a single gene (14, 15). It should be remembered that all race-specific genes do not result in a immune or hypersensitive response (1, 12), and that adult plant resistances is not necessarily race non-specific, e.g., *Lr22b* in Thatcher.

Breeding for Resistance

Perhaps the first stage in breeding for resistance is the careful observation of the proposed resistance. Why was a line selected as a resistant parent? Under what conditions was the resistance detected? Experiments or nurseries using the same or similar conditions are necessary to allow for detection of this particular resistance in progenies. It may be easier understand this if the mechanisms (components) of resistance, are examined instead of just disease severity and host response. Four components that can be measured are the number of lesions per unit area of leaf or stem (receptivity), size of sporulating area of the uredium, length of latent period (time from infection to sporulation) and duration of sporulation period per uredium. The genes for resistance that have been studied in detail may affect one or more of these components. *Sr2* reduces the number of lesions, but the reduction is not even through out the life of the plant nor on all plant tissues (5, 18). *Sr8a* reduces the size but not the number of lesions. *Sr36* lengthens the latent period and with most cultures also reduces the number of pustules (14, 15). Resistances that are expressed with chlorosis or necrosis (i.e., *Sr23*) often have shorter periods of sporulation per uredium. Early telia formation is another example of shorten sporulation period. Thus, knowing how the resistance is expressed should make it easier to design the proper test and to follow it though a breeding program. Breeding for resistance will not be made easier; in fact, more complex procedures may be required but the end result may be better. Resistance may have to be evaluated at different times or in different ways depending on the cross. An uniform test for resistance across all crosses may not be desirable or possible.

Gene-for-gene theory--The simple gene-for-gene model should be expanded to include the heterozygous pathogen and host genotypes. The expansion results in four, often distinct, low infection types from a single host-pathogen gene pair instead of one. With two pairs of host-pathogen genes interacting at least eight low infection types results. This variation in low infection type due to heterozygous host or pathogen genotypes causes the apparent loss or reduction in effectiveness of resistance when a heterozygous host genotype was evaluated or when a heterozygous culture is substituted for a homozygous culture. A range of phenotypes in the F_2 is an indication of a multigenic character. However, in a wheat-rust inter-organismal system a F_2 population with a single host-pathogen gene pair interacting at least five different infection types can occur. If the test was performed under field conditions additional phenotypes would be induced by the environmental influence with the host-pathogen interaction.

Interaction between genes and genomes--Wheats or wheat relatives with lower ploidy levels have often been considered potential sources of resistance to rust. Derivatives of some of these sources have been very useful, i.e., Thatcher and Hope to stem rust. However many attempts to use these sources have been disappointing. As the resistance is transferred into plants with higher ploidy the expression of the resistance decreases (3). This seems to be a "dilution" effect. Perhaps this can be overcome by transferring the resistance to another homologous pair of chromosomes so that four alleles of a resistant gene are present. The "dilution" effect is especially important for wheat leaf rust where broadly effective genes for resistance occur in only a few in hexaploid wheats and high levels of resistance exist in *Triticum monococcum* and *T. durum*. The resistance in the latter species apparently is effective and durable.

A suppressor gene for wheat stem rust resistance has recently been found on the 7D chromosome (3). Are there other suppressors? To what extent do they affect leaf rust resistance? Are they primarily on the D genome where they affect leaf rust resistance transferred from *T. durum* and *T. monococcum*?

Durable resistance--Durable resistance is that resistance that has been adequate against the disease for a number of years over a range of environments and pathogen cultures. It should not be assumed that it will always be adequate in the future nor should it be expected that it will be effective against all cultures. However, the use of resistance that has been effective over a range of environments and cultures and years is certainly more likely to lead to a resistant cultivar than is an untested resistance or resistances that have failed elsewhere. In the case of stem rust there are several known sources of durable resistance related to a "single" gene while for wheat leaf rust most durable resistance is associated with gene combinations.

Durable resistance to leaf rust is thought to be more difficult to obtain than with stem rust. However, success has been obtained occasionally by many breding programs and is the trademark of others. Leaf rust has a more diverse pathogen population for virulence than stem rust does. This diversity may result from the larger populations both between and within the wheat growing season and from the use of cultivars with only a single effective gene for resistance.

Sr2--This gene conditions an adult plant resistance (not effective until about the boot stage) and was derived from Yaroslav emmer by McFadden. It is generally available through the cultivars Hope and H-44 and their derivatives. This gene does not provide immunity and under high inoculum densities it often produces large susceptible lesions near the nodes the spike and awns (5,18). Cultivars with *Sr2* in combination with other genes have been grown on millions of hectares in North America without serious epidemics for nearly 30 years. In combination with other effective resistances *Sr2* is difficult to follow in progenies. The brown necrosis associated with *Sr2* has often been used to detect the presence of the gene for resistance.

Sr26--This resistance was derived from *Agropyron elongatum* and has given effective resistance worldwide. It has been widely used in Australia where it has been grown on a million hectares annually for over ten years (8). This gene is easy to follow using standard breeding techniques screening either seedling or adult plants for resistance.

Sr31--This gene was derived from Imperial rye. It is currently widely used in the world population. This gene is on the 1B/1R translocation which also carries *Yr9* and *Lr26*, and results in a sticky dough, a poor mixing characteristic.

Sr36--This gene, successfully used in much of the United States but has failed once in Australia (8). It reduces the number of lesions and increases the latent period (13, 14). This gene loses its effectiveness at or near maturity.

Thatcher--This resistance was derived from Iumillo durum by Hayes et al. (6). This resistance (2, 9) has been effective in the northern Great Plains since Thatcher was released in 1934. It was damaged in the 1953 and 1954 epidemics when grown in conjunction with more susceptible wheats.

Lr19--Leaf rust resistance provided by the single genes with the exception of *Lr19* are inadequate by themselves. The first cultivar with Lr19 has just been released so its durability is unproven. Unfortunately, Lr19 has usually been associated with a yellow flour color.

Lr13 **and** *34*--The resistance to leaf rust that is most durable is associated with *Lr13* and perhaps *Lr12*, both adult plant resistances, in combination with *Lr34*. The original source of these genes is unknown but *Lr13* and *34* were apparently present in Alfredo Chaves, a land cultivar found in Brazil about 1921. Americano 44D selected in 1918 from a land cultivar in Uruguay probably derives its resistance from *Lr12* and/or *Lr13* and *Lr34*. These two land cultivars which may be very similar, have been the main source of durable leaf rust resistance for the past 60 years. It is assumed that the land cultivars had a southern European origin but European cultivars with this level of resistance are unknown. Resistance conditioned by *Lr13* or *Lr12* is sometimes inadequate under conditions that are very favorable for the disease, in nurseries where inoculum levels are very high, in areas where wheat is grown at high temperatures, and in cultivars without other resistance genes.

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Résumé

Bien que les échecs en matière de résistance spécifique du blé à la rouille des tiges et à la rouille brune soient préoccupants, il existe un grand nombre de cultivars résistants. Comme la production du blé a augmenté dans les régions subtropicales et tropicales, il faudra consentir des efforts supplémentaires pour m..îtriser ces maladies, étant donné que leur développement est conditionné par l'environnement. La résistance durable provenant de Sr2, Lr 13 et Lr 34 pourrait être inadaptée à ces régions. Ainsi, de nouvelles sources de résistance seraient requises, ce qui nécessiterait de nouvelles techniques d'évaluation des descendances. En outre, il sera nécessaire de recourir à des pratiques culturales pour reduire le nombre de plants spontanés de blé sur lesquels les pathogènes survivent entre les saisons culturales.

A REVIEW OF CHEMICAL DISEASE CONTROL RESEARCH ON WHEAT IN ETHIOPIA

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Abstract

Wheat is an important rainfed crop in the highlands of Ethiopia. Though the three rust diseases and Septoria spp. are considered to be the major diseases, Helminthosporium spp., Fusarium spp., bacterial stripe, bunt and rots are also commonly found. In general around 31 fungal, 2 bacterial, and 4 nematode diseases have been identified on various wheat species of the country. In addition to the use of resistant cultivars, chemical control studies against a few diseases of wheat have been conducted. According to the different reports in the country, organomercury powder and thiram are found to be effective against wheat bunt; Benomyl against fusarium head blight; carbendazin, fentinacetate, captafol, Benomyl, Bayleton and Tilt against Septoria and Bayleton and Tilt against stem and stripe rust. Soil treatment trials and fungicide spray frequency and cost benefit analyses have also been conducted.

Wheat is an important rainfed crop in the highlands of Ethiopia. The crop grows in many ecological zones in the country at different altitudes and in different climatic and soil conditions. The land varieties of the crop are mostly mixtures and have undergone natural selection for years. This has enabled the indigenous lines to tolerate many adverse conditions. However, since improvement programmes on the crop have started, the balance has been disturbed and disease problems have increased (5).

About 31 fungal, two bacterial and four nematode diseases have been identified on various wheat species in the country (Table 1). Quite a number of studies have been made on stem, leaf and stripe rust physiologic race identification (6).

Of the disease types recorded in Ethiopia, the three rust diseases and *Septoria* spp. are considered to be the major diseases causing considerable yield losses. The others commonly found include *Helminthosporium* spp. *Fusarium* spp., bacterial stripe, bunt and root rots (7).

At present diseases are controlled by the use of resistant cultivars which are developed using different methods, such as hybridization, selection from indigenous germplasm collections and introductions (7). However, as an additional option to manage disease, chemical control studies have been conducted against a few wheat diseases at different research centers and organizations in the country.

Although it was reported that less than 10% of the yield losses in Chilalo area were caused by seed borne diseases (1), the earliest experiments in the chemical control studies against wheat diseases were seed dressing trials (5). In these trials among several fungicides under screening, dieldrex M, thiram, organo-mercury powder and benomyl were found to be effective against different diseases (Table 2).

Spray fungicidal screening has been also conducted against septoria leaf blotch and rust of wheat. Among many fungicides under test, benomyl, carbendazin, fentin acetate and captafol sprayed at heading, flowering and milk stages at recommended rates showed good controlling capacity of septoria leaf blotch (5). It was also determined that two times spraying of wheat with bayleton at a rate of 1 kg/ha and tilt at a rate of 0.75 kg/ha provided complete control of septoriosis and 80 - 90% control of stem and stripe rust. A different study in the same station, indicated that application of bayleton at a rate of 0.5 kg/ha showed better control of stem rust over the unsprayed check (6).

Similar spray fungicide screening trials using different sets of fungicides have been carried on by different research stations and organizations in the country (5). At Debre Zeit Agricultural Research center, five fungicides, namely, calaxin M (0.75 kg/ha), bayleton (0.5 kg/ha), plantavax (1 kg/ha), impact (4.5 lt/ha) and tilt (2.5 lt/ha) are under screening against stem and leaf rust. Application of fungicides has started from the first appearance of symptoms. Though the fungicides do not provide complete control of the diseases, there is an indication of significant yield differences among the fungicides and the unsprayed check (2).

Soil treatment against diseases has also been tried using quintozene in wheat at a rate of 30 kg/ha before sowing. However, the treatment was found to have no effect on the number of plants emerging or on yield (1).

Fungicide spray frequency and cost benefit analysis studies were made for benomyl (0.03%) and fentin acetate (0.1%) against septoria leaf blotch sprayed at heading, flowering and milk stage. A surplus of 240 to 290 dollars per hectare was estimated to be achieved by the sprays (3, 5). At CADU (Chilalo Agriculture Development Unit), three wheat varieties with different degrees of resistance to stem rust were treated 5 to 6 times with oxycarboxin and mebenil (considered to be specific fungicides). The yield loss of the untreated susceptible variety was found to be 38% below the yield of the susceptible treated variety. However, in spite of the good effect of the fungicides on the susceptible variety, 5 to 6 times treatment was not considered to be economic for stem rust control (1).

On the other hand, seedborne diseases were considered to be controlled easily and cheaply by seed dressing with suitable chemicals. Hence, investigational work has concentrated more on seed-dressing trials, irrespective of the significance of the losses caused by seed borne diseases (1).

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Résumé

Le blé est une importante culture pluviale sur les hauts plateaux de l'Ethiopie. Bien que les trois types de rouille et que la septoriose soient considérés comme les principales maladies, l'Helminthosporium spp, le Fusarium spp, la striure bactérienne, la carie et la pourriture des racines sont aussi observés couramment. D'une façon générale, environ 31 maladies fongiques, 2 maladies bactériennes et 4 nématodes affectant le blé ont été identifiés dans le pays. Outre l'utilisation de cultivars résistants, des études ont été realisées sur la lutte chimique contre les maladies du blé. Il ressort des différents rapports du pays que la poudre organomercurique et Thiram sont efficaces contre la carie du blé; le carbendazine, phentinacetate, captafol, le Benomyl, le Bayleton et le Tilt contre la septoriose, et le Bayleton et le Tilt contre la rouille des tiges et la rouille brune. Des essais de traitement du sol, de fréquence d'application de fongicides et d'analyse de rapport coût/bénéfice ont aussi été conduits.

Table 1. Wheat pathogens recorded in Ethiopia (5)

Pathogen		Disease
I. Fungi		
Alternaria longissima	Deighon et. McGarvie	--
Ascochyta graminicola	Sacc.	Leaf spot
Cladosporium graminum	Corda. ex.	--
Cochliobolus sativus	(Ito. & Kur.) Dreschsl.ex Dastur	Leaf spot
Coniothyrium fuckelli	Sacc.	--
Didymella spp.		
Dilophospora alopecuri	(Fr.) Fr	Twist diseases
Epicoccum purpurascens	Ehrenb. ex Schlecht	Blotched leaf
Erysiphe graminis f.sp. tritici	(em Marchal)	Powdery mildew
Fusarium culmorum	(W.G. Sm.) Sacc.	Root rot
Fusarium dimerum	Penzing	--
Fusarium graminearum	Schwabe	Crown rot
Fusarium longipes	Wollenw & Peink	Head blight
Fusarium semitectum	Berk & Pav.	Head blight
Gaeumannomyces graminis	(Sacc.) Arx & Oliv.	Take all
Helminthosporium spp.		--
Helminthosporium tritici -repentis	Died.	Tan spot
Hendersonia culmicola	Sacc. Var. minor Sacc.	--
Leptosphaeria avenaria	Waber f.sp. triticia Johnson	--
Phaeoseptoria sp.		
Phoma macrostoma Montagne		--
Phoma sorghina (sacc.)	Boer. Dorenb and Van Kest	--
Pseudocercosporella herpotrichoides	(Fron) Dei.	Eyespot
Puccinia striiformis	West	Stripe rust
Puccinia graminis f.sp. tritici	Eriks, & E. Henn	Stem rust
Puccinia recondita	Rob ex Desm.	Leaf rust
Septoria nodorum	Berk.	Glume blotch

Septoria tritici	Rob ex Desm.	Leaf blotch
Tilletia caries	(DC.) Tul.	Stinking smut
Tilletia foetida	(Mallr.) Liro	Stinking smut
Ustilago tritici	(Pers.) Rostr.	Loose smut
II. Bacteria		
Xanthomonas translucens	(L.R. Jones, A.G. Johnson, & peddy) Dows. F.sp. *Undulosa*	Bacterial blight
	(F.F. Sm., L.R. Hones & Peddy) Hagb.	--
Corynebacterium tritici	(Hutchinson) Burkholder	--
III. Nematodes		
Anguina tritici	(Sterin Buch)	Earcockle
Pratylenchus sp.		Root disease
Tylenchus sp.		Root disease
Tylenchorhynchus sp.		Root disease

Table 2. Fungicides found to be effective in seed dressing trials

Fungicide	Rate (gm/100 kg)	Disease	% Yield increase over the check	Reference
Dieldrex M	500	Seedborne diseases	88	3
Thiram	2	Bunt	15	1
Organic Mercury	200	Bunt	15	1
Benomyl	250	Fusarium head blight	germination and seed health improved	4

IMPORTANCE OF SELECTION, DISEASE-RESISTANT VARIETIES, AND IMPROVED CULTURAL PRACTICES IN WHEAT AND TRITICALE PRODUCTION IN RWANDA

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Abstract

Rapid resistance of wheat and triticale to diseases and insect pests is considered to be one of the major obstacles for the development of these two cereal grains in Rwanda. This makes it necessary to introduce, on a regular basis, new genetic materials for selection. Seed introduction for selection must be varied and systematic. Basic seed materials to be imported should be genetically selected for adaptation to the different agroclimatic zones of the wheat and triticale production areas.

High susceptibility of triticale to rust disease in the environmental conditions of the volcanic region constitute a major problem for increasing its production in Rwanda. Development of triticale varieties resistant to rust is considered necessary and urgent.

In brief, utilization of promising varieties for each agroclimatic region, utilization of improved cultural practices combining judicious use of manure and chemical fertilizers without doubt will increase national wheat and triticale production.

Introduction

Au Rwanda, la production nationale du blé (froment, triticale) se fixe autour de 3000 à 4000 t/ha. En 1980, les superficies récoltées étaient estimées à 4200 ha et le rendement moyen à 710-800 kg/ha. La potentialité de production du froment et du triticale se limite environ à 20 000 ha/an des superficies totales prévues en l'an 2000 et au rendement accrû de 2000 kg/ha dans les conditions de système de culture amélioré.

Actuellement, la consommation annuelle du blé au Rwanda est estimée à 11 000 t dont 8000 t importées. En 1978, la quantité de graines et farine de blé importées furent 8469 t, en 1979 (5119 t), en 1980 (7285 t), en 1981 (8370 t). Cette situation entraine le pays à dépenser énormément le peu de devises dont il dispose en vue de donner satisfaction aux besoins alimentaires de sa population en produits de blé (1).

Afin de réduire quelque peu ces dépenses, le pays a entrepris un programme de développement de la culture de froment et de triticale, aussi bien au niveau de recherche qu'au niveau d'extension.

Recherche

Les thèmes de recherche au cours des quatres dernières années (1984-1987) ont été définis sur base des problèmes rencontrés au niveau de la production de froment et de triticale en milieu rural chez les fermiers. Ces problèmes peuvent se regrouper en quatre catégories:

* Adaptation rapide des maladies sur les variétés de froment et celles de triticale.

* Allocation à ces cultures des champs aux sols pauvres.

* Utilisation des techniques culturales inadequates.

* Conditions agroclimatiques hétérogènes des régions aptes à la culture du froment et du triticale.

Dans le but de résoudre ces contraintes, une méthodologie de travail systématique et adapté a été établie. Le programme de recherche sur les deux céréales s'est fixé les objectifs suivants:

* La diffusion rapide de nouvelles variétés hautement productives, résistantes aux maladies et insectes principaux, adaptées à chaque région agroécologique.

* La délimitation (subdivision) de toutes les régions à vocation de blé aux différentes zones agroécologiques spécifiquement adaptées à chacune de deux espèces, au froment ou au triticale.

* La régionalisation des deux céréales.

* L'amélioration des techniques culturales:

a) Etude de bonnes rotations du froment et du triticale avec les autres cultures appropriées à chaque zone agroécologique.

b) Utilisation des intrants dont les engrais verts, composts, fumure minérale, protection phytosanitaire.

c) Etude de jachères améliorées à courte durée (3-6 mois au maximum).

Matériels et méthodes

En ce qui concerne la méthodologie de travail, la recherche s'est d'abord occupée de la subdivision des régions aptes à la culture de blé et de triticale en différents groupes; il s'agit de:

Groupe des régions aux sols acides (pH < 6)--Selon les diverses classifications, ces sols sont généralement appelés hygrokaolisols, latisols ou ferrasols. Ils peuvent être riches ou pauvres en éléments nutritifs organiques et minéraux pour la culture du blé en général.

Néanmoins, ils sont toujours moins fertiles par rapport aux autres types de sols qu'on rencontre au Rwanda, spécialement pour le froment et le triticale.

Groupe des régions aux sols peu acides ou neutres (pH > 6)--Ce sont les sols volcaniques en général se trouvant au nord et nord-ouest du Rwanda.

Groupe des zones de hautes altitudes au-dessus de 2000 m--Les altitudes au-dessus de 2000 m interfèrent avec les températures moyennes basses de 10 à 15° C, l'humidité atmosphérique élevée de 70 à 80% et la haute pluviosité (pluies régulières de 1200 à 1400 mm/an et beaucoup de journées couvertes de brouillards sans ensoleillement suffisant).

En accord avec la spécificité des conditions agroclimatiques de chaque groupe de ces régions, la sélection des variétés (écotypes) adaptées à chaque zone écoclimatique, voire les variétés écologiquement plastiques par leur adaptation à plusieurs conditions, est l'une des préoccupations actuelles du programme de recherche sur le froment et le triticale au Rwanda. Et c'est pour cette raison que les commandes du matériel végétal de sélection doivent spécifier les caractéristiques biologiques des semences de base souhaitées à recevoir du CIMMYT, soit de son germoplasm au Mexique ou des différentes pépinières de son programme régional au Kenya.

Résultats de recherche

Identification des maladies et insectes du blé et du triticale existant au Rwanda--A travers toutes les régions de blé et du triticale au Rwanda, les maladies et les insectes de deux céréales ont été inventoriés:

Maladies identifiées:

Rouilles
* Rouille jaune (*Puccinia striiformis*)
* Rouille brune (*Puccinia recondita*)
* Rouille noire (*Puccinia graminis*)

Septorioses
* *Septoria tritici*
* *Septoria nodorum*

Helminthosporioses (*Helminthosporium* spp.)

Fusarioses (*Fusarium* spp.)

Oïdium (*Erysiphe graminis*)

Jaunisse (Barley Yellow Dwarf Virus)

Bactériose (*Xanthomonas* spp.)

Ces maladies sont énumérées dans l'ordre d'importance de leur propagation et des dégâts qu'elles puissent occasionner au niveau de chaque zone agroécologique à travers toutes les régions à blé et triticale.

Insectes rencontrés:

Coccinelles (*Chnootriba* spp.)

Aphidiens (*Schizaphis* spp.)

Borers (Thrips)

L'invasion de ces insectes n'est pas régulière dans le temps; cependant, les borers sont observés de façon particulière au niveau variétal et sans influence régionale d'après les constatations faites.

Production du blé et du triticale dans les sols très acides et pauvres au Rwanda--Dans les conditions de sols très acides et pauvres se trouvant au sud et sud-ouest du Rwanda (en Préfectures de Gikongoro et de Kibuye), le potentiel de production du triticale s'est avéré plus élevé que celui du blé.

La production du triticale en stations expérimentales varie entre 2000 et 3000 kg/ha, contre 1500 et 2000 kg/ha du rendement moyen. En milieu rural, chez les fermiers encadrés par les projets de développement agricoles, le triticale produit 1500 kg/ha, presque le double de la production de blé (8000 kg/ha).

Au sud et sud-ouest du Rwanda, les maladies les plus menaçantes sont les rouilles et quelque peu la septoriose des épis (*Septoria nodorum*), mais sans beaucoup d'importance avec cette dernière maladie. On peut y rencontrer quelques cas de borers autant bien sur le blé que sur le triticale, toutefois sans dégâts significatifs. Les attaques de pucerons (Aphidiens) et des coccinelles sont occasionnelles, comme dans les autres régions. A part les cas des borers, les aphidiens et les chenilles de coccinelles n'ont pas été découverts sur le triticale dans ces conditions.

Influence des sols volcaniques sur la production du blé et du triticale--Les sols volcaniques, au nord et nord-ouest du Rwanda, se sont montrés excéllents pour la culture du blé et du triticale. La production moyenne sur les parcelles expérimentales en stations dans les meilleures conditions atteint 4 à 5 t/ha avec le triticale et 3 à 4 t/ha avec le froment. Dans les champs des fermiers, les rendements de 1500 à 2000 kg/ha y sont facilement obtenus sans aucun apport d'intrants fertilisants.

Cependant, le problème des maladies y est comme facteur limitant. Le climat humide de cette zone de volcans semble être très favorable aux maladies fongiques, dont la rouille (jaune, brune et noire), la septoriose, l'helminthosporiose, la fusariose et les différentes moisissures des grains après récolte. La virose (BYDV) et la bactériose (*Xarthomonas*) sont souvent observées sur les introductions, surtout sur celles du triticale. Ce dernier présente des cas de germination sur pied. Le cycle végétatif y est prolongé plus qu'ailleurs, dans les autres régions (plus de 140 jours).

Avant 1985, les variétés de triticale se montraient très résistantes à la rouille jaune et brune. Dès lors, tout le matériel de triticale, soit les anciennes variétés, les hybrides et les nouvelles introductions, est attaqué très fortement par la rouille jaune avec un degré de sensibilité de 80 à 100%. On remarque néanmoins que le triticale reste toujours indemne à ce champignon dans les autres régions.

Ce phénomène nous amène à supposer qu'il s'agit d'une espèce nouvelle de rouille spécifique à la culture du triticale dans les conditions écologiques et climatiques de volcans.

Influence de l'altitude sur la production du blé et du triticale--Les études menées sur le comportement du blé et celui du triticale sur les différentes altitudes au Rwanda ont révélé que l'élévation en altitude a une influence directe sur l'accroissement des rendements pour les deux cultures.

Les rendements obtenus ci-dessus, par exemple, avec les différentes variétés de triticale sur différentes altitudes, démontrent bien les observations précitées (Tableau 1 et Graphique 1).

Il a été constaté que plus on descend en altitude, la production abaisse et plus on monte en hauteur, la production augmente. Cependant, à cause des conditions climatiques très humides qu'on peut rencontrer à plus de 2500 m d'altitude, la culture du froment et du triticale est recommandée aux altitudes situées entre 1600 et 3000 m d'élévation. De ce fait, l'altitude est l'un des facteurs limitant de la distribution de la culture du blé et du triticale dans les conditions non irriguées.

Comportement du blé et du triticale dans les sols peu acides du nord, nord-ouest et du plateau central du Rwanda--Dans ces sols, la culture du blé et du triticale donne de bons rendements moyens respectivement de 3000 à 5000 kg/ha de façon constante sans fertilisation, seulement dans les conditions de la bonne application d'un système de culture amélioré (rotations, techniques culturales améliorées, bonnes dates de semis, semences de bonnes variétés triées). Avec de petits aléas climatiques, le triticale peut dépasser le blé en production dans les proportions de 20 à 50% de supériorité.

Les maladies principales connues dans ces régions sont surtout les rouilles, la septoriose, la fusariose et l'helminthosporiose.

Le triticale souffre de la fusariose et de l'helminthosporiose plus que le froment. L'oïdium infecte actuellement beaucoup le blé, quoique l'apparition de ce champignon sur cette culture soit récente. La germination du triticale sur pied n'est pas fréquente dans ces régions agroclimatiques du Rwanda.

Influence de rotations et petites jachères améliorées sur la production du blé et du triticale dans les différentes zones agroécologiques du Rwanda--Dans toutes les régions à vocation de la culture de blé et de triticale, il a été constaté que les antécédents culturaux ont une influence sur la fluctuation des rendements de blé et de triticale. La meilleure production de deux céréales s'obtient en rotations avec les plantes légumineuses, les cultures améliorantes et nettoyantes. Il s'agit des légumineuses, des tubercules et des racines. Les expérimentations conduites dans ce domaine de recherche ont démontré que les petites jachères améliorées, c'est à dire les jachères constituées de plantes légumineuses annuelles, augmentent les rendements de 20% de la production habituelle obtenue en milieu rural chez les fermiers (3).

Les types de rotations et petites jachères améliorées préconisées dans certaines régions sont les suivants:

Dans les régions des sols peu acides en haute du Rwanda (Buberuke Byumba, plateau central)

Type A	Type B	Type C
Haricot		
Blé	Patate douce	Pomme de terre Maïs
Vesce	Blé	Haricot
Triticale	Jachère	Blé
Jachère de vesce	Pomme de terre	Jachère
Blé	Choux	Triticale
Petit pois	Triticale	Petit pois
		Blé
		Mucuna
		Sorgho

Dans les régions de volcans au nord et nord-ouest du Rwanda

Type A	Type B	Type C
Pyrèthre	Pomme de terre	Pomme de terre
Vesce	Triticale	Petit pois
Blé	Jachère	Blé
Jachère	Choux	Jachère
Petit pois	Blé	Choux
Triticale	Jachère	Triticale
	Pomme de terre	Petit pois
		Maïs

Les types de rotations et jachères dépendent des cultures pratiquées dans chaque région. Les rotations peuvent être constituées par la succession des plantes nettoyantes et jachères uniquement (type B), des plantes ameliorées et jachères (type A) ou des plantes légumineuses, jachères et plantes nettoyantes (type C).

Régionalisation du blé et du triticale au Rwanda--En tenant compte des résultats obtenus des essais d'adaptabilité multilocaux effectués sur le blé et le triticale en différentes régions, avec les problèmes rencontrés au niveau de chaque zone agroécologique, la régionalisation de deux céréales s'avère nécessaire en vue de l'exploitation rationnelle du peu de superficie disponible à blé et triticale (20 000 ha en l'an 2000):

* Le triticale par sa rusticité écologique dans son adaptation aux conditions défavorables (sols acides et pauvres) mieux que le blé est souhaitablement recommandé pour les régions du sud et sud-ouest du Rwanda comme la culture principale et le blé y pourra le seconder;

* Le blé sera alors la culture principale dans la région des volcans;

* Dans les régions du nord et du plateau central du Rwanda aux sols peu acides (pH = 5-6), la production de deux cultures devra être équitable.

Sélection des variétés adaptées et productives--En considérant tous les problèmes rencontrés rela..ifs au comportement de différentes variétés du blé et du triticale et leurs rendements faibles en milieu rural et élevés en stations, le programme de sélection a fixé les critères de sélection des variétés du triticale et du blé pourvues des caractéristiques suivantes:

* Haute productivité de 4 t/ha et plus en station et de 2 t/ha en milieu rural chez les paysans.

* Durée du cycle végétatif réduite à 120 jours.

* Résistance aux maladies principales spécifiques à chaque région agroécologique.

* Résistance à la verse et aux insectes.

* Bonne qualité nutritive et boulangère.

La disponibilité du matériel végétal de sélection de base en quantité et génétiquement varié s'avère très indispensable pour parier à ces problèmes. La diffusion de nouvelles variétés devra être régulière afin d'endiguer la dégénérescence rapide des variétés de blé et de triticale à l'ère actuelle. Variétés réalisées en 1983-1985 est en Tableau 2.

Actuellement, le programme de recherche dispose d'une nouvelle série de lignées stabilisées de blé en parcelles de multiplication de semences de souche à diffuser aux projets chargés de vulgarisation et du développement agricole. Ces lignées sont issues des hybrides F2 en provenance du CIMMYT (Mexique) en 1984. Elles possèdent un haut potentiel de production et elles ont une bonne tolérance aux principales maladies.

Conclusion

L'adaptation rapide des maladies et insectes oblige la recherche à introduire constamment de nouveau matériel végétal de sélection de façon systématique.

Concernant les semences souhaitées, l'introduction des hybrides F2-F4 de blé et de triticale pourra permettre de réaliser des variétés adaptées aux diverses conditions agroécologiques du Rwanda.

L'importation systématique de ces semences de base implique les échantillons génétiquement adaptés à chacune des zones écologiques et édaphiques, ainsi que ceux donnant des solutions aux problèmes phytosanitaires rencontrés.

Enfin, l'utilisation des variétés performantes (écotypes), des techniques culturales améliorées, combinées avec l'emploi judicieux d'engrais organiques et minéraux, peut accroître le rendement de deux céréales. La régionalisation de blé et de triticale permettra au Rwanda d'utiliser rationnellement le peu de superficies prévues pour la production de son propre blé et triticale.

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Résumé

L'adaptation rapide du froment et du triticale aux maladies et insectes est actuellement considérée comme l'un des obstacles majeurs au développement de ces céréales au Rwanda.

Ce problème oblige la recherche à introduire constamment du nouveau matériel de sélection. Cette introduction devra être variée et systématique et comporter du matériel de base adapté aux différentes zones agroécologiques propices à la culture du froment et du triticale.

La forte susceptibilité du triticale à la rouille dans les conditions environnementales des régions volcaniques constitue une épreuve grave quant à l'espoir d'intensifier la culture du triticale au Rwanda. La mise au point de variétés de triticale résistantes à cette maladie est une nécessité préoccupante et urgente.

Bref, l'utilisation de variétés performantes (écotypes) pour chaque région agroécologique et la pratique des techniques culturales améliorées, combinées avec l'emploi judicieux des engrais organiques et minéraux, pourront sans nul doute accroître la production nationale du froment et du triticale.

Tenant compte de la diversité des conditions climatiques et édaphiques du Rwanda et des caractéristiques biomorphologiques du froment et du triticale, la maximisation de la production des deux céréales dépendra également de la régionalisation de ces cultures afin d'utiliser rationnellement le peu de superficies disponibles.

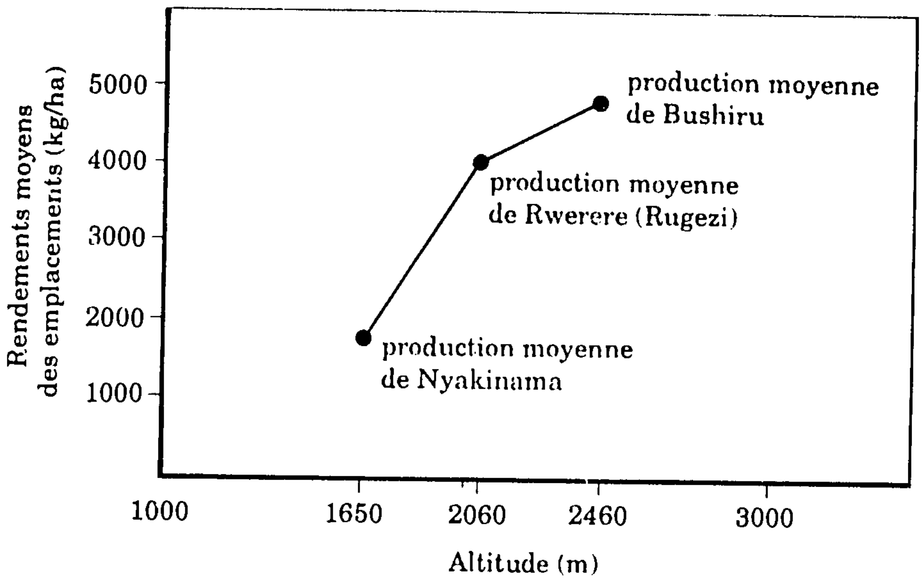
Tableau 1. Rendements moyens (kg/ha) des varietes de triticale en essai comparatif varietal multilocal sur differentes altitudes

No.	Varietes	Rendements moynes (kg/ha) Rwerere (2060 m)	Bushiru (2460 m)	Nyakinama (1650 m)	Moyenne (kg/ha)	% temoin
1	Yoco "R"	3.771	5.412	2.135	3.773	132
2	Beagle	4.263	5.141	1.864	3.756	131
3	Yoco	4.523	5.566	1.556	3.548	124
4	Navajoa	4.144	4.560	1.883	3.529	123
5	T-74	4.275	4.707	1.421	3.468	121
6	T-48	4.174	4.566	1.629	3.456	121
7	T-50	3.767	4.736	2.127	3.377	118
8	S-223	3.465	4.435	2.196	3.365	118
9	T065	3.992	4.537	1.406	3.312	116
10	Moshi (T)	3.271	3.781	1.525	2.859	100
Moyenne generale		3.914	4.644	17.744	3.444	

Tableau 2. Pour le ble et la triticale, une dizaine de varietes ont ete realisees en 1983-85

Espece	Varietes	Cross ou Pedigree	Rendement (kg/ha) en stations Rwerere	Tamira	Kinigi
Ble	Tamira	Gyrak = chova	3400	3500	4200
	Gicinya	Veery B	2600	3200	4300
	Mutsima	G 155xKenya Nyati	2500	2500	3800
	Kinigi	Bb-CnoxJar/Cno 7C x cc - Tob	2500	2500	4300
	Buberuka	Kenya Fahari	2100	2400	4000
Triticale	--	Octo-Bulk-Bush	4200	3600	4500
	--	Merino	4300	3500	4500
	--	Delfin 205	3800	3200	4100
	--	W 73.103 (A)	3500	2600	4000
	--	W 73.103 (B)	3200	2400	3500

Graphique 1.


Rendements moyens
des emplacements (kg/ha)
5000
4000
3000
2000
1000
production moyenne
de Bushiru
production moyenne
de Rwerere (Rugezi)
production moyenne
de Nyakinama
1000
1650
2060
2460
3000
Altitude (m)

REACTION OF SOME WHEAT LINES TO LEAF RUST RACES IN ZIMBABWE

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(presented by S. Machado)

Abstract

Out of a total of 25 single genes for leaf rust resistance tested under natural epiphytotics at three locations in three consecutive years, only two, Lr20 and Lr25, seemed to be effective. Lr9 and Lr19, which have been effective against wheat leaf rust races in Zimbabwe for a long time, are now ineffective.

Eight released varieties and eight local advanced lines were evaluated for leaf rust resistance at four locations, under natural epiphytotics in winter and artificial epiphytotics in summer, at two locations and in the greenhouse. Under artificial epiphytotics in the greenhouse, all the advanced lines and released varieties except Sengwa succumbed to leaf rust infection. Under natural infection there were variations in severity and field response. F83059, F83060, S79322-1-1-1 and Sengwa displayed better resistance to leaf rust than the other lines.

Introduction

In Zimbabwe wheat (*Triticum aestivum* L.) is grown as an irrigated crop during the winter season which is generally cooler and drier than the summer season. As a result, the disease encountered are few. However, leaf rust (*Puccinia recondita* f.sp. *tritici*), stem rust (*Puccinia graminis* f.sp. *tritici*), virus diseases such as maize streak, powdery mildew (*Erysiphe graminis*) and loose smut (*Ustilago nuda*) are still prevalent.

Powdery mildew is not a serious problem and occurs occasionally in certain seasons and locations of Zimbabwe. Loose smut is successfully controlled by seed treatment with carboxin (Vitavax). Maize streak virus is becoming increasingly important because of the wide host range of the vector, *Cicadulin ambila*. The host range includes maize, which is a major crop grown in the summer season, and a number of wild species of the Gramineae family.

Wheat rusts are mainly prevalent in the lowveld (300-600 masl) of this country. Most of the wheat varieties under commercial production are resistant to local biotypes of stem rust. At present leaf rust is the major problem.

On a worldwide basis, the most effective method for control of rust is the use of resistant varieties. (1, 7, 8, 16). Likewise, development of leaf rust resistant varieties is a major objective of the national wheat improvement programme.

The objective of this study, therefore, was to investigate the response of presently cultivated wheat varieties and some local advanced lines to leaf rust and monitor any change in the race composition in Zimbabwe.

Material and Methods

Experiment I: monitoring of leaf rust races in wheat growing areas

Twenty-five single-gene leaf rust resistance lines were grown in the major wheat producing areas at the following locations - Chiredzi Research Station, Mutare and Rattray Arnold Research Station for three consecutive seasons. The lines were planted in 2-m rows, 0.5 m apart and one row per entry. About 10 grams seed was used per entry. Morocco was included as a susceptible check. The whole nursery was surrounded with a border of Morocco which served as the disease spreader. Testing was done under a natural epidemic. Records were taken at the 11.1 stage (milk stage, Feeke's scale) and scored as percentage severity and field response.

Experiment II: response of released varieties and advanced lines to leaf rust

Greenhouse experiment--Eight cultivated varieties and seven local advanced lines were sown at the rate of 10 grains per pot and grown in the greenhouse at Harare Research Station. The seedlings were thinned 5 days after emergence to five seedlings per pot. Eight days after emergence, the seedlings were inoculated with a mixture of rust spores collected from naturally infected wheat crops at Chiredzi, Mutare, Panmure, Agriculture Research Trust, (A.R.T) farm (on the outskirts of Harare), Chisumbanje and Birchenough Bridge. A mixture of urediospores was used because the races were unknown. Records were taken 12 days after inoculation.

Field experiment--The same 15 wheat lines used in the greenhouse experiment were grown at A.R.T. Farm, Rattray Arnold, Mutare and Panmure in Winter 1986; and at Gwebi, Rattray Arnold and Nyanga in the 1986/87 summer season. At all locations in 1986 and at Rattray Arnold in 1986/87 summer season, the lines were tested under natural epidemics whereas at Gwebi and Nyanga a spore mixture as used in the greenhouse was used for inoculation.

Results and Discussion

Experiment I

Eighteen leaf rust single-gene lines showed a susceptible reaction at all locations. Results from lines showing reactions ranging from moderately susceptible to immune are shown in Table 1. *Lr20* and *Lr25* have been effective from 1984 to 1986 at all locations. *Lr19* conferred immunity to leaf rust at Chiredzi and Mutare from 1984 to 1985.

In 1986 it maintained its immunity at Rattray Arnold but showed signs of susceptibility at Chiredzi and Mutare. This shows that a new race(s) virulent on *Lr19* appeared at Chiredzi and Mutare at the same time but not at Rattray Arnold. In 1984 and 1985, *Lr9* was showing signs of susceptibility at Rattray Arnold but was found immune at Chiredzi and Mutare. The fact that *Lr19* conferred immunity in the three areas for two consecutive years of testing and then showed signs of susceptibility at Chiredzi and Mutare in the third year shows that Rattray Arnold had a different race flora as compared to Chiredzi and Mutare. A breakdown in resistance of *Lr9* in 1986 may be an indication that the race which was confined to Rattray Arnold has now spread to Chiredzi and Mutare.

The good performance of *Lr9* and *Lr19* is not surprising because these genes have also been found effective by many workers in different parts of the world (4, 5, 8, 11, 12, 13, 14, 15, 16, 19). Breakdown in resistance of *Lr9* and *Lr19* is also not surprising because susceptible responses have also been reported and have been used to detect new races (8, 17). This may be an indication that there is a new race(s) of wheat leaf rust that can counter these resistance genes.

Experiment II

The results from artificial inoculation in the greenhouse correlated well with the field results except for F83059 which was resistant or immune at both field locations but moderately susceptible in the greenhouse (Table 2). This may be an indication that F83059 lacks seedling resistance but has adult plant resistance. All the other advanced lines showed signs of susceptibility to leaf rust during the summer of 1987 both in the greenhouse and field, but the degree of severity in the field differed. F83012, F83060 and S79233-1-2-1 had a very low rust infection at both locations. The fact that Morocco showed high rust infection and these lines did not, might indicate that they have the slow rusting characteristic defined as "the phenomenon in which the rate of rust development is slower and the ultimate intensity is less than would be expected in a full susceptible variety" (3). Among the varieties only Sengwa showed low percentage infection with resistant to moderately resistant response to the disease (Table 2).

Under natural conditions the infection levels across the four locations were low in 1986 but higher in the summer 1987, but lines such as F830559, F83012, F83060 and S79322-1-2-1 still showed low levels of infection even in the summer (Table 3). This seems to confirm that these lines have the slow rate of disease development characteristic.

There was also variability in field response across locations, possibly due to different genetic bases of resistance in the lines and different race composition at the locations as illustrated by the leaf rust differentials. There may also be a genotype x environment interaction factor in play.

Among the varieties, Sengwa showed better resistance to leaf rust than all other varieties. An examination of the parentage of the varieties shown in

Table 4 reveals that Angwa, Chiwore, Gwebi and Torim 73 are closely related. The parents of Sengwa are Zaragoza 75 and Zopilote.

Zaragoza (Mengavi/8156) although it is related to the other varieties through 8156, gives a resistant response to leaf rust under Zimbabwean conditions. Sengwa has Zopilote, an Ecuadorean line as one of its parents that might contribute to its resistance. The resistance to leaf rust in Limpopo has held since 1973 and it is only now that it has started to show a tendency towards moderate susceptibility.

These studies indicate that there is a continued need for screening commercially used varieties and advanced wheat lines to leaf rust in various parts of Zimbabwe. This aspect is especially important for developing high yielding leaf rust resistant varieties for the future as well as to create back up material in case the present varieties succumb to new races of leaf rust.

Future Outlook

1) Efforts are underway to identify the wheat leaf rust race composition in each of the ecological zones of Zimbabwe so that genetic material resistant to these races can be used in future breeding programmes.

2) There is a need to develop lines with multigenic resistance to races occurring in Zimbabwe.

3) Promising lines are going to be tested during summer before they are advanced for further yield testing.

4) Promising lines are also sent for international rust testing through the Field Crops Laboratory in Beltsville, Maryland, U.S.A.

Acknowledgments

We are grateful for the assistance and cooperation received from the various members of staff at the following centers: Agriculture Research Trust Farm; Sisal Farm (Mutare), Chiredzi Research Station, Gwebi Variety Testing Center, Panmure Experiment Station, Rattray Arnold Research Station, Nyanga Experiment Station and Harare Research Station.

We also thank Professor C.L. Keswani for reading the draft of this paper and making constructive suggestions.

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Résumé

Sur un total de vingt-cinq gènes simples de résistance à la rouille brune, testés dans des conditions épiphytotiques naturelles dans trois sites et pendant trois années consécutives, seulement deux gènes, le Lr20 et le Lr25, ont semblé efficaces. Le Lr9 et le Lr19, qui ont donné de bons résultats pendant longtemps au Zimbabwe contre la rouille brune du blé, sont maintenant inefficaces.

On a évalue la résistance à la rouille brune de huit variétés diffusées et de huit lignées locales avancées dans des conditions épiphytotiques naturelles en hiver et dans des conditions épiphytotiques artificielles en été, dans deux sites et en serre. Sous conditions épiphytotiques artificielles en serre, toutes les lignées avancées et les variétés diffusées, à l'exclusion de Sengwa, ont été détruites par la rouille brune. En conditions naturelles, la sévérité de l'infection et la réponse au champ furent variables. Les variétés F83059, F83060, S79322-1-1-1 et Sengwa ont mieux résisté à la rouille brune que les lignées.

Table 1. Response of wheat leaf rust resistance genes to wheat leaf rust in Zimbabwe, 1984-1986

Resistance Gene	1984		1985			1986		
	Rattray Arnold	Chiredzi	Rattray Arnold	Chiredzi	Mutare	Rattray Arnold	Chiredzi	Mutare
Lr 9	5MS[a]	0	5MR-MS	0	0	70S	30S-MS	80S
Lr 12	5MR-MS	--	30MR-MS	--	--	50MR-MS	40R-MR	20MR-MS
Lr 18	10R	10S-MS	5MS-S	10S-MS	30R-MR	30R-MR	40R-MR	50R-MR
Lr 19	0	0	0	0	0	0	30S	40S-MS
Lr 20	0	--	0	--	--	0	0	0
Lr 25	0	--	0	--	--	5R-MR	0	5R

[a] Not tested.

0 = No visible infection on plants.
R = Resistant; visible chlorosis or necrosis, no uredia are present.
MR = Moderately Resistant; small uredia are present and surrounded by either chlorotic or necrotic areas.
MS = Moderately susceptible; medium-sized uredia are present and possibly surrounded by chlorotic areas.
S = Susceptible; large uredia are present, generally with little or no chlorosis and no necrosis.
T = Trace.

Table 2. Responses of high yielding advanced wheat lines and released varieties to leaf rust in Zimbabwe in the summer of 1987 under artificial inoculation in the field and greenhouse

Lines	Gwebi	Nyanga	Green House
Advanced Lines			
F 83012	5S	5MS	S
F 83059	0	TMR	MS
F 83060	TS	TMR-MS	MS
SS 78003-1-5	20MS-S	50S	MS
S 78297-6-2	15S	20MS-S	S
S 79322-1-2-1	5S	20MR-MS	S
S 79048-2-2	25S	40MS	S
MOROCCO	80S	90S	S
Released Varieties			
Angwa	30S	40S	S
Chiwore	70S	60S	S
Gwebi	5S	40S	S
Limpopo	10S	10MR-MS	S-MS
Rusape	10S	30MS-S	S
Sengwa	5R	5R	MR
Tokwe	80S	70S	S
Torim 73	10S	20S	S

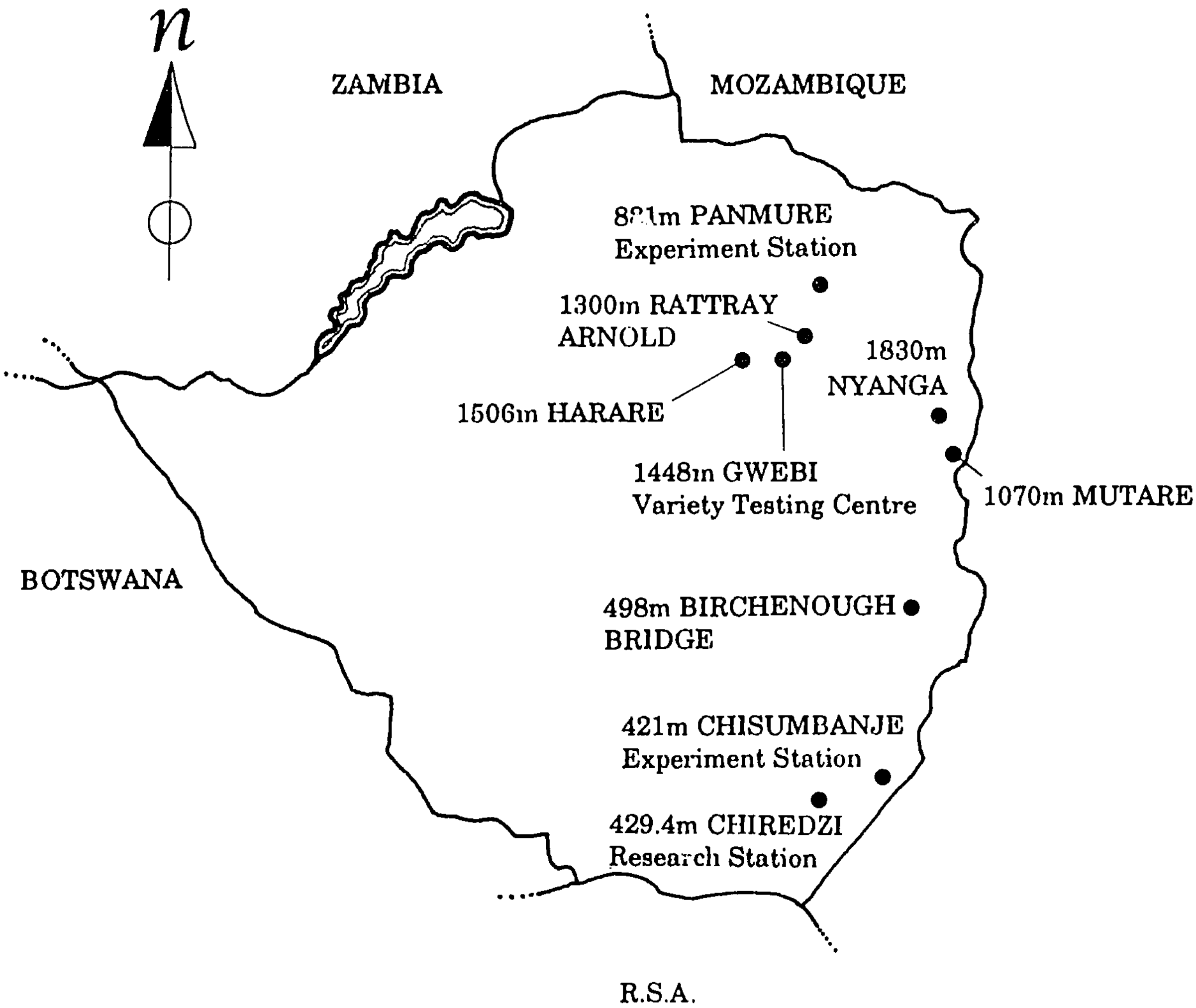
Table 3. Response of high yielding advanced wheat lines to leaf rust in Zimbabwe in the winter season of 1986 and summer season 1986/87 under natural epidemics

Lines	Winter 1986 A.R.T (Harare)	Winter 1986 Rattray Arnold	Summer 1986/87 Mutare	Summer 1986/87 Panmure	Summer 1986/87 Rattray Arnold
Advanced Lines					
F 83012	0	TS	TR	0	5S
F 83059	0	TR	TR	0	5MS
F 83060	30MS	0	TR	0	0
SS 78003-1-5	5R	TMR	5MR-MS	TMS	10MS-MR
S 79322-1-2-1	0	TS	10MS-S	TMS-S	0
S 79048-2-2	10MS	TR	TR-MR	TMS	60S
S 78297-6-2	30S	TMR-MS	TR-MR	5MS	40S-MS
MOROCCO	90S	95S	90S	90S	99S
Released Varieties					
Angwa	30MR	10S	5MS-S	20S-MS	30MS-MR
Chiwore	65S	20S	5MS-S	10S	60S
Gwebi	30S	20S	5S	30MS-S	20S
Limpopo	15MR	TR-MR	TR	5MR-MS	5MR-MS
Rusape	25S	10S	5S-MS	10S-MS	40S-MS
Sengwa	0	TR	5R	0	0
Tokwe	95S	10S	70S	60S	80S
Torim 73	60MS	5MS	5R	5MS-S	20MR-MS

Table 4. Percentage of some wheat varieties grown in Zimbabwe

Variety	Parentage
Angwa	Cajeme//Inia/Corre Caminos
Blue Bird "S"	Ciano//Sonora 64/Klein Rend/3/8156 =Yecora "S" = Gwebi = Cajeme
Chiwore	Tob/Ciano//Corre Caminos/Super X/3/ Azteca 67/4/Yecora "S"
Gwebi	Blue Bird "S"
Limpopo	Sonora 64//TZPP/Nai 60/3/Tokwe
Rusape	Kavkaz/Buho//Kalyansona/Blue Bird
Sengwa	Zaragoza 75/Zopilote
Tokwe	Yt 54/N10B21//Mazoe/3/Lee/ND 74
Torim 73	Blue Bird/Inia

Figure 1. Wheat leaf rust testing locations in Zimbabwe.



GENERAL RECOMMENDATIONS AND RESOLUTIONS

The Fifth Regional Wheat Workshop recommends that:

1. Germplasm introductions from both inside and outside the region increase, while at the same time ensuring the elimination of potential hazardous diseases and pests.

2. Proper levels of biotic and abiotic stresses in screening germplasm be used.

3. Regionally generated information and germplasm is shared between all national programs in the region.

4. CIMMYT, donors, governments and other agencies involved in wheat research and production, encourage exchange visits by national scientists to other countries within the region.

5. CIMMYT encourages the organization of local disease workshops, concentrating on pathogens of particular regional importance,.

6. Agronomists identify and prioritize the major constraints to wheat production in their geographic area of responsibility. This will ensure a focusing of limited resources of finances and scientific manpower on research themes having the greatest potential importance e.g., by conducting on-farm research, being particularly aware of the contribution that multi-factor trials can make by increasing our understanding of the relative importance of each factor being studied.

7. An on-farm research (OFR) program must be founded upon sound research findings from trials conducted on the station, but based upon farmer needs as identified by surveys or other appropriate means.

8. OFR should not be conducted at the expense of the on-station research programs. Rather the two must be complementary, multi-disciplinary and interconnected by a feedback process involving the researchers, extension and the farmers.

9. Research programs should include innovative studies beyond the scope of currently available inputs. Trials may be simple but should not be limited by current farmer practices.

10. There should be a continuous upward transmission of research findings to policy makers. These findings should be in a simple summarized format, emphasizing the impact of the proposed technology on the national economy. For example, in Madagascar, if threshing is identified as the major constraint to the expansion of wheat production, and if an appropriate mechanized thresher can be developed or identified then it is the policy maker's responsibility to react.

The Regional Wheat Workshop recommends that Madagascar:

1. Raise the number of introductions in order to increase the genetic variability of germplasm available to the National Breeding Programme, while at the same time ensuring the elimination of potentially hazardous diseases and pests.

2. Plant incoming germplasm at FIFAMANOR in collaboration with the quarantine officials to ensure rapid exploitation of internationally available germplasm.

3. Continue to maintain an adequate level of disease severity and virulence in the breeding materials by artificial means to ensure the selection of resistant materials.

4. Continue to execute epidemic studies on stem rust with a view to establishing the importance of factors contributing to disease development.

5. In order to establish the relative importance of the movement of rust inoculum, set up trap disease nurseries at appropriate locations.

6. Collaborate in regional disease surveillance efforts by proper collection and shipment of rust isolates for race identification purposes to appropriate international laboratories within the framework of CIMMYT's global disease surveillance project.

7. Collaborate in regional screening of CIMMYT germplasm for stem rust resistance and acid soil tolerance in order to identify lines of benefit to the country and the region as a whole.

8. Initiate a hybridization programme to develop varieties with resistance/tolerance to biotic and abiotic stresses prevailing in the country.

9. Because of the similarity of wheat production constraints in Madagascar and Zambia. encourage a greater exchange of information and materials between the two countries.

The Regional Wheat Workshop resolves that:

1. The participating national programs collaborate in a regional disease surveillance effort by the proper collection and shipment of rust isolates for race identification purposes to appropriate international laboratories, within the frame work of CIMMYT's global disease surveillance project.

2. Selected national programs cooperate to screen CIMMYT germplasm at locations within the region, where important biotic and abiotic stresses are particularly severe and reliable, in order to identify and disseminate lines with a greater likelihood of adaptation in particular countries of the region. The participating countries will be, according to the relevant stresses:

Stripe rust: Kenya, Ethiopia
Stem rust: Kenya, Madagascar, Ethiopia
Leaf rust: Kenya, Ethiopia

Septoria spp.: Ethiopia, Tanzania
Helminthosporium spp.: Tanzania, Zambia
Fusarium spp.: Tanzania, Zambia
Acid soils: Madagascar, Zambia

3. The next workshop will be held in Ethiopia in 1989, to be organized by IAR and CIMMYT's regional wheat office.

4. The workshop in 1991 will be held in Zimbabwe to be organized by the local wheat improvement team and CIMMYT's regional wheat office.

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