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PROCEEDINGS OF INTERNATIONAL WINTER CONFERENCE (IST) HELD AT ANKARA, TURKEY, ON 5-10 JUNE 1972

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This report is a compilation of the proceedings of the International Winter Wheat Conference held in Ankara, Turkey June 5-9, 1972. A total of 97 wheat researchers representing 24 countries participated in the conference. The purpose of the conference was to evaluate improved winter wheat varieties from different countries and identify promising winter wheat germplasm for use in breeding programs. An assessment was made of the significance of nursery findings and procedures were developed to accelerate the agronomic and nutritional improvement of winter wheat.

The texts of 51 reports presented at the conference are included in this proceedings.

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INTERNATIONAL Winter Wheat Conference

PROCEEDINGS . . .

1st

ANKARA, TURKEY
JUNE 5-9
1972

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E. F. FROLIK, DEAN; H. W. OTTOSON, DIRECTOR

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INTERNATIONAL WINTER WHEAT CONFERENCE

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FOREWORD

The conference was organized by personnel of the Nebraska Agricultural Experiment Station - Agricultural Research Service wheat research team with funding from the Agency for International Development, U. S. Department of State.

Impetus for the conference was provided by an International Winter Wheat Performance Nursery organized by the Nebraska - ARS group in 1968 to evaluate improved winter wheat varieties from different countries and identify promising winter wheat germplasm for use in breeding programs. The international nursery was initiated as a part of a University of Nebraska research contract with USAID (AID/csd-1175) to improve the nutritional quality of wheat.

From data provided by nursery cooperators a few winter varieties with superior international performance characteristics quickly emerged. Additionally, there was excellent phenotypic expression of genes for high protein in some varieties. A survey of cooperators in 1971 indicated their interest in an early conference to assess the significance of nursery findings and to develop procedures to accelerate the agronomic and nutritional improvement of winter wheat. A conference in 1972 was authorized by USAID.

Excellent conference facilities and proximity to the important winter wheat production areas of Europe and Asia made Ankara, Turkey an ideal conference site. The conference was officially hosted by the Ministry of Agriculture of the Republic of Turkey.

Supervision of conference and tour arrangements was provided by Dr. Ahmet Demirlicakmak (Turkish Ministry of Agriculture), Dr. E. J. Rice (USAID Mission, Ankara), and Dr. B. C. Wright (Wheat Research and Training Center, Ankara).

A successful conference was assured by participation of 97 wheat researchers representing 24 countries. They recommended that plans for a second conference to be held in 1975 or 1976 be initiated.

All speakers were requested to provide written versions of their presentations. A few did not. Written texts, that were submitted, are included in this Proceedings. Some editing of a minor nature was done in the interest of uniformity and clarity. It is hoped that this did not alter the intended meanings of the authors. Informal floor discussions following presentations were not recorded and could not be included herein.

Many individuals and agencies contributed significantly to this conference. Only a few have been specifically identified. The efforts of all are gratefully acknowledged.

V. A. Johnson
Conference Coordinator

WELCOME

by

İlyas Karaöz
Minister of Agriculture, Government of Turkey

Mr. Chairman, Distinguished Delegates, and Guests,

It is indeed a great pleasure for me to have this opportunity of welcoming all of you who are here to participate in the Winter Wheat Conference in our country.

I strongly believe that you will have very useful discussions and will reach the necessary recommendations for the development of winter wheat production.

As you may know, wheat is the most important crop in Turkey because of the ecological make-up of our country. Each year a large area, about 8.5 million hectares are sown to wheat. In this area there is land which is not suitable for wheat production. In spite of this extensive planting of wheat there are years when yields do not meet the consumption requirements of our population. Our goal is to become self sufficient in wheat production and to be able to meet the demands of our increasing population. Therefore, by applying modern techniques we are attempting to increase the wheat production per unit area. It is our hope that our scientists will be able to develop the improved cultural techniques needed to increase the production which could be utilized easily by the farmers. To reach this goal, serious efforts are expanded towards preparing national projects.

I would like to emphasize the importance of the contribution of the international organizations. The joint research conducted in our country in accordance with the agreement signed by the Turkish Government and the Rockefeller Foundation is a good example of such cooperative research. These efforts are of great importance not only to our country but to the other countries as well.

It is my belief that this kind of conference, at which researchers from many countries meet together in an atmosphere of scientific enlightenment, can be very beneficial. I am sure your conference will contribute to the welfare of humanity. In such a meeting you will be able to exchange ideas and information. As a consequence, the problems facing you can be solved more easily and in a shorter period of time. It is my hope that international cooperation in research can be broadened and directed to other important topics.

I hope the Winter Wheat Conference will be successful and that you will have benefited from your visit of our country.

PROBLEMS AND OPPORTUNITIES FOR INCREASED WINTER WHEAT PRODUCTION IN TURKEY

by

A. Demirlicakmak
Turkey

Because of its adaptation to dry land conditions, wheat has always been the most important crop in Turkey in terms of both acreage and production. It will continue to be the most important crop in area and in terms of domestic needs.

There are many problems facing the improvement and production of wheat in our country. Solution of such problems will be aided through the cooperative and coordinated efforts with the organizations and international agencies represented at this meeting.

As a result of this cooperation, this technical conference is being held. It is a great pleasure for me to welcome our guests and the delegates at the beginning of this conference. It is my hope that during the conference many ideas will be exchanged on wheat research which is of utmost importance to our country and that this exchange of ideas will be of mutual benefit.

Turkey was a wheat exporting country 20 years ago. Today, to meet the requirements of the increasing population, Turkey is importing wheat. During the last 15 years, because of climatic conditions, wheat production was not sufficient to meet the consumption requirements in our country. Therefore, our goal, as indicated in the Development Plans, is to reach a level in production which will satisfy our consumption requirements and then to keep this level steady.

It is recognized that our cultivated land cannot be increased further. The area available for reclamation is less than that of the land now cultivated. The object of the plan is to increase productivity per hectare by means of improved techniques and some irrigation rather than by expanding the total cultivated area.

As you know, Turkey has great production potential with land and water resources and good climatic and ecological conditions. Meeting the consumption requirements of the increasing population, and increasing our farmer income will be possible only with the exploitation of this potential. The most effective method to reach this goal will be to increase the production per unit area. Results of research carried out to date indicate that it is possible to increase yield by over 100% by the use of improved high yielding varieties, sufficient amount of fertilizers, improving soil management and cultural practices, and controlling diseases and pests.

As you probably know, there are two basic sets of conditions in Turkey under which wheat is grown. The first set of conditions is that of generous rainfall and mild climate which is found along the coast lands, and to a limited extent in certain parts of the Central Plateau. In this area fall-planted spring wheats are grown. The second set of conditions is that of limited rainfall and cold winter which covers most of the wheat producing area. Under these conditions which characterize much of the Central Plateau, south-eastern and eastern Turkey, winter wheat is grown.

About 80% of the wheat in Turkey is grown under rainfed conditions where yields are low, fluctuating in direct relation to rainfall, especially spring precipitation. Cultural practices are adapted to a livestock economy that depends on stubble and weeds coming up in summer fallow as one of the main sources of feed. These practices are not conducive to moisture conservation since weeds often remove most of the moisture.

At the present time, soil management is the major limiting factor in the wheat production in dry land areas. The varieties now grown are capable of much higher yields than are currently being produced. The problems are:

1. To accumulate as much moisture in the soil as is possible, preventing loss by excessive surface evaporation and transpiration by weeds.

2. To prepare a good clean seed bed with sufficient moisture near the surface into which the seed can be planted, thus insuring germination and continued growth of the plants until cold weather begins.

In general, under present cultural practices, the fall sown wheat depends on rain after seeding in order to germinate. Very often there is not enough precipitation and the seeds do not germinate until very late fall or next spring, thereby missing the favorable fall growing period for root development and tillering with a resulting sharp yield reduction. In this case, the development of a technique for soil and moisture conservation is very important. The large Central Anatolian plain and the region of South-eastern Turkey are very promising areas for the improvement of soil management.

The soils of Anatolia have very high clay contents, often 50% or more. The clay soils are difficult to cultivate. Root development is often limited to 1 to 1.5 meters depth, and these soils present many more problems with the use of agricultural equipment than a loam soil. For example, in clay soils power requirements are higher and the timeliness of cultural operations is extremely important. The farm equipment in general use in Anatolia may not be the most satisfactory for clay soils. Moreover, soils in Anatolia are low in available phosphorus and nitrogen.

These are major factors that will make it necessary to conduct extensive research in tillage methods, timing of tillage operations, different type of tillage equipment, use of fertilizers and other cultural practices such as seeding rates, dates and row spacing.

While problems of cultural management of the rainfed wheat crop may be the most acute, this does not mean that these are the only problems. It is expected that the present varieties, all of which are quite susceptible to diseases and have a fairly limited yield potential, will need to be replaced when better cultural management practices are used by farmers. It is well known that good cultural management encourages good pathogen growth as well as good plant growth. Therefore, it will be necessary that future varieties have good resistance to our principal diseases of which

Puccinia striiformis is the most important. Future varieties must also have more lodging resistance if they are to utilize the additional soil moisture and fertilizers to produce higher yields. Similarly, problems with grassy weeds, such as Bromus tectorum, will become more prominent, especially if the moldboard plow is not used as the primary tillage implement.

It is our belief that a successful research program must produce a complete set of information and materials in order to permit wheat production to increase. In the rainfed area where winter wheat is grown, a set of cultural practices is needed first. After this has been accomplished, then new disease resistant and high yielding varieties will be needed. It should be obvious that the development and refinement of the cultural techniques and the production of disease-resistant varieties is a never ending process.

Research on winter wheat has been conducted by the Faculty of Agriculture of Ankara University and Research Institutes for a long time. The Faculty of Agriculture is carrying on a wheat breeding program as well as studies relating to tillage and other agronomic questions.

Recently the Wheat Research Project has begun research to study these problems. A country-wide wheat research project has been organized which includes ten research stations in different ecological zones of Turkey. A series of tillage trials and other agronomic experiments studying fertilizer management, planting dates, and planting rates is being conducted in cooperation with Topraksu, the General Directorate of State Farms, and U.S.A.I.D. At the same time the breeding program is being strengthened and expanded and is supported by plant pathologists from the General Directorate of Plant Protection and the General Directorate of Agriculture who conduct systematic disease surveys and manage a series of disease nurseries. They also inoculate the breeding plots with the prevalent races of our most important pathogens. Thus, it is our goal to produce a series of practices and good varieties in the shortest possible time so that Turkey's wheat production may be increased. It should be understood that it will require the application of a combination of these practices, rather than any one individual practice, to achieve the most significant influence on dry-land wheat production on the Anatolian Plateau.

WINTER WHEAT IMPROVEMENT PROBLEMS

WESTERN EUROPE

by

A. Lein
Federal Republic of Germany

Improvement efforts on a crop like winter wheat must be based on breeding better varieties (plant breeding and seed supply). Other possibilities of improvement interact with variety characters and reactions. An optimal solution includes in all cases genetical factors on the side of the crop (interactions between genotypes and environment).

Western Europe started winter wheat breeding about 100 years ago. The present high level of productivity in larger districts and in nearly all regions is due to the fact that farmers always have had available a number of modern productive varieties specifically adapted to their environmental conditions.

Productivity of a variety

1. Elevated yield potential.
2. Use of the potential by means of necessary supply of nutrients at the right time.
3. Yield stability over the years or reduced risk under stress conditions and under infections by parasites or on other pests.

Adaptivity

1. Coincidence between developmental cycles in the crop and the periods of particular climatic conditions.
2. Coincidence with usual cultural practices.
3. Suitability to special crop management (e.g. also reaction and tolerance to chemical treatments).

Seed production and seed trade in Western Europe are exclusively dependent on an open market organized on private account, although under public control and legal or administrative regulations (certification after field inspection and seed control).

Multiplication of varieties is restricted to bred or introduced varieties registered on published lists of obligatory character or provable recommendations. Registration relies on systems of official and public tests. Otherwise farmers are free to sow their own seed or to buy certified seed of any variety from the seed trade.

Wheat breeding which is closely related and connected by history and by its aims to seed production in the countries of Western Europe, is practiced mainly by private companies. Started at the end of the last century by progressive and well-educated farmers, breeding has today a position somewhere between science and commerce.

Some winter wheat improvement problems in Western Europe are caused or influenced by this kind of organization. Certified seeds belong to the operating expenses. There are economical problems which are confounded with the general situation of agriculture and food industries, regional problems within the continent as well as worldwide problems. There are some problems of temporary structural character. The basic principle of self-financing of the breeding work -- though not absolutely accepted and a frequent subject of discussion for several reasons -- intensifies competition with positive as well as negative effects. There are some problems raised by the desire for or the necessity of breeders' rights.

I mention these problems, although the topics of this conference generally must be restricted to technical agrobiological problems. Most of the technical problems will be touched on or discussed in other special reports on the agenda. It is not my intention to avoid these technical problems. However, some of more urgent technical problems are confounded with commercial facts.

WINTER WHEAT IMPROVEMENT PROBLEMS

EASTERN EUROPE

by

R. Hron
Austria

To begin with I should like to define the geographical extent of my topic. A separate report will deal with wheat breeding in the USSR. My report will therefore refer to eastern Europe excluding Russia but including the east of Central Europe which will be rather more fully dealt with. I shall not consider the very interesting wheat breeding in the Mediterranean region of southern Europe. However, the importance of Italian winter wheat breeding to wheat production in the continental influenced climate of southeast Europe will be referred to.

In eastern Europe, excluding Russia, wheat is cultivated on about 10 million hectares. It is mostly winter wheat. Wheat production in some east European countries and its prospective development are shown in table 1. About 70% of the Austrian winter wheat area is situated in the plains and hill country of eastern Austria which may be classed with the eastern European wheat breeding region.

Table 1
Wheat production in eastern Europe[1]
(area - 1000 hectares; production - 1000 metric tons; yield - 100 kg/hectare)

Country	1961-1965			1966-1970			1980[2]
	area	production	yield	area	production	yield	production
Rumania	2,966	4,321	14.6	2,764	4,840	17.5	6,040
Yugoslavia	2,006	3,599	17.9	1,916	4,493	23.5	4,800
Poland	1,516	2,988	19.7	1,837	4,258	23.1	7,750
Hungary	1,078	2,009	18.6	1,231	3,000	24.3	4,560
Bulgaria	1,218	2,210	18.1	1,051	2,883	27.5	--
Czechoslovakia	735	1,779	24.2	989	2,845	28.6	--
German Democratic Rep.	430	1,357	31.5	544	1,982	36.3	--
Austria	276	704	25.5	299	949	31.7	--

[1] from FAO Production Yearbook 1970
[2] from FAO 1971

Wheat production in eastern Europe is mainly directed to supplying the local population. Alimentary habits show certain differences in the individual countries. Throughout, wheat products are an important part of human food. In some countries, as in Bulgaria, Hungary, Rumania and Yugoslavia, wheat is the prevalent or the only bread cereal.

As in other parts of the world, the first aim of wheat breeders is to improve yield and yield stability. With the increasing usage of fertilizers, the countries of eastern Europe are starting breeding programs to create high yielding varieties (Plarre 1971) which are adapted to local conditions (Borojevic and Potocanac 1966). But in this connection great differences among the countries of eastern Europe must be mentioned. Climatic conditions for wheat cultivation vary considerably in the eastern European countries. Fertilizers are used to varying extents in the individual eastern European countries and, by and large, do not reach the western European level.

Less intensive wheat production calls for some compromises with high yield breeding. Less intensive varieties which are adaptable also to regions with an inferior supply of water and nutrients and to light wheat soils must have a somewhat longer straw at the expense of standing power. There is also a correlation with drought resistance which is required in most parts of eastern Europe. The yielding potential of drought resistant varieties is more limited than the yielding potential of varieties for regions with higher rainfall. This is connected with the lower yielding potential of early varieties as well as with the difficulty of combining short straw and high absorption of nutrients with sufficient drought resistance. In order to breed varieties with an appropriate resistance to weather hazards and with moderate needs, ecotypes or varieties which are adapted to the local conditions must be used in crossing.

Among the wheat varieties endemic in eastern Europe and the east of Central Europe, some undemanding types and types with excellent resistance against weather hazards are found. However, there is a lack of such varieties which also show an adequate yielding potential which is indispensable for intensive wheat production with high fertilizer rates to attain maximum yields. Therefore, wheat varieties from other regions have to be used in the crosses in order to achieve high yielding varieties. Western European, Italian and Russian varieties may be used for this purpose.

To attain yield advances varieties of more distant geographical origin must be used in breeding. When only native varieties which are often similar in type or even related are used for cross-breeding, only small advances in yielding performance can be expected. Each of the aforesaid variety groups also carries a smaller or larger number of undesirable characteristics which very much complicate the recombination of desired characteristics and the selection. Anyway, they make it necessary to work with large numbers.

Western European varieties, mainly those from the northwest of Europe ripen late or very late and winterhardiness is often insufficient as well. Italian varieties generally are not hardy enough, above all when used in regions with a strong influence of continental climate and in northeastern Europe; nor do they adapt easily to the growing rhythm and the daylength of regions north of the Alps and the Carpathians. This fact very much complicates the use of Italian varieties as crossing parents in these regions. However, in southeastern regions of Europe with a milder climate, the use of Italian varieties has definitely stimulated the breeding of winter wheat. By way of the Italian varieties, genes from Japan have been introduced. One additional advantage of the Italian varieties is their early maturity.

Russian varieties have often proved to be very appropriate for cultivation in other eastern European countries, e.g. Bezostaja 1, Mironovskaja 808, Rannaja 12 and others. Russian varieties, being well adapted to the general conditions of cultivation and breeding in eastern Europe, are frequently being used as crossing parents and have influenced the breeding of winter wheat.

The development of new high yielding wheat varieties must be accompanied by attempts to optimize the cultivation of these novel variety types (Borojevic 1971). Fertilizer and seed rates for example had to be raised when, in Yugoslavia, older varieties with long straw were replaced by Italian varieties like San Pastore or Libellula and varieties derived from Italian crosses such as Sava (Borojevic et al. 1971) or Zlatna Dolina. Similar changes in the methods of cultivation were made necessary by the introduction of the Russian variety Bezostaja 1 in Hungary.

The great annual fluctuations of climate typical of the eastern European region, lead to serious difficulties in introducing new varieties and in testing cultivation methods. The development in autumn and spring, the time of planting as well as the development in the generative phase differ very much in individual years in relation to temperature and the distribution of rainfall.

The yield stability of wheat varieties makes a vital difference in eastern Europe. I should like to discuss the characteristics influencing yield stability in two groups: Firstly, characteristics which bring resistance against climate hazards, and secondly, disease resistance.

With regard to standing ability the older east European wheat varieties were altogether inadequate. Shortening the stem and improving standing power are necessary conditions for higher nitrogen doses and realization of maximum yields in fairly dense cereal stands. Under dry conditions and on lighter soils one has to be cautious in breeding for shorter straw, because it is difficult to combine a very short stem with sufficient drought resistance and, because wheat varieties with very short straw do not have a satisfactory yield stability on less nutritive or poorer soils. Medium to good drought tolerance is needed for most regions in eastern Europe. Generally this characteristic may only be tested in an indirect way. Breeding success depends on the site of the breeding plots and on the specific climates of the years when selection was carried out.

Early or medium early ripening varieties are needed in most of the wheat cultivating regions in eastern Europe. Sufficient shattering resistance is required. Also, the complex characteristic of winterhardiness demands special attention. Low temperatures, without sufficient snow cover, are typical of eastern European winters. However, resistance needs vary considerably in the individual countries and regions of eastern Europe.

Breeding of disease resistance has been increasingly considered in eastern Europe. The multiplicity of geographical and climatic conditions does not favour the development of epidemic diseases in large areas, but the diversity of physiological races and the proliferation of new ones, e.g. of stem rust, create great difficulties for the breeder. Individual cereal diseases differ in importance for the individual wheat breeding areas. Stem rust, leaf rust, yellow rust, mildew and septoria have to be taken into consideration in resistance breeding. Foot rot diseases, in the first place Cercosporella, are a serious problem but are not yet a concern of systematic resistance breeding. Breeders are less occupied with bunt and loose smut which can be controlled with conventional systemic fungicides.

Questions of quality breeding of wheat cannot be answered in a general way for eastern Europe. Alimentary habits and customary methods in the production of bread and pastries are decisive for the quality demands on wheat varieties. Furthermore, the various degrees of self-sufficiency and different trade policies strongly influence the quality breeding of wheat.

Large parts of the east European wheat-growing regions possess climatic conditions favourable to the production of wheat with excellent milling and baking characteristics. During the intensive and successful efforts to raise yields, wheat quality, particularly the baking quality, deteriorated. The novel varieties are inferior in baking quality in comparison with the older varieties and ecotypes previously used. This results partly from the negative correlation between yield and quality. The decline in baking quality may also be attributed to the fact that shortage of wheat supplies necessitated yield breeding so that wheat breeders had to pay less attention to quality requirements.

Therefore, eastern European wheat breeders must now, and in the future, come to grips with quality breeding (Kovacs 1971, Muresan et al. 1969). Besides the direct method of the baking test we have indirect methods of testing baking characteristics. We may distinguish those for testing the gluten quantity or the protein content from those which test the gluten quality, e.g. the sedimentation test according to Zeleny or the evaluation of the swelling number according to Berliner. Physical methods of assaying the dough are also in use, especially the Farinograph.

While it was easily possible to disregard consumers' wishes in consideration of general trade demands in the eastern European countries with their planned economies, quality requirements have been traditionally high in Austria which has a western style economic system. These requirements were even made more stringent by modern mechanized methods of dough processing and baking. Because Austria succeeded in reaching self-sufficiency in wheat during recent years, it became necessary for the eastern part of Austria with its poor rainfall (500-600 mm.p.a.) to grow wheat varieties with satisfactory yield as well as optimal processing characteristics and market quality. This was achieved with the older variety Record which is no longer entirely satisfactory because of its susceptibility to stem rust and its low lodging resistance. Erla Kolben and Probstdorfer Extrem may be mentioned as useful newer varieties.

Probstdorfer Extrem is now the most prominent variety in Austria (Hänsel 1971), leading by far in seed multiplication. Next comes the former leading variety Record (Meinx 1966). Probstdorfer Extrem already occupies nearly half the area of winter wheat multiplication in Austria. Its yield, standing power, protein content and gluten content are indeed exceeded by other varieties, but it has proved necessary in the Austrian situation to compromise and develop a variety which, above all, satisfies the high Austrian requirements for baking quality. Probstdorfer Extrem shows a medium gluten content and good gluten quality. It exhibits an outstanding baking value and has carrying power as well.

In the course of political and trade changes in eastern Europe after the World Wars I and II, changes were noted several times both in the aim and organization of plant breeding. This led to a stagnation in wheat breeding which now seems to have been overcome. New wheat varieties developed in eastern Europe have proved valuable for the special conditions of production in individual countries or wheat growing regions of eastern Europe and have induced a significant increase in wheat production. With the exception of some Russian varieties, none of the existing eastern European varieties of winter wheat have achieved a large area of propagation or any importance outside the eastern European region or the east of Central Europe. Recently, some very remarkable breeding results have seemed to make eastern European wheat breeding worthy of study at the international level.

Summary

The present statements deal with wheat breeding in eastern Europe, excluding Russia but including the east of Central Europe. The main stress is laid on winter wheat breeding in Yugoslavia, Hungary, Czechoslovakia and Austria. Occasionally problems in Bulgaria, Rumania and Poland are also mentioned.

Efforts to improve yielding potential, characteristics influencing yield stability, and to breed for better processing characteristics, especially baking quality, are outlined.

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SOME RESULTS OF WINTER WHEAT BREEDING IN THE USSR AND THE TRENDS OF ITS PROGRESS

by

P. P. Lukyanenko
Soviet Union

The USSR occupies the largest wheat cultivated area and produces the highest total yield of wheat grain in the world. In the Soviet Union more than 65 million hectares are sown to spring and winter wheats, i.e. one-third of the world acreage occupied by this crop. Winter wheat is planted on about 20 million hectares which is approximately the same as its total area in all of the European countries.

Spring wheat is mainly grown in the Volga River region, Kazakhstan and Siberia, in the areas with a sharp continental arid climate. The major winter wheat growing areas are in the steppe and forest-steppe regions of the European part of the Soviet Union, mostly in the Ukraine and the North Caucasus.

For the last decades winter wheat acreages, yields, and the total grain production have greatly risen. Thus, in 1913-1966 the area sown to winter wheat increased from 8.3 million hectares to 19.7 million hectares, i.e. by 2.5 times. The gross output of grain reached 40.3 million tons against 8.3 million tons, i.e. fivefold increase. For the same period, the average yields of winter wheat in the Soviet Union more than doubled and achieved 22.8 q/ha by 1970.

In the areas of our country with more favourable climate the average yields of winter wheat are essentially higher, sometimes reaching 35 q/ha and more. Thus, in the Krasnodar region there were obtained 36.6 q/ha in 1970 and 37.1 q/ha in 1971 from a harvested acreage of about 1.5 million hectares. Of this acreage there were 400-500 thousand hectares with sufficient rainfall where 40-45 q/ha were produced. Previously, the yields of 18 q/ha were never exceeded here.

It should be noted that such increase in yield was achieved here when applying small mineral fertilizer doses not surpassing 3-4 q/ha. Besides improvement in agricultural technology, higher yields of winter wheat are mainly accounted for by the development and release of new high-yielding varieties of an intensive type which replaced the old extensive cultivars possessing a long stem, low resistance to lodging and some other poor characters.

Our new high-yielding winter wheat varieties recently bred by crossing ecologically and geographically remote cultivars, exhibited high ecological plasticity. They are widely cultivated, not only in the Soviet Union, but also in a number of foreign countries which never happened before. It is known that the Bezostaya 1 variety, a strong-type wheat with high productivity and good milling and baking qualities, is exclusively grown in the Balkans.

It is also sown in south-eastern Poland, and Czechoslovakia and, according to FAO data, this variety is being introduced for commercial production in Turkey, Iran and Afghanistan. The total area occupied by Bezostaya 1 is more than 13 million hectares, including more than 8 million hectares in the USSR, i.e. 40% of the total harvested acreage in our country. In the International Winter Wheat Performance Trials this variety also exhibited wide adaptability and, according to Prof. V. A. Johnson's reports, it proved the best in yield in 1969 and 1970.

In the last few years some other varieties of the Soviet breeding programme were also released abroad. For instance, Mironovskaya 808 bred at the Mironovsky Institute of Wheat Breeding covers 40% of the total acreage under winter wheats in the USSR and is introduced in Czechoslovakia, Poland, East Germany and Hungary. It is of interest to note that in the Soviet Union with 115 winter wheat varieties released, 85% of the total area sown to this crop are occupied by two varieties: Bezostaya 1 and Mironovskaya 808. The former is grown in the southern regions and the latter in the northern and eastern parts of our country including the areas of non-black earth and the Volga River region.

Release of these varieties had a great economic effect. In the Kuban (the North Caucasus) and in a number of the Balkan countries, the Bezostaya 1 release together with more intensive cultivation allowed yields to increase by 1.5-2.5 times. The yields of 50 q/ha and more are obtained on the best farms.

At the same time Bezostaya 1 has become a very valuable gene source which is widely used now in the Soviet and European breeding programmes for developing new winter wheat varieties by hybridization. Fifty-eight newly developed home varieties of winter wheat are obtained by crosses involving this line or its initial cultivar Bezostaya 4. Some of them such as Aurora, Kavkaz, Mironovskaya 50, Odesskaya 51, Dneprovskaya 521, and Krasnodarskaya 39 are already released, and other promising varieties are in state trials.

The highest-yielding new varieties in Bulgaria as well as some new varieties in Hungary, Rumania and Yugoslavia were bred incorporating Bezostaya 1. In France, at the Dijon experimental station some hybrid lines excelling the standards by 25-30% were obtained from crossing Bezostaya 1 with the native variety "Prior".

Among the newly released varieties of an intensive type now widely introduced into commercial production, Aurora and Kavkaz should be mentioned. They are sister lines selected in the F_3 from the hybrid population Lutescens 314 h 147 x Bezostaya 1. Lutescens 314 h 147, in its turn, was developed from crossing Neuzucht, a wheat of the West European ecological type, with Bezostaya 4. Among the set of the Soviet winter wheats now available, Aurora and Kavkaz are distinguished by more productive ears, high complex resistance to leaf, yellow, and stem rusts and to powdery mildew. These varieties have a short stem resistant to lodging (which is especially true for Aurora), high baking qualities with medium strength of flour. They markedly outyield Bezostaya 1 as illustrated by the data from our competitive varietal trials. (Table 1).

Table 1. Yielding ability of winter wheat varieties.

Variety	yield (q/ha) 1967	1968	1969	1970	1971	mean of 5 years q/ha	±
Bezostaya 1	54.4	68.9	45.5	56.2	61.8	57.3	standard
Kavkaz	66.2	74.0	50.0	60.0	66.6	63.3	+ 7.0
Aurora	66.4	72.9	52.4	66.0	65.3	64.6	+ 7.3

High productivity of these varieties is confirmed by numerous varietal trials at the state nursery sites, research centers, and by high yields obtained on the farms. Aurora and Kavkaz often yield 70-80 q/ha in rainfed areas and 85-97 q/ha under irrigation. The average increase in yield is 5-8 q/ha and sometimes 10-20 q/ha over Bezostaya 1 (Table 2).

Table 2. High yields of winter wheat varieties.

Nursery site	Year	Aurora q/ha	±	Kavkaz q/ha	±	Bezostaya 1 q/ha	±
				Krasnodar region			
Ust-Labinsky	1968	76.8	+10.3	75.1	+ 8.6	66.3	standard
	1970	71.1	+ 8.2	70.1	+ 7.2	62.9	"
	1971	73.3	+ 6.7	70.9	+ 4.3	66.6	"
Timashevsky (irrigated)	1968	81.3	+ 9.2	87.4	+15.3	72.1	"
	1971	85.6	+ 9.9	86.0	+10.3	75.7	"
Korenovsky	1970	73.3	+13.9	70.6	+11.2	59.4	"
	1971	73.1	+ 8.5	73.5	+ 8.9	64.6	"
Kavkazsky	1971	76.0	+ 8.0	78.3	+10.5	68.0	"
				Kirovograd district, Ukraine			
Novo-Ukrainsky	1971	85.5	+17.4	92.9	+24.1	52.9	standard
Bobrinitsky	1971	82.4	+10.9	84.5	+13.0	43.2	"
				Kirghizia			
Przhevalsky (irrigated)	1968	82.5	+ 8.0	91.7	+17.2	74.5	standard
	1970	93.0	+ 7.8	95.2	+10.0	85.2	"
				Kazakhstan			
Jambulsky (irrigated)	1970	93.7	+ 8.7	97.4	+11.8	85.6	standard

The data given demonstrate the high yield potential of the new varieties. In 1971 Kavkaz produced a remarkable yield of 92.2 q/ha against 68.1 q/ha for the standard Bezostaya 1 when sown on summer fallow lands in the Novoukrainsky nursery site (Kirovograd district, Ukraine). This is the highest yield of winter wheat ever obtained without irrigation.

In 1971, when grown on a large commercial scale, Aurora and Kavkaz yielded 60 q/ha and more, thus having successfully exceeded the 50 q/ha level set by Bezostaya 1. This is evident from Table 3. The average yields of winter wheat, excelling 60 q/ha on large non-irrigated areas, are unprecedented in our farming.

They became possible due to introduction of the new high-yielding varieties and more intensive cultivation. High yield potential and some other valuable characters of Aurora and Kavkaz have made them popular and provided their rapid multiplication for commercial production. In 1972, the first year of their release, these varieties covered more than 2 million hectares which is an extraordinary case in the Soviet and world seed production.

Table 3. Winter wheat yields on the best Kuban farms in 1971.

Farm	Total acreage (ha)	Average yield (q/ha)	Variety			
			Kavkaz		Aurora	
			ha	q/ha	ha	q/ha
			Ust-Labinsky region			
Kuban Collective Farm	4589	61.4	2164	62.5	1708	64.3
Krupskaya Collective Farm	1080	63.4	630	64.5	256	64.1
			Korenovsky region			
Seed Multiplication State Farm	2937	60.3	338	59.7	2599	61.8

Plant breeding is confronted with the problem of further increase in yield potential of winter wheats. It is known that when solving this problem much attention must be paid to breeding semidwarf varieties. The striking success of Dr. Norman E. Borlaug in developing the Mexican semidwarf varieties of spring wheat widely introduced in many countries, is a good evidence in favour of this trend in wheat breeding. In Europe, first in Italy (N. Strampelli) and later in some other countries, winter wheat breeding for a short stem traces back to the 1920's. Since then, the stem height has undergone some further changes to shortening. We can observe the same trend in our varieties bred in Kuban. The stem height of our new varieties (Bezostaya 1, Rannyaya 12, Aurora and others) ranges from 100 to 110 cm, i.e. 30-50 cm shorter than that of the old varieties (Ukrainka, Stavropolka 328 and others).

Should the stem height be reduced further and to what level? The accumulated evidence shows that semidwarfs manifest their merits only in the soils well supplied with water, i.e. under irrigation or when cultivated in the areas with sufficient rainfall.

When breeding our semidwarf varieties, we proceed from the fact that further increase of yield potential can only be achieved without loss of the total plant productivity (i.e. total biomass per hectare) and with considerable increase in the grain output percentage of the total yield. Hence, when breeding short stem varieties, the decrease in non-productive part of a plant should be balanced by increase of its productive part, i.e. greater grain per ear. With a decrease in the total plant productivity of a short stem variety, its grain yield per hectare will be lower than that of a long stem one.

Therefore, our breeding programme for yield is based on continuous rise in ear productivity combined with a whole complex of characters conditioning yield capacity and adaptability of a variety to local environments and cultural practices.

To increase yield potential of an ear remote intergeneric crosses are used in our programme besides the intraspecific diversity of common wheats. In this respect wheat-quitch grass hybrids obtained by Dr. M. G. Tovstic in Kirghizia from crossing Bezostaya 1 with Agr. Elongatum and then Tompus, a Tibet dwarf variety, are of great interest. These dwarf hybrids considerably surpass all the available common wheats in ear productivity (number of spikelets per ear, number of grains per ear and grain weight per ear), and are of great value for further breeding. Of interest are some intergeneric wheat-wild rye hybrids first obtained in our country by Academician N. V. Tsitsin. These hybrids are constant and have a productive ear.

Short stem varieties from Mexico, the USA and other countries, mostly derivatives of Norin 10, a Japanese variety, as well as our dwarf mutants of Bezostaya 1 and others, are employed as sources of dwarfness. In these crosses the higher-yielding winter wheat varieties such as Aurora, Kavkaz, Predgornaya 2 and others having a productive ear, immunity to rusts and powdery mildew, are usually taken as parents. The semidwarf lines resulted from crossing these varieties with short stem cultivars essentially outyielded the standards by producing 81-82 q/ha (see Table 4).

Table 4. Studies of semidwarf lines in comparison to the standards.

Variety	Year	Grain yield (q/ha)	Deviation from the standard q/ha	Deviation from the standard %	Resistance to lodging (rank)	Plant height (cm)
A. Semidwarfs						
Lutescens 745	1968	82.0	+12.2	+18	4.8	85
"	1970	58.6	+12.0	+26	4.4	71
"	1971	81.0	+12.4	+31	5.0	95
Lutescens 66	1971	81.9	+20.1	+32	5.0	87
B. Standards						
Bezostaya 1	1968	69.8	std.	std.	3.7	110
"	1970	46.6	"	"	2.6	100
"	1971	61.8	"	"	4.5	108
Aurora	1968	72.8	+ 3.0	+ 5.0	4.3	109
"	1970	55.2	+ 8.6	+18.0	3.0	105
"	1971	73.6	+11.8	+19.0	5.0	117

Analysis of our first still imperfect semidwarf lines makes us believe that developing varieties of such a type will surely result in further increase of yield potential in winter wheats.

Heterosis is an important, still not employed, factor of yield gain in wheat. As you know, breeding for heterosis became possible after cytoplasmic male sterility discovery (H. Kihara and H. Fukasawa), the most valuable source of which proved to be a Georgian species, T. timopheevi found by Zhukovsky. This CMS source is widely utilized in wheat breeding all over the world.

Investigations on this problem were started in our country in 1965. The Krasnodar Research Institute of Agriculture, the All-Union Research Institute of Plant Breeding and Genetics in Odessa, the Agricultural Institute for Non-Chernozem Zone in the Moscow district, and some other research centers of our country are dealing with this problem. The system of genetic lines necessary for obtaining hybrid seeds is available at present. At our Institute the sterile counterparts for such high-yielding varieties as Bezostaya 1, Aurora, Kavkaz and others and the restorer lines showing full restoration and high combining ability have been developed. This year, our native hybrids on a sterile base, including 220 of this type bred at our Institute, are being tested under field conditions. We think that the data obtained will enable us to identify productive heterotic hybrids that outyield the standards.

Also, some new easier ways of heterosis employment in wheat are being investigated. At the Ukraine Institute of Agricultural Technology a new method of hybrid seed production through chasmogamy and selective fertilization is being worked out by Dr. Y. Miryuta. The hybrids which resulted from crossing specially selected chasmogamic lines with productive varieties of winter wheats, display a very high level of heterosis (60% and more above the standard). Such investigations are being carried out in a number of research centers. Probably this method will become a major one as the easiest and the most economic way of hybrid seed production in wheat. The progress already achieved in hybrid wheat breeding on CMS base and the outlined easier methods of hybrid seed production make us optimistic about the possibility of heterosis employment for wheat productivity increase on a commercial scale.

The problem of winter wheat immunity is also highlighted. Breeding for rust resistance was begun at our Institute as long ago as 1930. Release of the newly developed rust resistant varieties allowed us to almost eliminate the crop losses caused by this dangerous disease. At present, Aurora, Kavkaz and other new varieties combining a complex resistance to rusts and powdery mildew with high productivity and other valuable characters, have been released and are being introduced into commercial production. Studies on genetic and physio-biological fundamentals of wheat immunity are conducted at the All-Union Vavilov Institute of Plant Industry and at some other research centers of our country.

Wheat is the main resource of plant protein. Protein deficiency in the world made it necessary to sharply increase the protein content in grain and improve its amino-acid composition through an increase in essential amino-acids, especially lysine. All these characters are to be combined with high milling and baking qualities.

Owing to a wide range of climatic and soil conditions in our country, there are areas with widely different protein content in grain from as high as 18% to as low as 8-10%. For the last few years, due to the increase in yield of winter wheat, some tendency to lower grain protein has been observed in the main winter wheat growing regions of our country. It also has made us intensify winter wheat breeding for grain protein.

The breeding program is realized by intraspecific hybridization using commonly known donors of high protein (Atlas 66 and others) and by mutagenesis.

Having used the chemical mutagenes (N-nitrosoethylurea and N-nitrosomethylurea) some induced mutants of Bezostaya 1 with high protein content of 20-20.5% against 13.69% in the initial variety have been produced. These mutants are used in our hybridization programme. As sources of high protein content, we also are using some wheat-quitch grass hybrids of an intermediate type (2n = 56) with 20-22% protein developed by Dr. N. V. Tsitsin and his coworkers, high protein Triticale obtained by Dr. V. E. Pisarev and Dr. A. F. Shulyndin, and some hybrids from remote crosses developed by Dr. I. D. Mustafaev. Crosses of common winter wheats with the tetraploid T. dicoccoides showing the maximum protein content among the all-wheat species, are being made.

There were years when the protein content in the grain of some emmer cultivars reached 37%, i.e. 3.5 times higher than that of the cultivated wheats. Using all these sources of high protein content it appears possible to develop high-yielding winter wheat varieties with much higher protein in grain (5-6%). It might be of great economic importance, since an increase in grain protein content, for instance, up to 15% as against 14% (i.e. per each absolute percent) is equivalent in protein terms to a 10% increase in grain production. Certainly, it is a very complicated problem for it is rather difficult to combine high yields with high grain protein content because of a negative correlation existing between these characters. Surely, this negative correlation will be overcome.

In the USSR, as in some other countries, intensive research work is carried out on identification of wheats with high lysine content. Thousands of samples from the world wheat collection have already been analysed for lysine content at the All-Union Vavilov Institute of Plant Industry (VIR), as well as at our Institute and in some other research centers. But, so far, no high lysine samples in wheat similar to opaque-2 in maize have been found. However, a number of samples with higher lysine content, up to 3.2-3.5% of the total protein against 2.5% for the standard Bezostaya 1 have been isolated. But these are still to be tested. Among the hybrids resulted from crossing home varieties with Atlas 66, lines with improved lysine (up to 3.2% of total protein) and relatively high protein level (15-16%) have been identified.

At our Institute we have induced Bezostaya 1 mutants of a "defective endosperm" type with high lysine content (up to 0.72% in dry matter) and with very high protein in grain which have been steadily maintained for years (Table 5).

Table 5. Protein and lysine content in the grain of Bezostaya 1 mutants.

Line	Protein content in grain	Lysine content in	
		100g dry matter	100g protein
M 86/8	18.78	0.72	3.83
M 88/8	19.95	0.69	3.46
Bezostaya 1	13.47	0.32	2.38

These data show that the commonly observed negative correlation between grain protein content and lysine percentage of the protein is not absolute.

Unfortunately, these mutants are low-yielding but they seem promising for breeding fodder wheats. The investigations devoted to this new interesting trend in wheat breeding are at their very beginning. Probably it will take much time and a lot of effort to obtain the desired results, but their importance can scarcely be exaggerated. For instance, on our country's scale a 0.1% increase in lysine content of dry matter would enable us to provide an additional 100 thousand tons of lysine a year.

In a number of regions of the Soviet Union winter wheat is grown in rather severe overwintering conditions. In the case of snowless winters the temperature at the tillering node may drop as low as to 24-28°C below zero which causes an entire killing of winter wheat plants. The most winter-hardy varieties in the world (Ulyanovka and others) were developed in our country. But even these varieties do not assure complete survival of the crop. Besides, the varieties having the maximum winter-hardiness display low productivity. Mironovskaya 808 is a more productive winter-hardy variety among those released.

Recently some promising varieties combining high productivity with higher winter-hardiness were evolved by crossing Bezostaya 1 with winter-hardy cultivars of a steppe ecological type. They are: Priboy, Chernomorskaya and others bred at the All-Union Institute of Plant Breeding and Genetics in Odessa, Krasnodarskaya 39, Krasnodarskaya 46 and others developed at the Krasnodar Research Institute of Agriculture, and Donskaya Ostistaya produced at the Zernograd experimental station.

Soviet plant breeding faces the problem of finding ways to further improve winter-hardiness and develop varieties that exceed the wheat species in winter-hardiness potential. For a long time the plant breeders all over the world have desired to combine wheat characters with rye winter-hardiness. Now this problem is practically being solved by the Soviet plant breeders through developing highly winter-hardy Triticale. Wheat-rye amphidiploids (2n = 56) resulted from crossing the most winter-hardy Siberian ryes (Zima, Zhitkinskaya) with winter wheat varieties developed by Prof. V. E. Pisarev at the Institute of Agricultural Technology for Non-Chernozem Zone. Some of these amphidiploids display greater frost resistance than that of the most frost resistant winter wheats (Ulyanovka and others) and in this respect they come close to rye. These high winter-hardy lines of winter Triticale are used by our plant breeders to extend winter wheats to Siberia.

The new possibilities of winter-hardiness improvement in common wheats from inherited characters of rye were found by Dr. A. F. Shulyndin at the Yurjev Institute of Plant Breeding and Genetics in Kharkov. Of a particular interest are some Triticales developed by crossing three species, rye x common winter wheat x durum winter wheat incorporating in their genome 14 rye, 14 durum wheat and 14 common wheat chromosomes. These Triticales show high fertility, high productivity, and good milling and baking qualities. The winter-hardiness of these tri-specific Triticales consistently excels the Mironovskaya 808 winter wheat variety, and comes close to rye.

The wheat-quitch grass hybrids of an intermediate type (2n = 56) used now as donors of high winter-hardiness were obtained by Acad. N. V. Tsitsin and his coworkers. Hybridization of common winter wheats with spring durum ones is practiced in the Soviet Union for developing winter durum wheats. The most winter-hardy and drought-resistant durum varieties of a commercial value (Novomichuzinka and others) were developed by Acad. F. G. Kirichenko at the All-Union Institute of Plant Breeding and Genetics. These varieties already have been released and are being introduced into 5 regions of the South Ukrain. Similar work is carried out at our Institute and in some other centers as well.

In conclusion, I should like to note that requirements for improved wheat varieties have become so high and the problems are so complicated that it is rather difficult to solve them by a single method. Different methods, such as intraspecific and remote intergeneric and interspecific hybridization, mutagenesis, breeding for heterosis, aneuploidy and others must be combined. Nevertheless, hybridization on Michurin's principle of crossing geographically and ecologically remote cultivars and directional selection remains our main method of plant breeding. Our experience, accumulated for many years, shows that by this method new winter wheat varieties with a complex of the desired economical characters and properties can be systematically developed; the potential of their productivity being gradually increased.

As a result of our breeding work started in early 1930's the yields of winter wheat varieties have risen from 25.0 q/ha to 65 q/ha, i.e. by 2.5 times. By applying to more extensive genetic stock, this method in combination with others will enable us to successfully solve the complicated problems that wheat breeding confronts.

It is of great importance to widen the international cooperation of the plant breeders to ensure further progress in wheat breeding. The International Winter Wheat Performance Trials is one of the useful ways of such cooperation. I believe all of us are very grateful to Prof. V. A. Johnson, General Coordinator, for the arrangement of these trials and his valuable initiative to convocate this first International Winter Wheat Conference which is very interesting and fruitful for us.

WINTER WHEAT IMPROVEMENT PROBLEMS IN THE NEAR EAST AND NORTH AFRICA

by

Abdul Hafiz
Egypt

Introduction

During the last few years, a large number of high-yielding varieties (HYV) of spring wheat were identified in most of the Near East countries through the national breeding and testing programmes. With the extended use of such varieties some countries were able to achieve self sufficiency or at least to increase the overall production to meet a large proportion of their rising demands from domestic production. However, comparatively few efforts were made to develop or identify HYV of winter wheat (except testing of some varieties under Nebraska University/FAO programme), in countries where large areas can be grown annually with winter wheats. In the Near East Region, the winter wheat areas are concentrated in Turkey, Iran, Afghanistan and Pakistan (Quetta) and parts of Iraq where the environmental conditions are suitable for growing this type of wheat. However substantial areas exist on highlands of Algeria, Tunisia and Morocco, in which spring wheats possessing winter hardiness or varieties possessing intermediate habit of growth can be grown. Growing the right type of wheat varieties in such areas will help to increase the overall production in these countries.

Present Status

Production

Turkey: Wheat occupies a very important position in Turkey. Approximately 8.5 million ha. of wheat are grown annually. (45% of the total cultivated area.) Of this area about one million ha. of spring wheats are grown while the rest is occupied by winter wheats. As a result of testing programmes during the past few years, some HYV of spring wheats as well as winter wheats were identified. The identified winter wheats were Bezostaya (Russian variety) and Wanser (American variety). The average yields of these varieties approximated 2.3 and 1.9 ton/ha. respectively as against 1.5 ton/ha., obtained from the local varieties. By 1970 the area under winter wheat (exotic and local improved varieties) was very much increased in Central Anatolia and Thrace, totalling 1,048,285 ha. as shown below:

Bezostaya	250 542 ha
220/39 (local)	621 645 "
Wanser	37 133 "
1593 (local)	96 150 "
4-11 (local)	42 833 "

The extended use of these HYV helped considerably to increase the overall production.

Afghanistan: Wheat occupies about 2.3 million ha., (1.3 million under irrigation). The crop sown in the valleys in fall remains under the cover of snow during winter. Winter wheats and spring wheats capable of withstanding cold injury are suitable for cultivation in this area. From 1964 onward the varietal testing programme was stepped up and extended to all the regions, resulting in the identification of some HYV of the spring type (mostly of Mexican origin) and a winter wheat variety (Bezostaya). However, the area under the latter is still small. In localities where cold injury affects the present wheat varieties, it is necessary to replace them with identified HYV of winter wheats or winter hardy spring wheats.

Iran: Wheat occupies about 5 million hectares annually (of which about 45% are winter or semi-winter wheats). The estimated total production in 1969 was 4.4 million tons. Considering the annual increase in population and the need to meet the local demand, an impact programme to increase wheat production was started in 1968. Work was mostly concentrated on identification of HYV of spring wheat through the testing programme and on breeding suitable varieties both for coastal areas and highlands. For the highland areas (Azerbijan, Khorasan, Kermanshah) where only winter wheat can survive, it is essential to develop local winter wheats and/or identify HYV from introductions. From the International Winter Wheat Performance Nursery (IWWPN) the Russian winter wheat variety Bezostaya was identified which out-yielded the local varieties - Roshan and Omid. Bezostaya was introduced on a large scale and was expected to occupy 25,000 ha. in 1971/72 crop season.

Other countries: In some other countries like Morocco, Algeria and Tunisia there are large highland areas where the temperature goes below the freezing point during winter. For example, in Algeria about 60% of the total wheat area (3 million ha.) is located on highlands (1200-1500 meters) with very severe winters. In such areas it is essential to carry out yield testing programmes in order to identify HYV suited to the local conditions.

Thus, it can be concluded that there are quite large areas in some of the Near East and North African countries where production can be considerably increased through the introduction of suitable high-yielding winter wheats and/or spring wheats possessing winter hardiness. This is obviously clear from the performance of such varieties identified from IWWPN. This type of yield testing has proved of immense value and needs to be strengthened and continued even in North African countries.

Breeding and Improvement

Until recently, winter wheats did not receive proper attention as regards their breeding and improvement in the Near East Region. The only efforts under-way were to select frost-resistant lines out of the breeding programme on spring varieties. While making single plant selections only those were selected which were either winter hardy or flowered late to escape frosting period and pollen injury. Through this method it was possible to develop and release some suitable varieties in Iran and Turkey for high plateau areas.

The importance of winter wheats was actually highlighted through the initiation of IWWPN and the breeding programme on winter x spring wheats started by the Rockefeller Foundation at Davis, California. Through the latter, segregating populations are supplied to some countries for making selections either for spring types or for spring types possessing winter hardiness or for winter types. This programme is most likely to help the breeders in selecting useful lines for their countries.

Conclusions

From the present status of winter wheat production and improvement programmes in the Near East it may be concluded that there is a big opportunity to intensify the various activities for increasing overall production of winter wheat in the Region. Some suggestions are given below:-

1. In order to have immediate results on production it will be desirable to continue with the testing of varieties through the IWWPN which may also include some local cultivars (winter type and/or winter hardy spring types) from this Region. The sets of this nursery should also be sent to Morocco, Algeria and Tunisia. Through this nursery it will be possible to identify high-yielding varieties and release them in a short time.

2. The breeding programme started at Davis should also use some of the local varieties, including durums which are more prevalent in this area, as parents in order to give wider adaptability to the material. The segregating material should then be supplied to the breeders in these countries.

3. The breeding programmes on winter wheats in the Near East should be encouraged to develop close contacts with the University of Nebraska, where necessary facilities exist in various disciplines. This can be done through regular visits of Nebraska people, arranging training centres for the local breeders to learn breeding and selection techniques as well as by offering 4-6 scholarships to the breeders from the Region for higher studies to work on problems of winter wheats.

4. In the breeding programme to be developed in the region apart from other existing problems of winter wheat, special attention should be paid to incorporate drought resistance because of the prevalent water stresses in rainfed areas during the flowering and ripening periods. The incorporation of drought resistance will also help to improve cold tolerance. This programme should also consider the importance of improving grain quality.

5. Since very little information is available about the potential areas in Near East Region for growing winter wheats or winter-hardy spring wheats, it may be appropriate to carry out an intensive survey to identify and define these areas and assess the opportunity of growing such varieties to maximize production.

6. It will also be necessary to intensify studies on the cultural requirements of winter wheat or winter-hardy spring wheats under rainfed and irrigated conditions to exploit the real potential of such varieties. These studies should also include the possibilities of topping or grazing of winter wheat without affecting the yield in order to help sheep production.

It is appreciated that the improvement and production of winter wheats is now being realized as an important item in the Near East Region. No doubt, the holding of the First International Winter Wheat Conference will go a long way in identifying the problems and formulating cooperative programmes towards their solution.

WINTER WHEAT IMPROVEMENT PROBLEMS IN THE FAR EAST

by

T. Gotoh
Japan

Winter Wheat Area in the Far East

In Japan, winter wheat is grown from Hokkaido in the north, to Kyushu in the south. However, winter wheat often suffers from the long rainy season which occurs during ripening. In the southern regions wheat is planted in paddy fields following rice harvest in Oct.-Nov. In Korea, most winter wheat is grown south of the 40th parallel and in the northern regions wheat is grown mainly in paddy fields as in Japan. In China, winter wheat is grown to the south of the Great Wall. In southern China, where rainfall is high, wheat is cultivated in paddy fields. In central China frequent summer rains produce enough soil moisture for seeding. However, dry spells often occur from late autumn to late spring. Irrigation is necessary to produce good wheat crops in this district. Before World War II, irrigation was rare but recently the use of irrigation techniques with wheat has become common practice.

Representative Winter Wheat Varieties

Japan

Winter-hardy and high-yielding Hokuei was grown in Hokkaido. But, because of its susceptibility to quality deterioration by rain during ripening period, it is now being replaced by newly bred Mukakomugi. The famous Norin 10 variety, which was bred in our field in 1936 and once grown in a large area of the Tohoku district, now has been totally replaced by the winter-hardy, high-yielding and early-maturing Nanbukomugi variety. In the southern part of Tohoku district lodging-resistant Aobakomugi is cultivated. Aobakomugi is suitable for the farming practice of intercropping, because of its straight stem.

In Japan, winter wheat varieties are classified into 7 groups, I-VII, according to their winter habit. Group I wheats are like spring wheats in that they need almost no vernalization but differ in their reactions to photoperiod. Group I winter wheat is day-neutral and heads even under short days. Group VII winter wheats need the longest vernalization period. In southern Japan, group I-II winter wheats are grown. Short-culm and high-yielding Norin 61 variety has been grown most widely. But, recently, powdery mildew-resistant Ushiokomugi and early-maturing varieties such as Hiyokukomugi are replacing Norin 61.

Korea

Wheat breeding work started in Suwon about 50 years ago, and many Suwon series of winter wheat varieties were bred. Before World War II, Yunseung, Suwon 85, Suwon 96 and Turkey were grown in northern and central Korea while Japanese varieties such as Norin 4 were grown in southern Korea. After the war, high-yielding Chang Kwang and Yung Kwang were released and recommended. However, because of their late maturity, efforts were directed to the breeding of earlier varieties. As a result, early-maturing Jae Kwang and early and short-culm Ching-poon were produced. Recently, high-yielding and early-maturing Won Kwang was recommended for central Korea, and early-maturing Kyung Kwang and Nam Kwang were recommended for south Korea.

China

Breeding work began in 1936 and shortly after the establishment of the People's Republic of China, two superior varieties, Bihmaa 1 and Nanda 2419, were released. Each of these was grown on over 5 million hectares, about one-fifth of the wheat area of China. They were resistant to stripe rust and produced high yields on heavily fertilized soils. However, Bihmaa 1 has recently lost its stripe-rust resistance. Consequently, breeding work for rust resistance was set up with the cooperation of plant pathologists, and new wheat varieties such as Peiching 8, Chinan 2 and Chengchon 24, which are resistant to the now prevailing stripe rust race Tiaozhong 1, have been produced.

Objectives of Winter Wheat Improvement

Japan

In northern Japan, resistance to winter injury, rust resistance and improvement of quality are the main objectives while in southern Japan, early maturity and resistance to scab (*Gibberella zeae* (Schw.) Petch.) are the main objectives.

Korea

In northern Korea, high yields and resistance to winter injury are the main objectives. In southern Korea, high yields combined with early maturity are the main objectives.

China

In the central part of the winter wheat area, stripe rust resistance, lodging resistance and high yields are the main objectives. In southern China, resistance to scab and early maturity are the main objectives.

New Attempts

Japan

Introduction of rust resistance from alien species using chromosomal technology and generation acceleration methods has been practiced. Mutation breeding was applied to wheat improvement and a dwarf mutant of Igachikugo-oregon was obtained. It was added to Norin wheats in 1968. Many attempts have been made to produce earlier wheats by mutation but no success has been recorded for southern Japan.

China

After the two big wheat varieties Bihmaa 1 and Nanda 2419 were attacked by new stripe rust races, pathological studies were undertaken to clarify races of stripe rust and stem rust. As a result, wheat varieties resistant to the prevailing races have been produced. To future problems of this type, combination and rotation of wheat varieties have been planned in addition to the breeding of wheat varieties that are resistant to many races of rust diseases.

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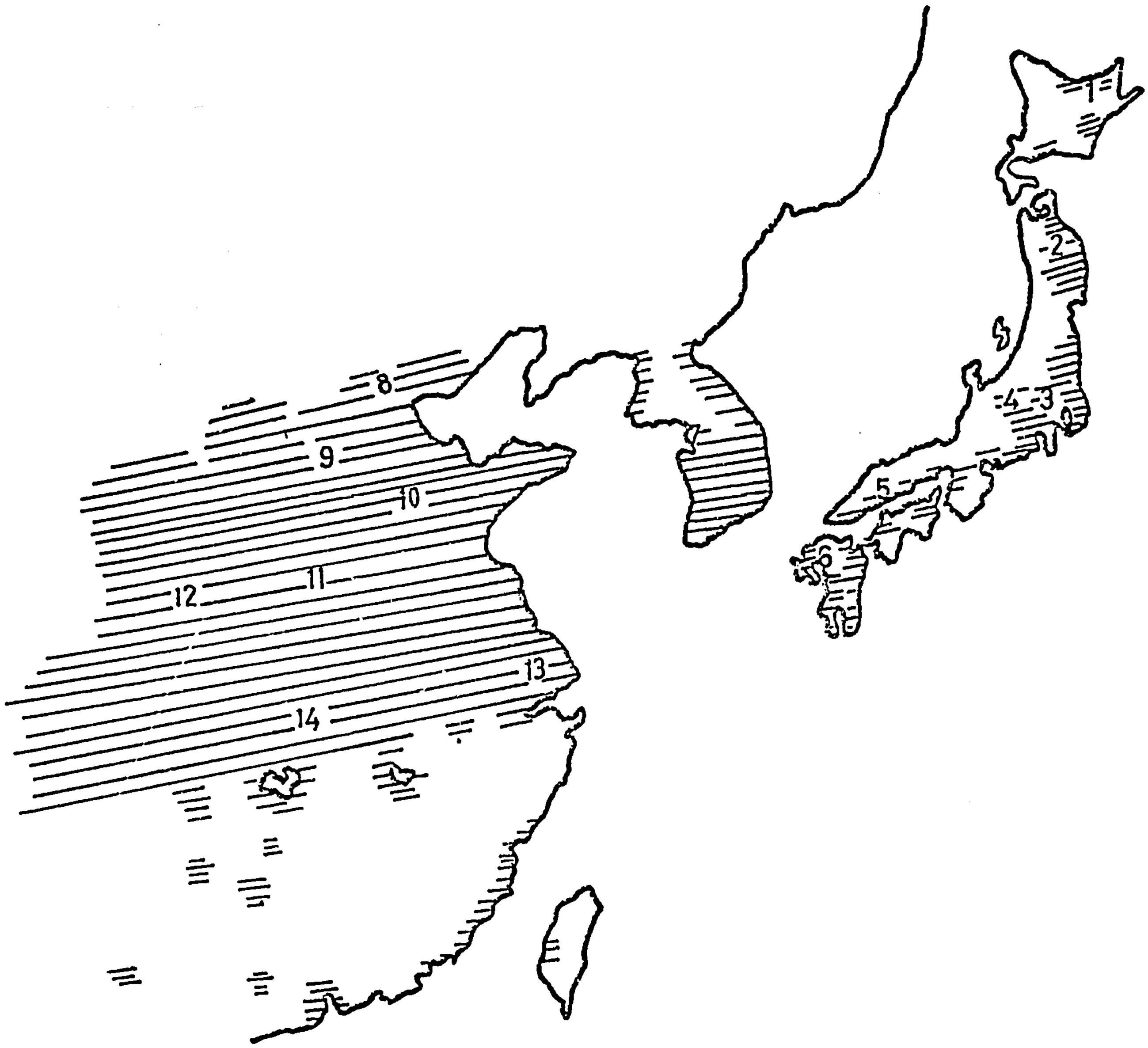

Figure 1. Winter wheat cultivation area in Far East and locations of winter wheat breeding stations. 1) Kitami Agr. Exp. Sta.; 2) Tohoku Nat. Agr. Exp. Sta.; 3) Central Nat. Agr. Exp. Sta.; 4) Nagano Agr. Exp. Sta.; 5) Chugoku Nat. Agr. Exp. Sta.; 6) Kyushu Nat. Agr. Exp. Sta.; 7) Crop Exp. Sta.; 8) Chinese Acad. Agr. Sci. Inst. Crop Res. & Peiching Agr. Univ.; 9) Hopei Wheat Res. Sta.; 10) Shantung Acad. Agr. Sci. Inst. Crop Res.; 11) Honan Acad. Agr. Sci.; 12) Szechwan Prov. Wanhsien Dist. Agr. Sci. Inst.; 13) Chinese Acad. Agr. Sci. Kiangsu Branch; 14) Hupei Acad. Agr. Sci.

WINTER WHEAT IMPROVEMENT PROBLEMS IN THE U.S.A.

by

E. L. Smith
United States

Wheat breeding and improvement centers are located in about 25 of the 50 states in the U.S. Most of these programs are a part of the State University Agricultural Experiment Station system and are staffed by state and/or USDA personnel. Some of these programs are rather modest; consisting of one or two workers. Others are more elaborate with several breeders and geneticists supported by pathologists, entomologists, cereal chemists, physiologists, soil scientists and other specialists. In addition, private seed companies have entered the wheat breeding field on a large scale during the past 10 years. The private breeding programs have been concerned primarily with the development of hybrid wheat. State and USDA cooperative wheat improvement projects are grouped into four regional programs in which workers from the private sector participate on an informal basis. These regions, in general, conform with the areas of production of particular market classes of wheat.

Market Classes and Areas of Production

Five different market classes of wheat are grown in the USA. These are: Hard Red Winter, Hard Red Spring, Soft Red Winter, White Wheat, and Durum.

Each market class is traditionally grown in a particular area of the country and although there is some overlapping, a specific region is generally associated with the production of a certain market class of wheat. Market classes and areas of production became associated in the early days of wheat culture when certain varieties dominated the production in certain parts of the country. This led to the establishment of market classes which were defined by the color and texture of the wheat kernel and by the inherent quality of the flour produced from these varieties. These market classes were established originally to permit the orderly marketing and processing of different types of wheat according to their best end-use potential.

Varieties have changed over the years, but the market classes have persisted. Grain standards set by the USDA and quality demands by the milling and baking industry have had a great deal of influence in variety development. Wheat breeders have improved yield potential, added disease and insect resistance, changed maturity, straw strength and other characters, but new varieties have generally conformed to the old market class standards in terms of quality.

The following brief discussion of the five market classes is based laregly on reports by Reitz (1970) and Reitz and Lebsock (1972).

'Turkey' wheat laid the foundation for the Hard Red Winter Market Class. The region of production of this class is the Southern and Central Great Plains area. Hard red winter wheat is used primarily for the manufacture of bread flour. This class is considered to be equal to Hard Red Spring in intrinsic baking value at comparable protein content, but traditionally, the hard red springs are slightly higher in protein. However, both classes of hard red wheats are generally higher in protein than the soft wheats. In 1969, 'Scout' was the leading hard red winter wheat variety, followed by the 'Triumph' group of varieties.

'Marquis' set the standards for the Hard Red Spring Market Class. The area of production is in the North Central States in the northern part of the Great Plains. This class is used in the manufacture of bread flour and, by tradition, is the premier bread wheat in the USA. In 1969, the leading hard red spring wheat varieties were 'Chris', 'Fortuna', and 'Manitou'.

'Fultz' and 'Fultz Types' established the Soft Red Winter Market Class with the area of production dispersed over the eastern half of the U.S. This class is used in the manufacture of pastries, crackers, biscuits, and cakes. The leading soft red winter wheat varieties in 1969 were 'Monon', 'Redcoat', 'Benhur', 'Blueboy', and 'Knox'.

The White Wheat Market Class is somewhat more complex than the others. There are two main areas of production, one in the Pacific Northwest and the other in the states of Michigan and New York. In addition, there are subclasses. Common white winter, as well as club wheats and a limited amount of white spring are grown in the west. 'Pacific Bluestem' set the pattern for the common white winter wheat in the Pacific Northwest. Soft white wheat production in the Michigan-New York area was established at a later date and was based on such varieties as 'Dawson' and 'Yorkwin'. The soft white wheats are used in the manufacture of pastries, crackers, biscuits, and cakes. In 1969, the leading white wheat varieties in the Pacific Northwest were 'Gaines', and 'Nugaines', and the leading white wheat varieties in the Michigan-New York area were 'Genesee' and 'Avon'.

The variety, 'Kubanka', established the Durum Market Class with the area of production concentrated in the North Central States. Durum is used in the manufacture of macaroni, spaghetti, vermicelli, and other alimentary pastes. In 1969, the leading durum varieties were 'Leeds' and 'Wells'.

In terms of seeded area and production, the Hard Red Winter Class far exceeds any other market class. Relative production figures of the five market classes for the 1971 crop are presented in the following table. (USDA Crop Reporting Board, 1972).

1971 U.S. Wheat Production by Market Class

Market Class	Percent of Total Production
Hard Red Winter	46.3
Hard Red Spring	22.3
Soft Red Winter	13.5
White (winter & spring)	12.5
(white winter common & club)	(11.2)
(white spring)	(1.3)
Durum	5.3
All winter wheat	71.0
All spring wheat	23.7
Durum	5.3

Total Wheat Production = 44.7 million metric tons

Yield Trends

Average yields of winter wheat in the U.S. have shown a steady increase during the past 10 years. Harvested area, average yields and production data for all winter wheats from 1962 to 1971 are presented below. (USDA Crop Reporting Board, 1972).

U.S. Winter Wheat Statistics, 1962-1972

Year	Area Harvested	Yields	Production
	million ha	(q/ha)	million tons
1962	13.7	16.4	22.4
1963	14.1	17.7	24.9
1964	15.4	18.0	27.9
1965	15.2	18.2	27.7
1966	15.7	18.4	29.0
1967	18.4	17.9	32.9
1968	17.2	19.6	33.7
1969	14.9	21.0	31.3
1970	13.5	22.4	30.3
1971	13.4	23.7	31.7

Undoubtedly, much of this increase in yield/area has been due to the widespread use of more productive varieties developed and released within the past 10 years. In the Pacific Northwest, Gaines and Nugaines are by far the predominant varieties, and both came into production during the past decade. Scout, comprising about 25% of the hard red winter wheat area, came into production in the second half of the past decade. Monon, Benhur, and Blueboy together account for about 50% of the area planted to soft red winter wheat. Monon came into production in the early 1960's while Benhur and Blueboy came into production several years later.

Average yields of winter wheat vary considerably from one region to the next. The highest average yields are found in the Pacific Northwest followed by the Eastern Region. Yields in the hard red winter wheat area are generally the lowest; particularly in the southern part of the region. Average yields of winter wheat in 1971 for selected states are shown below for regional comparisons (USDA Crop Reporting Board, 1972).

Average Yields of Winter Wheat by Selected States, 1971

Region & State	Yields (q/ha)	Percent of Total Winter Wheat Area Harvested
Pacific N.W. (Primarily Common White Winter)		
Washington	33.6	6.7
Oregon	30.9	2.1
Eastern Soft Wheat Area		
Northeast (White Wheat)		
Michigan	24.2	1.7
New York	26.9	0.4
Ohio Basin (Soft Red Winter)		
Indiana	30.3	2.2
Ohio	29.2	3.0
Southeast (Soft Red Winter)		
Virginia	29.6	0.6
North Carolina	28.9	0.8
South Carolina	26.9	0.4
Georgia	25.5	0.7
Great Plains (Hard Red Winter)		
Nebraska	28.2	7.7
Kansas	22.9	27.4
Oklahoma	13.4	10.5
Texas	14.1	4.5
Subtotal		68.7

Total winter wheat area harvested = 13.4 million ha.

Winter Wheat Improvement Problems

Some of the more important wheat improvement problems and related research activities are presented for each major winter wheat production region and its associated market class of wheat. The help of several wheat breeders in each market class-production area was enlisted in order to get a better idea of the current problems. The assistance of these wheat workers was most helpful and much appreciated. They are acknowledged at the end of this report.

Pacific Northwest

Wheat production in the Pacific Northwest is concentrated in eastern Washington and in the Columbia River Basin in Washington and Oregon. Wheat is produced under predominantly dryland culture on rolling land that often runs to severe slopes. Rainfall varies, but much of the wheat is in the drier zones where summer fallow is often practiced. Moderate temperatures and deep soils allow for relatively high water use efficiency. Current wheat improvement problems in the Pacific Northwest are listed below. (The following is based largely on communications from O. A. Vogel and F. H. McNeal.)

1. Yield potential. Increasing yield potential is of special importance in programs concerned with the development of varieties that can be seeded earlier in the fall for controlling soil erosion. Germination, emergence, and stand establishment from early planting in warm dry soils are problems, and research activities along these lines are underway. For early seeding, new varieties must have the ability to withstand longer periods of moisture stress and adjust to greater temperature fluctuations.

2. Dwarf bunt is the most serious smut disease at the present time. The casual organism is soil-borne, and seed treatment is not effective. For many years, common bunt dominated the wheat improvement efforts in the Pacific Northwest, but it has now been brought under control through the use of resistant varieties and chemical seed treatment. Flag smut causes problems in local areas and appears to be on the increase.

3. Stripe rust is the most serious rust problem at the present time and poses a threat to wheat production in the area. Stripe rust epidemics occurred in 1960 and 1961 and serious losses resulted. Damage was particularly severe on the club wheats, and production of these wheats declined rapidly following the epidemic. Activities concerned with breeding for stripe rust resistance were intensified following the epidemic. Leaf rust is also a factor but is not a serious threat at the present time.

4. Cercosporella foot rot is a serious problem, and this disease, along with other foot and root rots is becoming more important as a result of the intensive culture and management systems being used with semidwarf wheat varieties. Earlier seeding dates will also tend to intensify these problems. More effective screening techniques need to be found to adequately deal with these diseases.

5. Snow mold is a problem in some areas especially at higher elevations. Varietal differences in reaction to snow mold are known and at least two programs are working on this problem.

6. Pre-harvest sprouting can be a serious problem especially in areas of higher rainfall. Current breeding activities are centered around the development of lax-spike types that will shed water more readily.

7. Genotype-management systems. More information is needed in regard to variety development for higher management situations. This is particularly important for irrigated culture which has increased during the past few years.

8. Other problems of less serious nature are low test weight of the semidwarf types, shattering, and powdery mildew.

Eastern Soft Wheat Region

Soft white winter wheats are produced in the states of Michigan and New York. Soft red winter varieties are grown in the remainder of the eastern part of the U.S. with an area of concentration in the Ohio Basin. Areas of production are scattered along the Atlantic Coast states and in the southeast. The eastern region spreads across the subhumid and humid climatic zones of the U.S. and moisture conditions are generally adequate. This is a region of diversified farming systems, and wheat is often grown in rotation with other crops. (The following list of problems in the eastern region is based on communication from E. H. Everson, N. F. Jensen, K. L. Lebsock, H. N. Lafever, and C. F. Murphy.)

1. Yield potential. Wheat competes with other high-value crops such as corn and soybeans in this region. In some areas, wheat is being replaced by other crops with higher production potentials. A partial solution to this problem could be obtained by developing wheat varieties for double-crop culture with corn or soybeans. A wheat-soybean double cropping scheme has considerable merit, especially for the southeast. Some progress in this connection has been made already.

2. Lodging is often a serious problem in the higher rainfall areas. Work is underway in developing varieties with shorter, stronger straw. Semidwarf germplasm is being utilized extensively in these programs.

3. Leaf rust is serious, and most new varieties carry some level of resistance. The widespread use of leaf rust resistant varieties in the Ohio Basin has brought on serious problems with other foliar diseases.

4. Powdery mildew is a constant threat and the recent appearance of new races of this organism in the southeast poses additional problems to breeders in that area.

5. Hessian fly is ever present, but the use of resistant varieties has eliminated serious losses in major wheat growing areas. However, the potential variation in fly populations poses a serious threat. The cereal leaf beetle is a potential threat in the northern part of the soft wheat region. Resistant germplasm is being utilized in breeding programs and chemical control systems are being evaluated.

6. Septoria leaf blotch is an important problem in the Ohio Basin, and breeders may be making some progress by selecting disease-free plants from certain crosses. Septoria glume blotch is a problem, especially in the southeast. Low levels of resistance to this disease have been found in adapted types.

7. Winterhardiness levels need to be increased in the soft white wheat area, especially in Michigan. Serious problems are often encountered by rapid freezing after a period of thawing.

8. Genotype-management systems. Information is needed on optimum fertilizer applications, seeding dates and other cultural practices

with regard to the newer varieties. More information is needed on variety response to early harvest and forced drying as a possible practice for double-cropping systems.

9. Other problems include soil-borne mosaic and foot and root rots. Common and dwarf bunt are often problems in the eastern soft white wheat area. Low test weight of semidwarf types is a minor problem. There are indications that aluminum toxicity may be a problem in certain areas.

Hard Red Winter Wheat Region

Hard Red Winter Wheat is produced in the Southern and Central Great Plains. The area has a rather severe continental climate with great extremes in temperatures. Precipitation is low and erratic. Water use efficiency tends to be low because of high evaporation rates. Drought is a common hazard, especially in the southern part of the region and often results in a high rate of abandonment. Most of the wheat is under dry-land culture, although some irrigation is used in the southern part of the region. Summer fallowing is practiced to some extent along the western side of the region. (The following list of problems for the hard red winter wheat area is based on discussions with and reports from a number of workers in this region.)

1. Yield and stability of yield. The release of earlier maturing, more productive varieties has resulted in substantial gains. Still, inherent yielding potential needs to be increased with regard to conventional cultural systems. Also, varieties more efficient in water absorption and utilization are needed to provide greater yield stability in the region.

2. Stem rust. A serious epidemic occurred in 1961 and 1962 in the northern part of the region and this disease is a constant threat in certain areas. Stem rust is seldom a problem in the southern part of the region because crops usually mature early enough to escape serious damage. Leaf rust occurs throughout the region and poses a threat in the form of reduced yields and quality. Medium and late maturing types are usually more seriously damaged.

3. The greenbug is the most serious insect pest in this area, being particularly destructive in the southern part of the region. No resistance to present biotypes is known in wheat. Research is underway to determine the effectiveness of biological control through the use of parasitic wasps as well as in the transfer of resistance from rye to wheat. Hessian fly is potentially a threat in Kansas and Nebraska and must be given consideration in breeding programs.

4. Wheat streak mosaic virus is potentially the most serious virus disease, especially in the western part of the region and breeding programs are attempting to deal with this problem. Soil-borne mosaic virus is prevalent along the eastern edge of the region. Resistance to this disease is available in a number of adapted varieties.

5. Grazing characteristics. In the southern part of the region, wheat pastures are extensively and often intensively grazed by beef cattle during the fall and winter months. The livestock are

removed from the fields in February or March so that a grain crop can be produced. Much work is needed in connection with variety development and management systems to maximize both forage and grain production. Fall infections of leaf rust and slow recovery after grazing are serious problems.

6. Helminthosporium root rot and other root and foot rots are becoming more serious in the western part of the region. These diseases apparently increase in importance under intensive culture and stubble-mulch tillage. Several research studies have been started in attempts to deal with this problem.

7. Genotype-management systems. More information is needed on genotype X environmental interactions under present cultural systems in the Great Plains as well as for irrigated production and for systems that involve earlier planting schedules for wheat pastures.

8. Other problems. Protein content is below standard in certain areas in some years. Shattering is sometimes a problem. Lodging is often a problem and winterhardiness has to be reckoned with.

General Considerations

It is evident that yielding potential is of prime importance in wheat improvement programs in the U.S. Most workers appear to be optimistic that significant gains can yet be made through variety development and improved management practices. There exists, also, the need to develop higher yielding types to fit modified and changing cultural systems such as envisioned with earlier seeding dates in the Pacific Northwest for soil erosion control and for double-cropping systems with corn or soybeans in the southeast. There is also a need, particularly in the Great Plains area, for varieties that will provide for greater stability of yield at higher performance levels under various degrees of moisture and temperature stress. Semidwarf germplasm is being exploited in many programs in attempts to increase yields and straw strength. Significant gains have been made by this approach in areas with good moisture relationships. Whether the semidwarf types will serve the Central and Southern Great Plains remains to be seen. Newly developed semidwarf types are being examined critically for possibilities in that area.

Disease and insect problems have consumed an enormous amount of the wheat breeder's time and resources in the past and will continue to do so in the future. There is no getting around it. Protective breeding is important and cannot for long be minimized or ignored. The pattern of protective breeding may change. There appears to be a renewed interest in general resistance systems to replace the pyramid-breeding approach that adds new race-specific genes for resistance as the need arises. Perhaps both general and vertical resistance systems can be utilized so that one compliments the other.

Research workers in all areas of the U.S. are concerned about the general lack of information on genotypic response to different systems of management for local production areas. In particular, more information is needed with regard to types of varieties best suited for intensive management under irrigation. Cultural practices are being changed in various parts of the country, and information on genotype by environment interactions under these conditions is needed to serve as guidelines for variety development.

There seems to be no serious quality problem in any of the market classes of wheat at the present time. Apparently, this means that the wheat breeders and cereal chemists have been doing an adequate job. Perhaps, also, the milling and baking industry has become more flexible with regard to quality requirements. There are, however, some minor problems with protein content. In the hard red winter wheat area, when moisture stress is not a factor, protein may be too low. Conversely, in the Ohio Basin, the protein content of soft red winter varieties grown under high management systems is sometimes too high for processors who are accustomed to lower protein levels.

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SPECIFIC ADAPTATION IN WINTER WHEAT

by

G. D. H. Bell
England

A New Approach

Plant breeders have been much concerned for many years with the more effective exploitation of genotype/environment interaction in order to achieve improvements in crop performance in terms of higher yields of acceptable quality. The degree of success achieved by a new variety has been measured largely by the proportion of the area of the particular crop on which the variety is successfully cultivated and supersedes older varieties, and breeders have naturally tended to concentrate on wide or general adaptation. But it cannot be claimed that, even with the tremendous improvements that have been achieved by breeding, there has been anything approaching a rational and systematic approach to progressive maximising of genotypic performance for clearly defined specific environments.

There has been a compromise between breeding for closely defined ecological conditions and the wider concepts of a more generalised environmental approach. Basically, the ultimate determination of objectives in this respect has rested on what is economically worthwhile rather than what might be achieved. Further, there has been a lack of knowledge to define quantitatively the important characters of the plant which determine yield potential in particular environments whose characteristics have similarly lacked definition in terms of significant parameters.

These circumstances were recognised by Findlay and Wilkinson whose work with barley in Australia in 1963 provided the basis for a more ambitious approach, though the context of their work must be borne in mind when extending the application of their thinking and techniques to other circumstances. Their contribution, which is of great significance, is that they devised, as they claimed, a simple and dynamic means of measuring and interpreting varietal adaptation to natural environments. But, as they pointed out, it has been the lack of quantitative measure of natural environments that has held up, more than any other single factor, advance in the exploitation of adaptation in breeding programmes.

I shall hope to demonstrate that significant progress is being made in applying new knowledge, and this has already achieved most significant advances in wheat improvement under the environmental conditions of England. I must also state at this point that further valuable contributions to our knowledge have been made by the publication of the Agro-Climatic Atlas of Europe in 1965 and the Atlas of the Cereal Growing Areas of Europe in 1969. The compiling of these Atlases has demonstrated clearly the necessity for increasingly refined definitions in local or zonal environmental characterisations.

It is my view that the conclusions reached by Brockhuizen, Thram, Kupers and Dantuma in their text to the Atlases has revealed clearly the practicability of achieving more delicately balanced varietal adaptation. At the same time these authorities have made a most valuable contribution by giving greater precision to the major environmental parameters while linking these with biological functions such as Phenological Type, and with farming systems, crop husbandry standards and the incidence of pests and diseases. Finally, there is available the analysis of some plant characters which are significant as ecological or adaptive features and reflect yield performance in particular environments.

We can but anticipate, therefore, progress towards a wider application of specific adaptation, though it must be agreed that it is not yet clear what the practical possibilities are, nor yet what is realisable. We shall at least have the greater satisfaction, though, of testing our technical skills based on sound knowledge, against the requirements that are scientifically known and better understood.

English Wheat Growing

Wheat in England is predominantly autumn sown (October - November) and occupies usually 800,000-1,000,000 hectares. Approximately 70% is situated in the eastern and southern part of the country where there occurs the highest proportions of arable land and the soils are of heavier texture. The variation in terms of climatic zones is restricted, but on any accepted criteria the climate is free from extremes, is mild and of a maritime nature, but is variable from season to season. This variability is a potent cause of fluctuating yield levels, which are reflected in average national yields and are responsible for much of the local yield variations at trial sites.

Although English wheat yields have always ranked among the highest in the world, there was outstanding improvement during the 30 years from 1936 to 1966 when yields doubled. This rate of improvement has not been continued since on a national scale. The reasons for this are not clear, but are considered by some to be due to soil condition, aggravated by changed farming systems and structural damage, as well as to foliage diseases. The period has also coincided with some adverse growing conditions caused by excessive rainfall which have aggravated soil and husbandry limitations.

The lack of any strong ecological differentiation in the wheat growing area of England in relation to the wheat varieties available has precluded any very precise local recommendations for particular varieties, while for many years wheat growing was dominated by single varieties, for example Squareheads Master and then the French variety Cappelle-Desprez. Specific adaptation was confined to soil texture and soil fertility, and it may be noted that Western European bred varieties have been widely grown, as may be seen from the distribution of Cappelle-Desprez and Champlein. The use of these varieties, superseding the more northerly bred varieties from Scandinavia, was very significant in marking a change in physiological type and the increasing emphasis on shorter straw, higher yield, less extreme low temperature requirement and shorter growing season. Undoubtedly this led to a closer adaptation to major climatic requirements and to higher farming conditions, while in recent years there has been the intrusion of another major parameter - resistance to the foliage diseases stripe rust (*Puccinia striiformis*) and powdery mildew (*Erysiphe graminis*), and to the soil-borne disease eyespot (*Cercosporella herpotrichoides*). Climatically, recent specific adaptation has been characterised by reference to varieties for the higher rainfall districts of the west which are relatively of minor importance but afflicted by the higher incidence of powdery mildew and *Septoria* disease.

The current situation (1972) is that the highest yielding varieties recommended for general use in England - Cama (Belgian), Joss Cambier (French) and Maris Ranger (English) - are derived from crosses involving Cappelle-Desprez. They were bred in similar ecological conditions and they have a common parent, but the two continental European varieties are suspect on their reaction to stripe rust. Nevertheless, they may be regarded as good examples of specifically adapted varieties and exemplify a new situation arising from the superseding of Cappelle-Desprez which started in 1960 when the variety Professeur Marchal broke through as a superior yielder and subsequently made a significant contribution in the next phase of the breeding work.

It is in regard to the operation and results of this breeding work that the concepts and precepts of specific adaptation have particular reference. There is clear evidence of a much more effective synthesis of knowledge involving a range of scientific disciplines and the integration of these with the problems of increasing agricultural potential based on farming systems as these are constrained by environmental factors.

Fitting the Genotype to the Environment

In an address entitled "Biological Productivity and Environment" given at the British Association in 1971, I said it was a fair assumption that the natural environments of specific agricultural areas in Britain were not being fully exploited in terms of their productive capacity. There is immediate scope for improvement by applying the relevant, though inadequate, knowledge regarding the operation of the primary controlling meterological parameters on the one hand, and the known variation in physiological plant characters on the other hand.

Critical parameters are operative at the macro- and micro-climatic level at different stages of plant growth, and the really significant consideration is that quantification of the complementary systems - plant and environment - is now practicable. It would thus seem that more effective use of the resources can be made by matching plant models to environmental models, though more exact knowledge on a wider scale is necessary for really efficient exploitation.

It can be reasonably claimed that the task of matching genotypes to environments is no longer a matter of judgement or empiricism only, but has become a matter for sophisticated experimentation. This situation has been reached through a multi-disciplinary approach by which we have micro-climatologists, plant physiologists, physicists, geneticists and plant breeders all attacking the same main problem - the improvement of biological efficiency.

Inadequate knowledge has made it inevitable that breeders should work principally on generally adapted varieties, though this in itself ultimately requires as great a degree of sophistication as special adaptation. But there is still no very clear view as to the degree of sensitivity in adaptation it is practical or possible to achieve by the fullest exploitation of the available genetic variation adjusted to specific environments. However, I think the wheat breeding work at Cambridge being conducted by Mr. Bingham and Dr. Lupton can be used as an indication of significant advances in this difficult and complicated subject.

Bingham's approach has been to consider the basic physiology of the wheat plant in relation to photosynthetic capacity during grain filling and the ability of the grain to store carbohydrate (the so-called "source" and "sink"); the phenotype during the vegetative phase; and the phenotype during the post anthesis period. He has come to a number of interesting conclusions regarding the operation and possible manipulation by breeding of these characters each of which is significant in relation to adaptation. First, both source and sink are important in limiting yield and enough is known to use both features in plant breeding. Second, in the European climate in which he worked, and with optimal husbandry, there is intense competition between plants and shoots before anthesis especially for light and probably for assimilate, so that efforts should be made to minimize the adverse effects of both forms of competition. Thirdly, the most promising opportunity for improvement during the vegetative phase is to increase the allocation of assimilate to ear and flag leaf: this may be achieved by shortening the straw or by increasing the ear size. Fourth, adjustment of the timing of floret differentation. Fifth, prelongation of the period of ear development.

Bingham lays stress on the importance of maintaining the photosynthetic activity of the crop as long as possible and extending the period of grain filling. In this connection he draws attention to increasing the longevity and photosynthetic rate of the lower leaves and in having erect flag leaves. While there are other refinements relevant, and Lupton's work on an effective model is particularly pertinent here, with reference to adaptation to Cambridge conditions, it must suffice to mention that Bingham alludes to the appropriateness of reconsidering the significance of awns in wheat. The experimental evidence indicates that awns in general increase yield only when the post anthesis stage is shortened by hot, dry conditions, but he speculates whether in the climate of Western Europe, and as new higher yielding varieties are bred, the increasing importance of photosynthetic activity may put a premium on awns, particularly for dwarf varieties.

Of course, it is obvious that these considerations have the widest application in breeding for improved performance, and there are others, such as the length of life cycle, the partition of the life cycle, photoperiod sensitivity and low temperature requirement, which are relevant. But, I must emphasize once more, there must surely be a most significant element in regard to specific adaptation. The most effective way to demonstrate this is in regard to what has been achieved by Bingham and Lupton in the breeding of varieties of improved performance for English conditions. Before I give the details it can be asserted that new high levels of yield have been attained and we have thus moved into a much more effective sphere of adaptation.

The Improvement of Wheats of Conventional Height

The results from the 1969 International Winter Wheat Nursery Trials indicate that the variety Cappelle-Desprez has specific adaptation to high yielding conditions, and this character has been exploited in the breeding programme (Figure 1). In 1968 Maris Ranger was marketed having been selected on Bingham's main selection criteria from a cross of Cappelle-Desprez with the Swedish variety Peko. Its performance on the basis of national trials (1971) gives Maris Ranger's yield as 6 per cent above Cappelle. It has, however, been established that Professeur Marchal was a higher yielding variety than Cappelle-Desprez, though of inferior standing capacity, and the basis of its higher yield potential was confirmed from its physiological components and photosynthetic activity in different light intensities.

Bingham used this potential in hybridization involving a complex cross involving Cappelle-Desprez, Hybrid 46 and Professeur Marchal from which he derived three still higher yielding varieties - Maris Beacon, Maris Nimrod and Maris Huntsman. Maris Beacon was not marketed because of susceptibility to stripe rust, but the yield performance of the other two at six centres in 1971 show their superiority. Maris Nimrod is currently rated from national trials as being 17 per cent above Cappelle-Desprez and is in a yield class of its own among recommended varieties (Table 1).

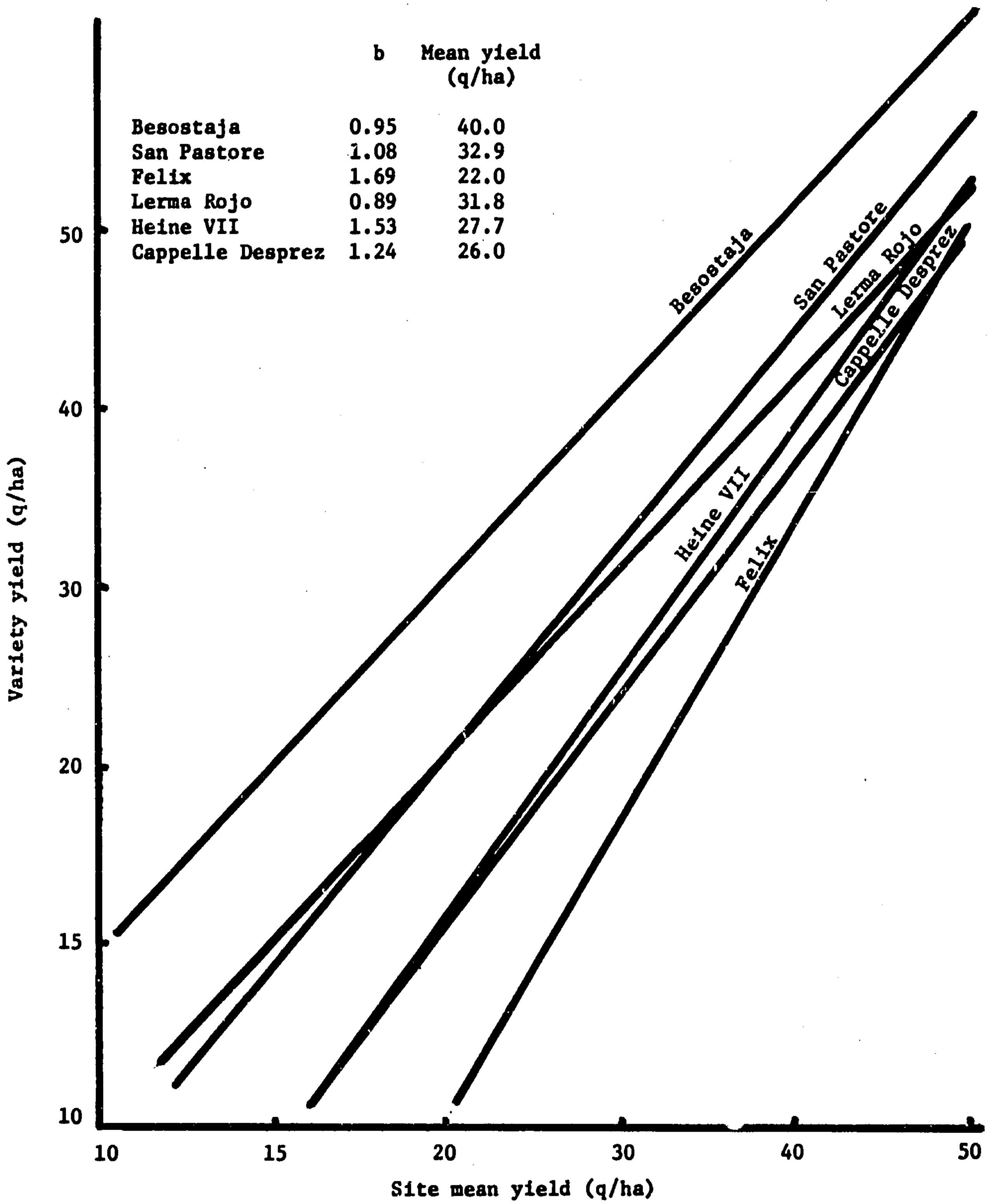


Figure 1. Relation of variety yield to site mean yield, I.W.W.P.N. 1969.

Table 1. Winter wheat yields, 1971, % (Cappelle Desprez + Maris Ranger)/2.

	Cambridge	Cockle Park	Harper Adams	Morley Manor	Sutton Bonington	Terrington
Cappelle Desprez	92	90	97	98	95	98
Maris Ranger	108	110	103	102	105	102
Joss Cambier	82	93	91	103	92	97
Maris Nimrod	87	138	125	120	115	115
Maris Huntsman	81	138	122	107	112	115
Maris Templar	108	151	120	120	119	117
LSD	9.7	9.2	5.7	5.0	3.6	6.2
Control yield (q/ha)	53.0	37.0	49.2	52.0	60.1	61.5

(Selected NIAB Sites with acknowledgements)

These data demonstrate conclusively the inferiority of Cappelle-Desprez and Joss Cambier in these five selected sites in one year, the unsuitability of the Cambridge site in some respects, and the outstanding performance of Maris Templar. This variety, which has not yet been recommended, is a complex hybrid involving Cappelle-Desprez, Nord Desprez, Heine 110 and Viking, and has been subjected to similar selection criteria as the other Cambridge varieties.

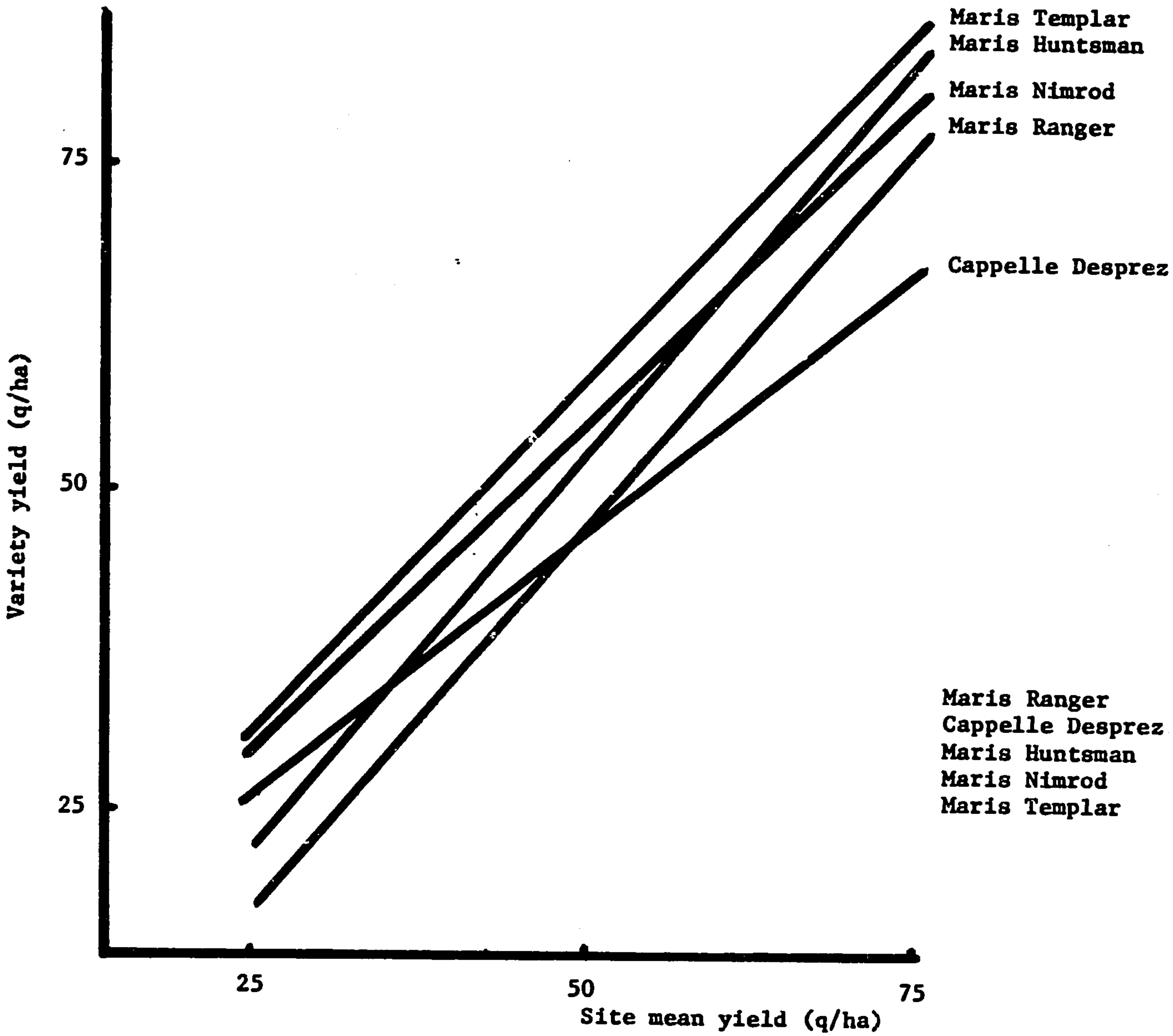
Using the Findlay-Wilkinson analysis on these data the regression coefficients of the four Cambridge varieties are clearly of an order which indicates specific adaptation. Their performance is in marked contrast to that of Cappelle-Desprez, which on these criteria must be regarded as a variety of general adaptation (Figure 2). This is confirmed by Plant Breeding Institute trials, 1965-68, of Maris Ranger, Joss Cambier and Cappelle-Desprez (Figure 3).

The Exploitation of the Dwarfing Genes

Lupton has been exploiting the dwarfing genes originating in Norin 10, but transferred to genotypes adapted to English conditions through a series of complex crosses via material developed by Vogel in the USA. He has used the varieties Maris Beacon, Maris Templar and Maris Nimrod and high yielding selections as the "indigenous" parents, with other varieties such as Maris Widgeon, Maris Huntsman and the Swedish variety Alte for incorporating non-race specific resistance to stripe rust. Comprehensive developmental and physiological studies among selected semi-dwarf segregates have demonstrated clearly that they possess characteristic features which provide new models for more efficient genotype/environment interaction.

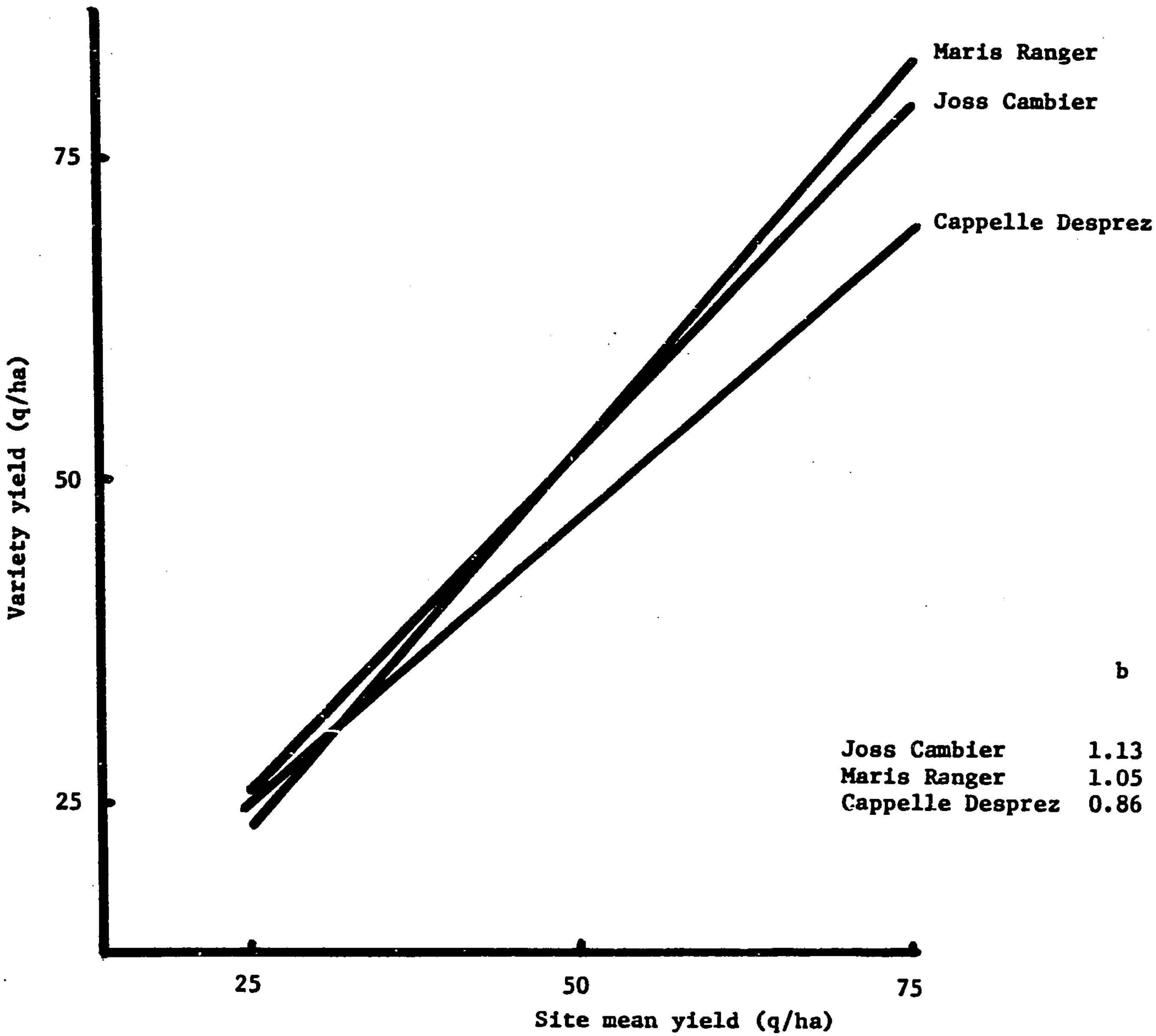
The most obvious feature of the semi-dwarfs is a more efficient partition of assimilates to the grain as demonstrated by growth analysis. They also show a slightly more efficient photosynthetic activity, a higher loss of juvenile tillers but a greater number of ears per square metre. The semi-dwarfs produced a heavier and longer root system than the standard varieties compared with a higher proportion of deeper placed roots.

The gratifying result of selection within these forms has been a significantly better yield than the variety Maris Huntsman which, as has been previously shown, is in the new bracket of high yielding English wheats of conventional height (Table 2). But what is even more significant, some of these semi-dwarfs responded



	b	Mean yield (q/ha)
Maris Ranger	1.13	54.8
Cappelle Desprez	0.82	50.5
Maris Huntsman	1.17	59.8
Maris Nimrod	0.99	60.5
Maris Templar	1.08	63.5

Figure 2. Relation of variety yield to site mean yield, 1970-71.



	b	Mean yield (q/ha)
Joss Cambier	1.13	54.0
Maris Ranger	1.05	53.6
Cappelle Desprez	0.86	49.0

Figure 3. Relation of variety yield to site mean yield, 1965-68.

significantly in one set of trials by increased yields with intensive nitrogen applications, when other varieties showed little response. This feature has still to be confirmed as a specific adaptative characteristic, and it certainly does not occur under all conditions.

Table 2. Yields of semi-dwarf wheats, 1971, % Maris Huntsman.

	Cambridge	Headley Hall	Morley Manor	Seale-Hayne	Boxworth	Mean
Maris Huntsman (q/ha)	50.6	34.3	47.7	44.7	35.7	
TL 363						
Cult 16/3	116	104	108	98	96	104
19/3	126	128	107	90	103	110
30/5	104	124	114	104	100	110
TL 365a						
Cult 34/1	118	129	110	104	85	109
37/6	118	113	104	74	101	102
LSD (P = 0.05)	10.9	12.4	7.9	8.6	7.8	

Some Concluding Thoughts on Specific and General Adaptation

If the increasing population pressures on the world's natural resources, in terms of biological materials and the physical environment, are to be met it is inevitable that there must be a greater intensification of agriculture through better adjustment of farming systems and higher levels of biological efficiency. As the requirements become more demanding, and the biomass production becomes a more critical consideration, meeting the environmental requirements to achieve the maximum effort becomes more difficult and entails more critical adjustment of the genotype. Applied to any crop species this means an adjustment of a dynamic biological system over the whole of its growth to a fluctuating environmental system of more or less infinite variation on which husbandry management is superimposed. The evidence available supports the conclusion that a more efficient adjustment is practicable by exploiting specification adaptation.

It must be accepted, though, that the same scientific concepts are applicable to specific and general adaptation, and thus also are the scientific methods and techniques. Consequentially also, both forms of adaptation have their particular connotations in which they are especially applicable, and conditions in which one or the other at any point in time has special relevance. This does not mean, however, that it is not more effective to operate on the basis of specific adaptation in most circumstances and particularly so under conditions of intensive production and environments of high productivity.

The extension of the concepts of Findlay and Wilkinson as knowledge becomes more precise is logically towards specificity in adaptation. This does not mean that a highly successful specifically adapted variety will not have application under other circumstances. Indeed, there is evidence that this is so. My thesis is, though, that improved performance results from more sophisticated adjustment to environment than is practicable from more general adaptation, and it must be remembered that Findlay and Wilkinson did their work "without the complexities of defining or analyzing the interacting edaphic and seasonal factors".

This is what is now being done. The dynamic relationship between all the important characteristics of the productive system of the cereal plant and the major physical parameters of the environment is yielding to intensive research. This is what we mean when we talk about specific adaptation within the context of life cycle and physiological manipulation. Breeding for resistance to water stress, to more effective growth rate and photosynthetic activity at low temperatures, to higher photosynthetic activity at lower light intensities, to the most effective crop canopy and maximum efficiency at the post anthesis stage are all examples of meeting the requirements of specific adaptation. We have not really met this challenge adequately in the improvement of wheat for English conditions, but there is every prospect of further improvements resulting from the valuable advances made in recent years.

THE CASE FOR GENERAL ADAPTATION

by

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Plant breeders have long recognized the desirability of a variety stable over a range of environments. They have recognized, also, that variations for stability among crop varieties exists. Yet, most breeding programs have been geared toward the breeding of varieties adapted to the particular area in which the breeding center is located. Reich and Atkins (1970) state that this is due largely to the fact that methods for determining general adaptation have not been available. We would add that these should be relatively simple methods if they are to be used widely. However, the methods used in selecting and/or testing of lines have been factors also.

The wide adaptation of many of the spring wheats coming from the CIMMYT program is due in part to selecting the highest yielding segregates successively in different environments (Finlay 1970, Borlaug 1968). Borlaug (1968) credits part of this to the introduction of light insensitivity into this material. Allard and Bradshaw (1964), in their discussion of genotype-environment interaction, suggest that there has been progress in raising average performance in varieties. For example, the average wheat yield in the United States has doubled in the last 20 years (Figure 1).

Genotype-environment interactions have been under study for a long time. However, the recent flurry of papers on this subject was sparked by the research reported by Finlay (1963) and Finlay and Wilkinson (1963). They used regression analyses to determine adaptation. Specifically, they used mean nursery yields to classify the environments from low to high yielding. The response of a variety to these changes in environments was measured by its regression coefficient. Using the regression coefficient and mean yield, they were able to classify lines into those having specific adaptation for either high or low yielding environments, general adaptability to all environments, or poor adaptability to all environments. Finlay (1963) states that varieties having a regression coefficient of 1 would be considered to have average stability, those with values above 1 would be less stable, and those with values close to zero would be highly stable over all environments. He describes, "the ideal variety as having maximum genetic potential in the highest yielding environment and maximum phenotypic stability". This may not be attainable, but new varieties with increased average performance and near average stability are a step in that direction.

Scott (1967) defined average stability as "that showing the least change in relative performance with other varieties in many environments". These varieties would have a regression coefficient near 1. In experiments with corn materials, he found that those F_2's selected as low yielding had the lowest b values and those selected as medium or high yielding had b values above 1. Baker (1969), on the other hand, did not find the regression technique particularly useful in an analysis of Canadian wheat yields. However, diseases were a factor in these experiments, and therefore the yield data were not always a true test of yielding ability. Walton (1968), in discussing similar tests, points out that leaf rust was a confounding factor and that different conclusions were drawn depending on

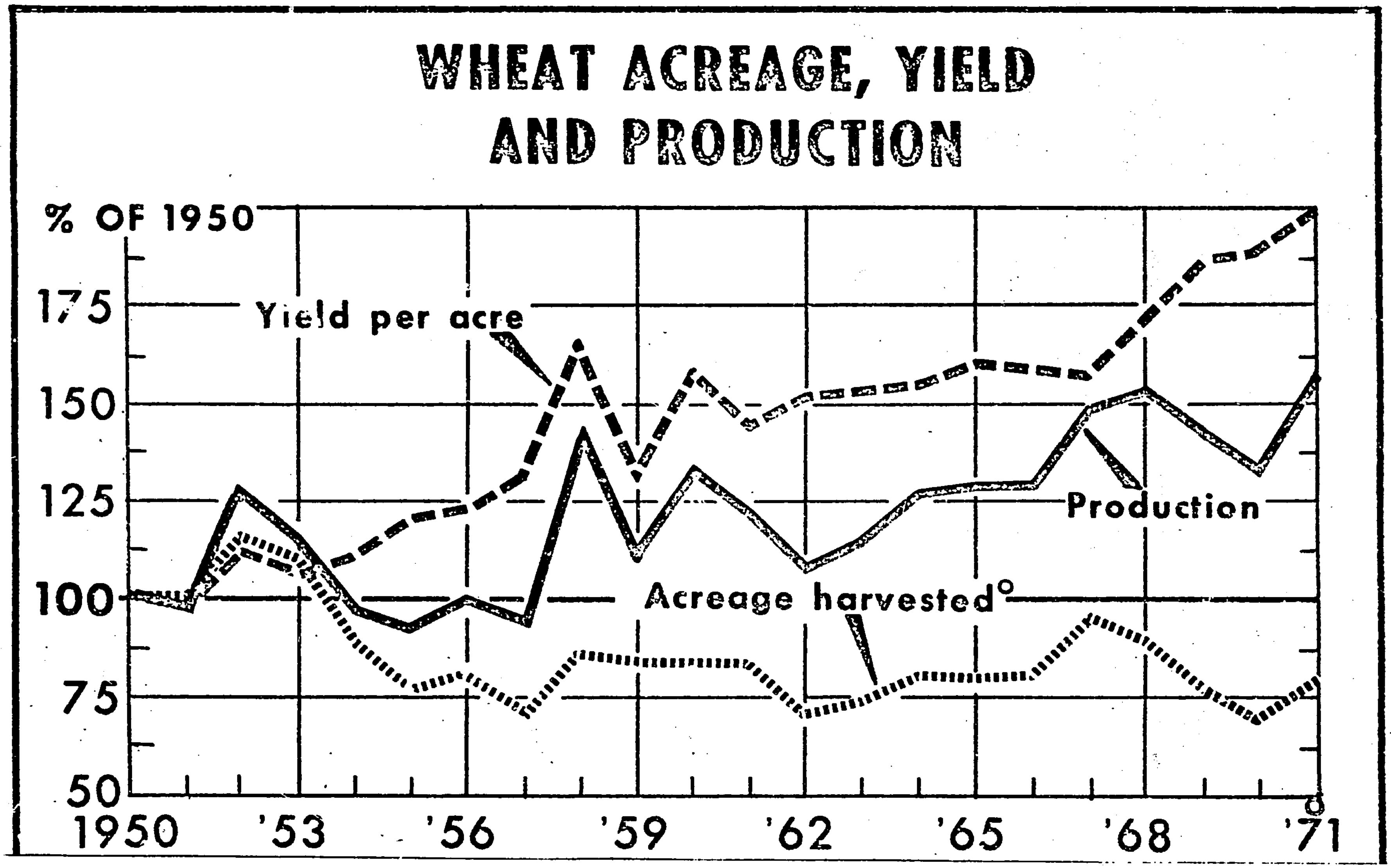

Figure 1. Wheat acreage, yield, and production in the United States, 1950-1971 (based on information from the U. S. Department of Agriculture, Economic Research Service ERS 3967-71(8)).

the exclusion or inclusion of certain tests. Walton concludes that, in general, stability of performance has been sacrificed to yield because phenotypic stability and yield appear to be negatively correlated. Joppa et al. (1971) found the regression method valuable in analyzing uniform regional nursery data. They placed greater emphasis on the mean square deviations from regression ($\bar{s}_d 2$). They pointed out that varieties deviating significantly from the slope of the average regression line (b = 1) should be examined carefully for possible deficiencies.

All of the papers reviewed point out that testing over a wide range of environments is essential if widely adapted varieties are to be identified. Russell and Eberhart (1966) suggest that when locations are limited as they usually are during the selection process, "extra locations" at any one site can be produced artificially by differential fertility applications, planting dates, and moisture additions.

The Great Plains of central North America represents an area of extensive wheat production under highly variable and often precarious conditions. The climate is continental and highly variable from year to year and within seasons. Soils are highly variable. Rainfall over the area ranges from about 12 inches to 40 inches, and elevation from about 500 feet to 5,000 feet. In this region is the Hard Red Winter Wheat belt of central North America, the region that Johnson et al. (1968) had in mind when they said that "a variety's capacity for yielding well in a range of environments has importance equal to that of its yield potential". This is the area that cradled the introduction of Turkey hard red winter wheat from southern Russia nearly 100 years ago. The wide adaptation of the Turkey variety is obvious from the fact that by 1919, 21.6 million acres were being grown in the United States. This represented 27 percent of the 80 million acres in wheat production at that time.

Some 40 years ago, the U.S. Department of Agriculture and the experiment stations of the Great Plains area recognized the importance of wide adaptation in wheat varieties for that area and initiated a cooperative testing program to identify high yielding but widely adapted varieties. That program, begun in 1931, is still active today. Two nurseries, the Southern (SRPN) and the Northern Regional Performance Nurseries (NRPN), provide the testing vehicles for this cooperative effort. Testing sites range from about 32° N latitude in central Texas to 50° N latitude in southern Alberta, Canada, and from Illinois in the East to the Rocky Mountains in the West.

The effectiveness of this program can be measured by the success of this cooperative testing venture. Pawnee wheat, identified as a widely adapted variety in these tests, was released in 1942-43 and by 1949 occupied over 11 million of the 86 million acres under wheat production in the United States that year. This is about 13 percent of the acreage. Triumph, Wichita, and Comanche, all tested under this program, at one time reached acreages of 6 million or more. More recently, Scout and its derivative Scout 66, were identified through this program and in 1972 are estimated to occupy 8-9 million (15-17 percent) of the 53 million acres in wheat in the United States. Data from the Southern Regional Performance Nursery (Table 1) show the step-wise yield increases by the varietal releases identified in this nursery.

Table 1. Step-wise yield increases of new winter wheat varieties identified through the testing mechanism of the Southern Regional Performance Nursery, 1931-1971.

Variety	Year Released	Bu/A 1968	1969	1970	1971	Percent Increase
Centurk	1971	45.3	48.1	45.0	50.1	8% over Scout 66
Scout 66	1966	39.1	43.9	43.3	48.8	10% over Comanche
Comanche	1943	36.8	38.5	39.6	44.2	14% over Kharkof
Kharkof	(check)	32.8	33.5	34.2	38.5	

Johnson et al. (1968) used the Finlay and Wilkinson regression analysis method to study varietal performance and stability in such regional nurseries. Sites that were damaged by diseases or winterkill were not used in the analyses. Regression lines (Figure 2) of variety mean yield on nursery mean yield for 3 varieties and the Kharkof check variety were drawn from the regression coefficients calculated from 44 SRPN test sites over a 3-year period. Nursery mean yield was used as a measure of environment. Regression coefficients were: Scout, b = 1.13; Gage, b = 1.08; Triumph, b = 0.92; and Kharkof, b = 0.86. Using these regression coefficients, the expected performances of these three varieties relative to the Kharkof check variety were graphed (Figure 3). If we assume that Kharkof (representative of the Turkey group of wheats) is relatively well adapted in the Great Plains, then we can presume that Scout has maintained that average stability but at a much improved yield level. This greatly improved yield performance of Scout, Gage, and a third variety, Lancer, is evident in Nebraska statewide average yields from 1960 through 1971. These three varieties released in 1963 came into major production in 1966 and have had a dramatic effect on average wheat yields in Nebraska, an area much more restricted than that of the testing region (Table 2). It should be noted that these three varieties are F_3 plant selections, and, therefore, may have a somewhat greater degree of heterogeneity than later-generation selections. Allard and Bradshaw (1964) suggested that heterogeneity could provide populational buffering and provide general adaptation.

Table 2. State average wheat yields in Nebraska, 1960-1971, and annual precipitation, 1959-1970, in the wheat growing districts of Nebraska. Major production of the varieties, Gage, Scout, and Lancer, began in 1966.

	Bu/A, yield		Inches Precipitation	
1959			25.27	
1960	28.5		25.02	
1961*	24.5		25.04	
1962*	19.5	6-year	26.46	6-year av. 23.97
1963	21.5	av. yield 23.1 bu/a	21.41	
1964*	24.5		20.64	
1965**	20.0		31.97	
1966	35.0		18.96	
1967	26.5		24.14	6-year
1968	32.0	6-year	23.86	av. 23.99
1969***	31.5	av. yield	24.85	
1970	38.0	34.2 bu/a	20.26	
1971	42.0			

*Stem rust years
**Winterkilling and stem rust in 1965
***Frost in western Nebraska

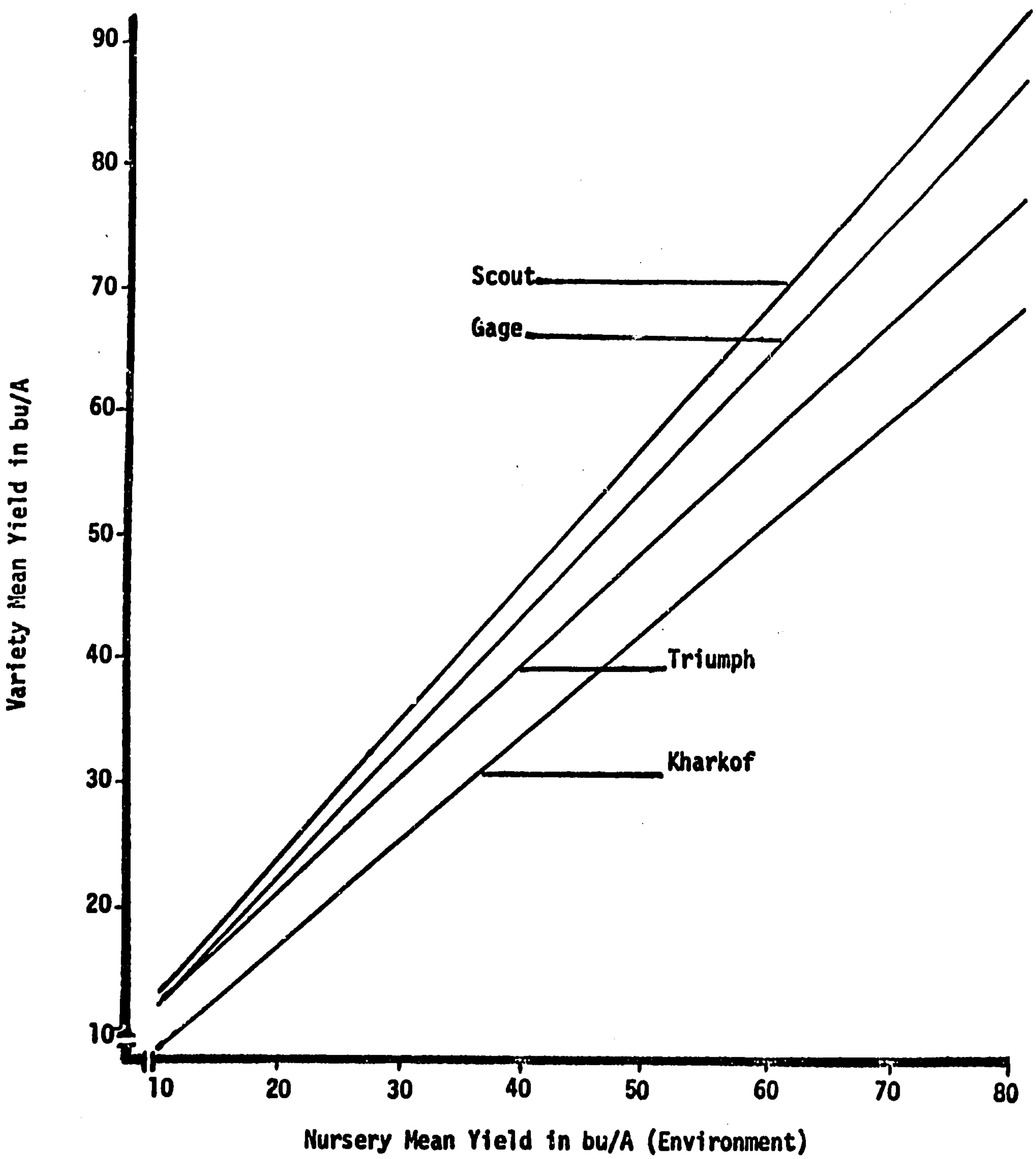

Figure 2. Regressions of the yields of four winter wheat varieties on the nursery mean yield of the southern regional performance nursery during the period 1961 to 1963.

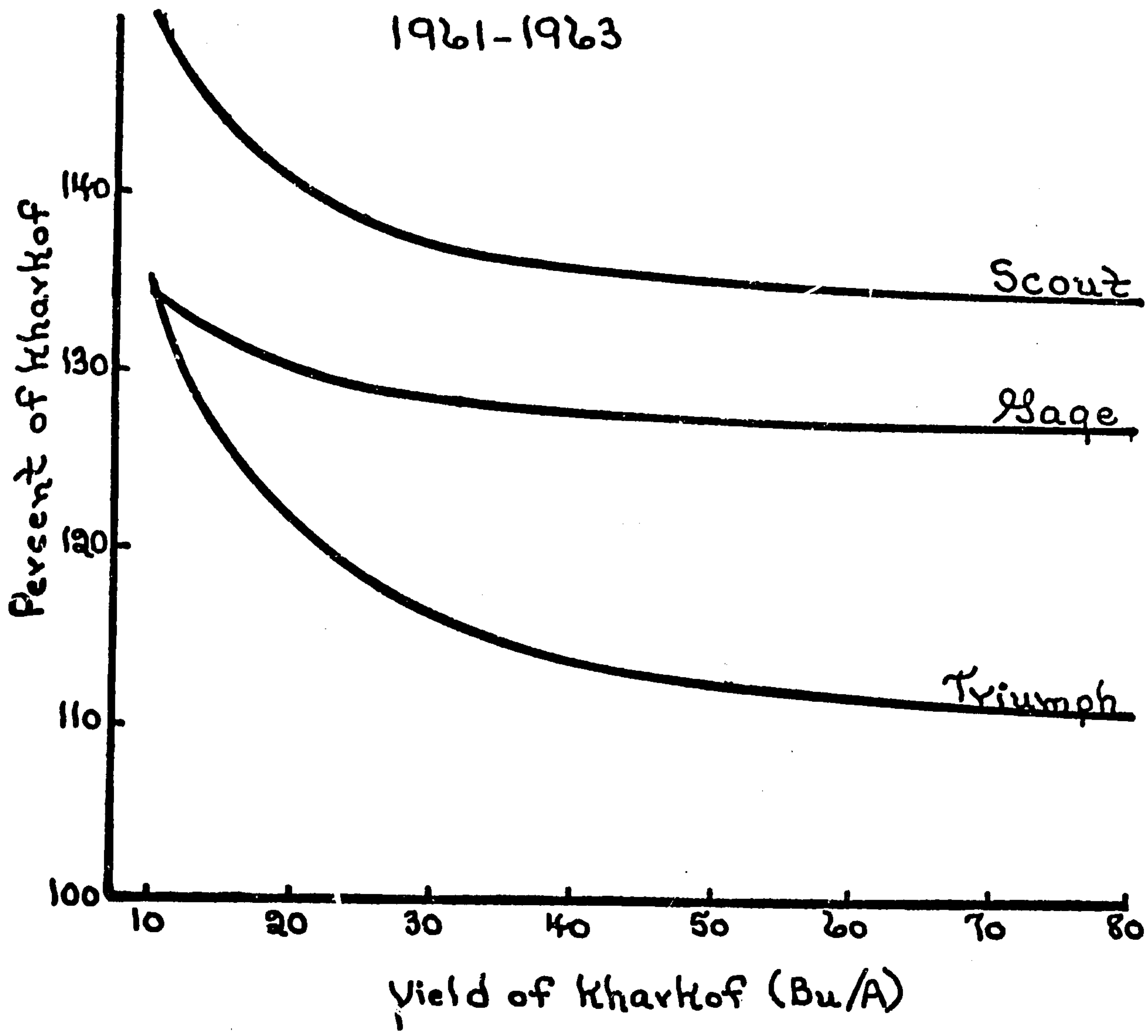

Figure 3. Yield relationship of three winter wheat varieties to Kharkof predicted from the linear regressions of the variety yields on nursery mean yields in the Southern Regional Performance Nursery, 1961-1963.

Regression and correlation analyses were applied to 1971 SRPN data on 32 entries at 24 testing sites. Disease was not a factor at these sites and winter survival was good at all locations. Data are shown in Table 3 only for the top five entries and Scout 66, Bezostaya 1, and the Kharkof check variety. While the average yields of the first seven varieties shown may not differ significantly from each other, the regression coefficients are markedly different. Centurk is the most unstable phenotypically and the most responsive to improved environments. Two of the experimentals behave somewhat similar to Centurk, while the others except Kharkof are near average in stability.

Table 3. Data* for selected entries from the 1971 Southern Regional Performance Nursery (SRPN).

Entry	Yield Bu/a	Yield Rank	Reg. coef. (By.x)	Mean of individual nursery ranks
Experimental A	50.8	1	1.08	12.13 ± 1.83
Experimental B	50.2	2	1.10	12.15 ± 1.44
Experimental C	50.1	3	1.03	11.42 ± 1.73
Centurk	50.1	4	1.16	12.54 ± 1.88
NE68435	49.9	5	1.01	11.17 ± 1.17
Scout 66	48.8	11	1.00	13.13 ± 1.77
Bezostaya 1	48.3	17	.96	14.21 ± 2.09
Kharkof (ck)	38.5	32	.80	27.21 ± 1.42

*Data based on 32 nursery entries at 24 locations

These data are shown graphically relative to the performance of Kharkof in Figure 4. Behavior of Scout 66 relative to Kharkof in 1972 was very similar to its behavior in 1961-63 (Figure 3). This provides a degree of validity to the performance of the other varieties. Joppa et al. (1971) suggested that varieties that had a regression coefficient deviating considerably from 1 could have a serious deficiency. This erratic behavior of Centurk in 1971 may have been due to its tillering ability which was a liability in the very low rainfall test sites. While Centurk's potential yield, partly due to its tillering ability, makes it an attractive variety for growers, it may be expected to be unstable in certain low yield environments. On the other hand, NE68435 appears to have improved yielding ability as compared with Scout 66 and has retained desirable phenotypic stability. Bezostaya 1, which has been superior in both yielding ability and stability in international nurseries, showed stability in this nursery but not superior yielding ability.

Additional information regarding general adaptation on stability can be gained from a simple examination of the average nursery rankings of these entries (Table 3). At Nebraska, average rank has been a key item in the decision of advancing or discarding a line. NE68435, which was fifth in average yield in the 1971 SRPN, had the best average rank and the least variability in rank. On the basis of the 1971 data, this variety appears to have general adaptation combined with above average yield and is an improvement over Scout 66.

1971 Southern Regional Performance Nursery

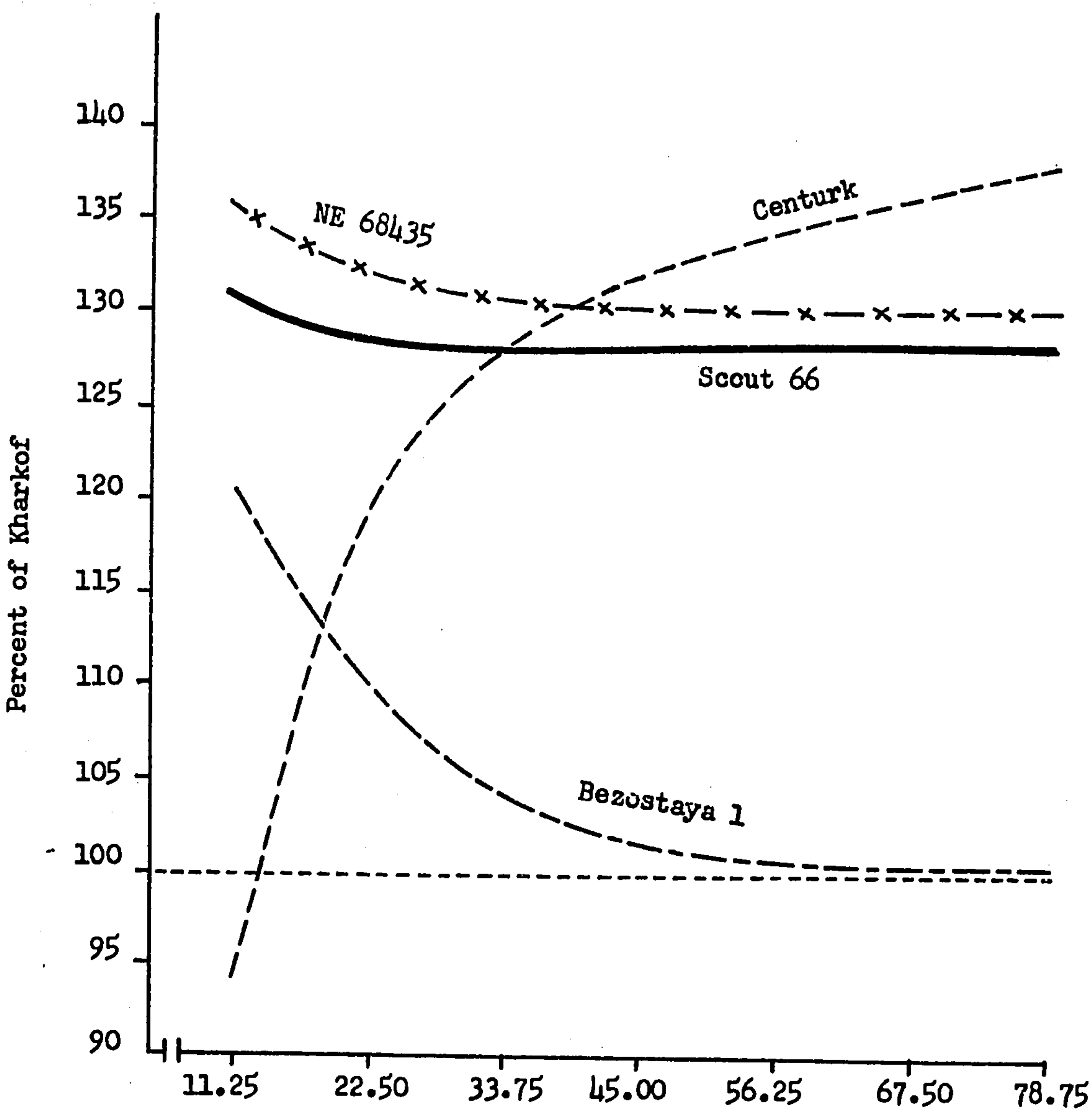

Figure 4. Yield relationship of four winter wheat varieties to Kharkof predicted from the linear regressions of the variety yields on nursery mean yields in the Northern Regional Performance Nursery in 1971.

Wide adaptation need not be at the expense of high yield in more restricted areas. The varieties that performed well in the SRPN also had excellent performance in the more restricted Nebraska state tests in 1970-71 (Table 4). However, it is true that Nebraska shares a climate similar to that of the Great Plains.

Table 4. Yields of promising experimentals and check varieties in Nebraska tests in 1970-71.

	1970 Intrastate Bu/a	1971 Intrastate Bu/a	1971 Nebraska State Tests Bu/a	Average Bu/a
Centurk	54	56	57	55.6
NE68435	55	56	55	55.3
NE68493	52	55	51	52.7
Scout 66	52	53	53	52.7
NE68427	49	55	53	52.3
NE68440	48	54	52	51.3
Lancer	51	53	49	51.1
NE68437	46	53	51	50.0
Turkey (ck)	--	--	41	----

The Northern Regional Performance Nursery (NRPN) is grown from Nebraska northward into Alberta, Canada. Yield advances have been much more difficult to achieve in this region of hard red winter wheat production. In this region, Warrior has been a stable variety but has lacked the ability for outstanding performance under highly favorable environments. In 1971 (Table 5), Centurk had the highest average yield, the highest average rank and consistency of rank, but a very high regression coefficient. NE66403 appears to be quite unstable while NE68427 is stable but lacks outstanding yield performance. Data from the more restricted Nebraska tests would agree with these regional data. The performance of Centurk relative to Kharkof in the NRPN (Figure 5) is similar to its performance in the SRPN but not as extreme in responsiveness to environmental improvement. Warrior behaves as expected and NE68427 is similar to Warrior in response to the environment.

Table 5. Data* for selected entries from the 1971 Northern Regional Performance Nursery (NRPN).

Entry	Yield Bu/a	Yield Rank	Reg. coef. (By.x)	Mean of individual nursery ranks
Centurk	41.9	1	1.21	4.38 ± 1.14
Warrior	40.0	2	.96	7.08 ± 0.98
NE66403	39.4	3	1.25	7.46 ± 1.65
NE68427	39.0	4	.98	8.08 ± 1.14
Winoka	38.7	5	.88	10.38 ± 1.31
Kharkof (ck)	35.7	17	1.00	12.46 ± 1.41

*Data based on 19 nursery entries at 13 locations.

1971 Northern Regional Performance Nursery

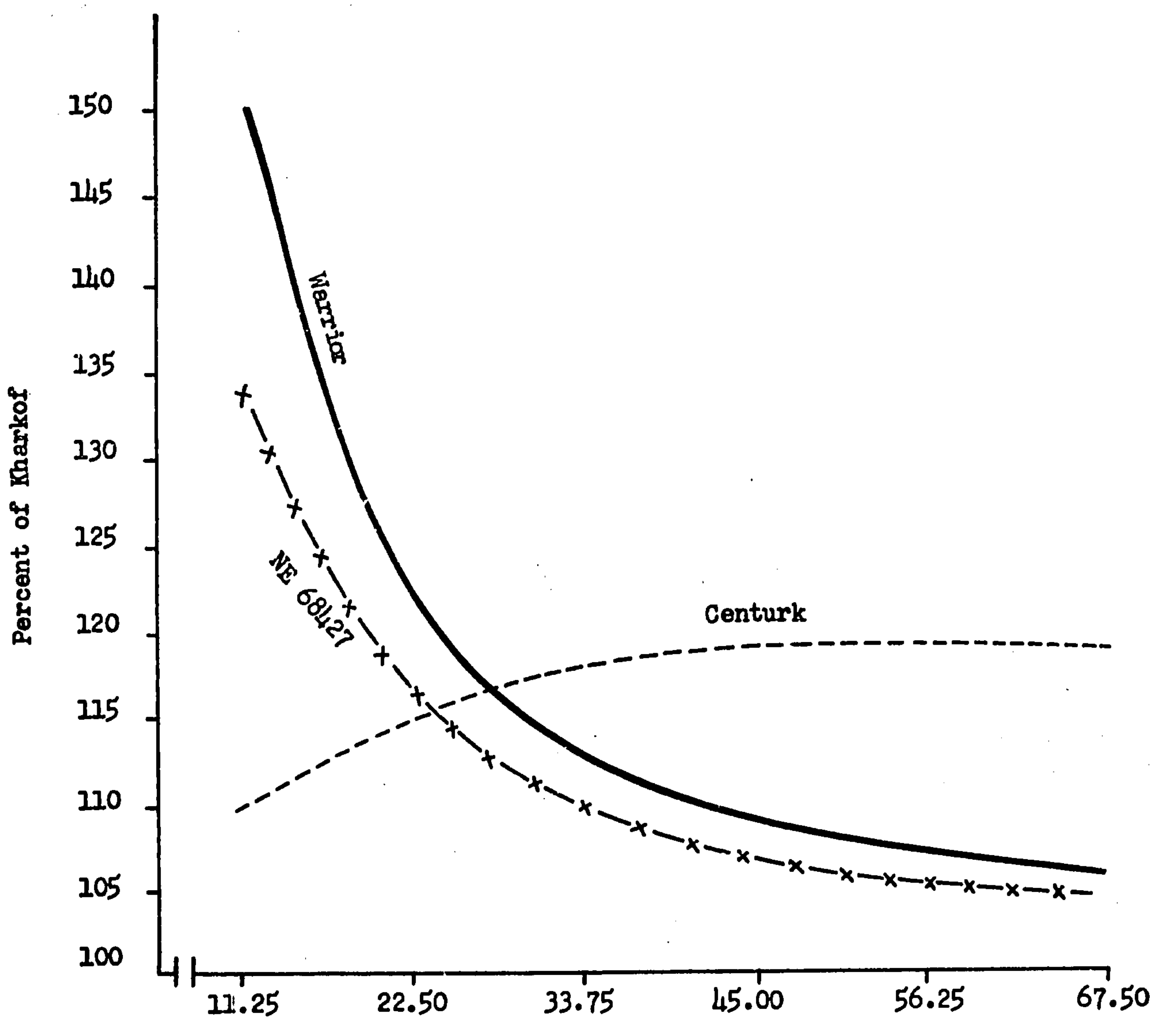

Figure 5. Yield relationship of three winter wheat varieties to Kharkof predicted from linear regressions of the variety yields on nursery mean yields in the Northern Regional Performance Nursery in 1971.

Finally, we would like to look very briefly at data from the 1969 IWWPN (Table 6). These data will be discussed in greater detail in another paper. In general, average yield and average rank agree quite well. In certain instances, however, the average rank and consistency of rank indicates that a variety has greater stability than the varieties that outrank it in yield. These varieties, then, on the average would be better recipient varieties in programs where general adaptation is important than some of those that outrank them in yield. Parker and Gage would be two such varieties. Riley 67, Stadler, and Yorkstar would be poor choices where general adaptation is desired.

Table 6. Yield and yield rank data from the 1969 International Winter Wheat Performance Nursery (IWWPN).

	Yield		Rank		Rank of
Entry	Bu/a	Rank	Av.	S.E.	mean rank
Bezostaya 1	63.9	1	6.05	± 1.36	1
Blueboy	60.2	2	7.42	± 1.56	2
Sturdy	57.7	3	8.84	± 1.48	3
Timwin	56.8	4	10.68	± 1.46	7
San Pastore	55.3	5	9.53	± 1.58	4
Benhur	54.9	6	10.95	± 1.12	8
Parker	54.1	7	9.68	± 1.29	5
Fertodi	54.0	8	10.63	± 1.43	6
Scout 66	53.7	9	11.42	± 2.03	9
Arthur	53.2	10	12.90	± 1.89	10
Riley 67	51.3	11	15.21	± 1.44	17
Stadler	51.2	12	15.68	± 1.79	18
Yorkstar	50.6	13	15.16	± 2.29	16
Gage	50.3	14-15	13.84	± 1.20	11
Yung Kwang	50.3	14-15	14.32	± 1.61	12
Triumph 64	50.0	16	14.63	± 2.00	14
Lancer	49.8	17	14.47	± 1.61	13
Shawnee	49.4	18	15.11	± 1.29	15
Bankuti	47.6	19	16.37	± 1.63	20
Heine VII	46.8	20	15.90	± 2.06	19

*19 locations

In summary, we would conclude that there has been considerable improvement in yielding ability in the 40 years of wide scale cooperative testing in the Great Plains of Central North America without a marked loss in stability of performance. Performance over this wide region has not been dissimilar to performance in a smaller area such as the state of Nebraska.

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FERTILIZATION OF FALL-PLANTED SPRING WHEAT UNDER IRRIGATION

by

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In most of the areas of the world where irrigated wheat is grown the soils are deficient in plant nutrients, especially nitrogen and phosphorus. Consequently, these nutrients must be added as fertilizer to produce high yields. It is also true that the "high yielding" varieties do not yield high without adequate amounts of fertilizer. It has been stated many times that if a farmer is not going to use fertilizer, then his choice of varieties is immaterial; almost any variety will yield poorly without adequate fertilization.

The amount and kind of fertilizer required by a wheat crop will vary with many factors, such as the climate, the soil, the variety, and other factors. Therefore, specific fertilizer recommendations for a given area must be determined by research in that particular area. Nevertheless, there are interesting similarities in the recommended fertilizer practices in many countries that are now growing fall-planted spring wheats. One reason for these similarities may be that all these irrigated areas are in relatively warm regions which permit double cropping. Furthermore, most of these regions are former deserts. Under such conditions one would expect low levels of soil organic matter (hence soil nitrogen) and low levels of available phosphorus.

It may be useful to review research that has been carried out in one country growing irrigated spring wheat and compare their general results with those of other countries. Since India, through the All-India Coordinated Wheat Improvement Project, has a large back-log of data on this subject, I shall present a summary of their results.

In a series of coordinated experiments at several locations in India which were begun in 1964 and which still continue, response to fertilizer rates and methods of fertilizer use have been studied. Response to nitrogen and phosphorus fertilizers is universal and dramatic in all irrigated areas. Among the experiments conducted were trials to measure response to rates of N, to rates of P, to sources of N, to methods of N application, and to interactions of these nutrients with each other and with varieties and intensity of irrigation. The response to secondary and micronutrients were also studied but, in general, response to these nutrients is not widespread.

Figure 1 gives the generalized response to nitrogen from experiments conducted over the period 1965-69. From this figure, one may see that tall varieties respond up to about 40 kg N/ha and dwarf varieties respond to about 120 kg N/ha. The general recommendation in India is for 120 kg N/ha which is the most economic dose.

The general results of the experiments studying methods of N application indicate that there is usually little difference when nitrogen is applied all at planting time, or split into applications at planting plus application prior to the first or second supplementary irrigations. Illustrative data are

FIGURE I

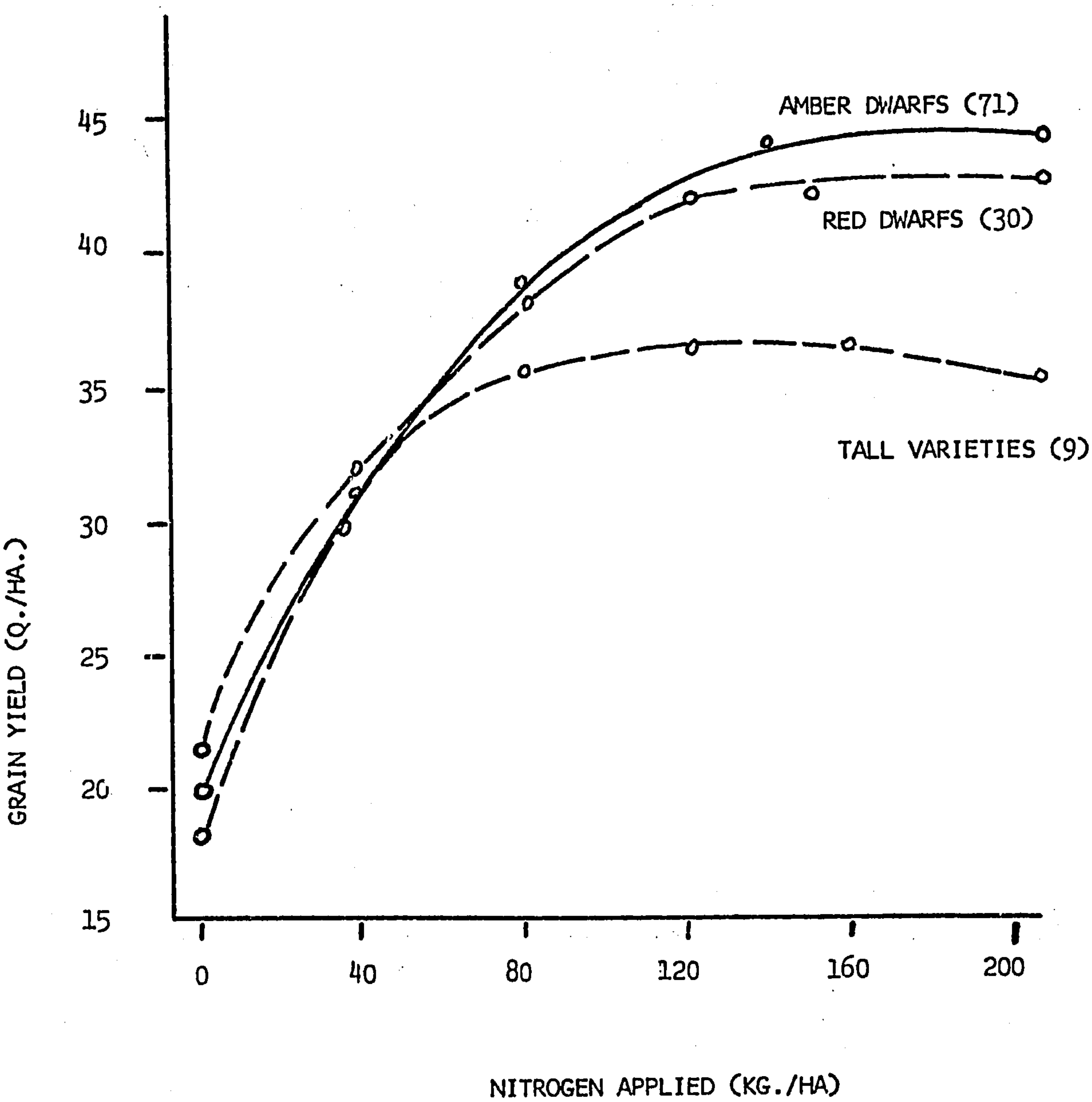

FIG. I: THE EFFECT OF RATE OF NITROGEN APPLICATION UPON AVERAGE GRAIN YIELDS OF TALL, RED-GRAIN AND AMBER-GRAIN DWARF WHEAT VARIETIES DURING 1965-69. (THE NUMBERS IN PARENTHESIS INDICATE THE NUMBER OF VARIETIES X TRIALS AVERAGED FOR EACH CURVE.)

given in Table 1. Exceptions are in sandy soils which are subject to over-irrigation resulting in leaching losses. Also split applications which are delayed too long (until the boot stage for example) are less effective. Also it has been shown that spray applications of urea are no more effective than soil application, and sometimes are less effective. These studies also show that there are no differences among commercial sources of nitrogen if they are applied properly. Furthermore there is in general no difference between band applications and broadcast application of nitrogen fertilizers. Response to phosphorus usually ranges up to 17-26 kg P/ha (40-60 kg P_2O_5/ha) and the general recommendation is for 22 kg P/ha (50 kg P_2O_5/ha). As in most all countries, it is recommended that the phosphorus fertilizer be banded in close proximity to the seed. As with nitrogen, there is a differential response of dwarf and tall varieties to phosphorus, the dwarfs utilizing phosphorus more efficiently than the tall varieties. Often nitrogen and phosphorus show a positive interaction effect.

Table 1. Yields of wheat as affected by methods of N application.

Method of N application	Grain yield in T/ha		
	N dose kg/ha		
	60	120	140
All preplant	4.0	4.2	4.3
40 preplant + 1 top dressing	4.0	4.3	4.3
40 preplant + 2 top dressing	4.0	4.3	4.4
40 preplant + 1 top dressing + urea spray	4.0	4.3	4.4

Source: C. H. Datta, Indian Agricultural Research Institute

Other studies have shown that there are only a few isolated areas which show a response to K. Response to zinc is somewhat more widespread but still of relatively little significance. Response to most of the other plant nutrients has not been detected.

There is considerable data available from other countries in this area of the world regarding fertilizer response. These are summarized in Table 2.

Table 2. General fertilizer recommendations.

Country	N	P	K
India (1)	120	22	0
Afghanistan (4)	133	35	0
Iran (2)	90-120	20-26	0
Egypt (3)	96	usually none	0

(Numbers in parentheses refer to literature cited.)

Thus, we see that the general recommendations for all these countries are strikingly similar. Of course these recommendations are for the general case and many specific locations will depart from the general recommendations to fit their specific needs. There are other similarities: Research in Egypt has shown that there is no difference between applying nitrogen all at planting or splitting it into two or three applications. The Egypt research also indicates little difference among commercial sources of N.

It appears, then, that in the general case fall-planted spring wheat under irrigation can economically utilize 100-120 kg N/ha and about 20-25 kg P/ha. Responses to other nutrients appear to be relatively rare.

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FERTILIZATION OF NON-IRRIGATED WHEAT IN REGIONS OF MODERATE AND LOW RAINFALL

by

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Moisture has long been recognized as the number one limiting factor in the production of winter wheat in the dry regions. Certainly this growth factor cannot be overlooked wherever rain-fed cropping is practiced under semiarid to arid climatic conditions, and all possible must be done toward moisture conservation. Recognition of this requirement has been responsible for the development of the suite of practices embodied in 'dry farming' in these regions. It has become increasingly apparent in recent years, however, that moisture conservation cannot be overemphasized to the exclusion of all else, most specifically the fertility requirements of the wheat crop.

With moderate rainfall as occurs in subhumid climatic regions, fertility needs are generally well recognized. In this situation, convincing farmers of the need for fertilization is usually less difficult than relaying educational details concerned with precisely which nutrients are needed and effective fertilizer management practices for the nutrients involved.

Effective Fertilizer Management Practices

Kind of Nutrient. It is generally recognized that N and P are the nutrients most likely to be deficient for optimum yields throughout the wheat-producing regions of the world. Supplemental K need is less common, in considerable part because wheat is conventionally grown in drier regions where inherent soil K levels are notably higher than in the humid regions.

The data of Table 1 summarizing 1284 simple trials and demonstrations of the FAO Fertilizer Programme in 1966/67 give evidence of the general NP requirement of the wheat crop and the good probability of a highly profitable response to the application of these nutrients in all but the very driest regions. A summary of 133 simple fertilizer trials on winter wheat in the Near East-North Africa region, for example, showed the following main effects in kg/ha: N +235; P +225; and K +65 (3).

Calcium and Mg shortages limit yields even less commonly than K, and for the same reason. Deficiency of S has become increasingly apparent, in part due to higher yield potential of improved varieties and because of decreasing amounts of S 'impurity' in carriers of primary nutrients and in applied pesticides. Especially are sandy soils of low organic matter content and the more thoroughly leached soils (of whatever texture) in humid regions likely to be S deficient. Yield limitation from shortage of one or more of the trace elements Zn, Fe, Mn, Cu, Mo and B is also being noted more and more frequently. The bases among this group are especially likely to be deficient with heavy applications of the primary nutrients for high yields on calcareous soils.

It perhaps goes without saying that wheat grown in nurseries for evaluation purposes should never suffer for lack of nutrient. Soil and plant tissue testing with adequate research base of correlation and calibration can give invaluable assistance in determining the kind of nutrient(s) required. This is the topic of a later presentation in this conference. Suffice it to say at this point that something better than an educated guess based on experience on adjacent soil is needed.

Table 1. Response of non-irrigated winter wheat to fertilizers in demonstrations and trials of the FFHC Fertilizer Programme of FAO, 1966-67 (2).

Country and Region	No. of sites	Average Yield of Control	Yield increase to Fertilizer* N	P	NP	NPK	Value/cost ratio of best treatment
		kg/ha	%	%	%	%	
Colombia							
Narino	14	1135	36	--	62	50	3.7
Narino	6	1974	30	4	33	38	5.2
Guatemala							
West Plateau	10	1427	--	--	93	99	1.8
Lebanon							
South Lebanon	9	1125	49	16	79	120	3.6
Bekaa	15	1631	17	18	17	15	1.7
Morocco (Southern)							
Hard wheat	63	742	--	22	38	--	1.3
Soft wheat	7	272	--	105	234	--	1.7
Syria							
Anti-Lebanon foothills	6	967	--	23	40	59	1.3
Southern Provinces	10	1052	--	24	38	40	1.3
Jezireh	14	1207	--	45	86	57	2.8
Western Plains	36	1026	--	42	57	73	2.4
Turkey							
Black Sea Coast	53	1065	--	33	66	--	3.3
Thrace and Marmara	39	982	--	23	73	--	2.2
Aegean Coast	24	1108	--	37	107	--	5.0
Mediterranean Coast	284	981	--	33	78	--	3.0
Southwest Coast	54	995	--	--	90	117	3.1
Northern Transition	171	254	--	35	68	--	2.6
Southern Transition	37	957	--	53	77	--	3.2
Central Anatolia	432	758	--	63	--	--	2.7

*Rate of N was generally between 20-60 kg/ha, P_2O_5 between 40-60 kg/ha, and K_2O between 30-40 kg/ha.

Rate of Nutrient. Appropriate rate for a deficient nutrient is governed by the amount residually present within the crop rooting depth of soil, the soil's capacity for releasing the nutrient, the crop demand, and to some extent the environmental conditions surrounding the crop's growth. Where little or no regard is paid to the first three of these criteria, deficiency or excess of the nutrient involved is likely to result, either of which can impose yield limitation with at least some nutrients.

The data of Figure 1 demonstrate the varied responses that are obtained in a given region, from positive in a part of the locations to progressively more negative in others with increasing N rate.

No standard rate can properly be assigned for a given region based on averages of a few trials, since different soils do vary tremendously in nutrient supply from pedogenic processes (1) and from previous management. Note the substantial differences in available P and K contents of the profiles of western Nebraska soil series expressed in Figure 2. Although they occur intimately associated, P deficiency is common with the Ulysses soil and is unknown with the Kuma. It is especially necessary that rate of any deficient nutrient be adjusted to moisture supply likely to be available to the crop as discussed in a subsequent section.

Time of Application. The proper time of application of a fertilizer nutrient varies in accordance with mobility of the nutrient in soil and time of major crop demand. On the one hand, wheat absorbs most of the N required for high yields between the period when growth commences in the spring and the heading stage, and commonly gives maximum response in grain and protein yield per unit of N when applied in the spring rather than in the fall at planting (5). This fact also permits evaluation of moisture stored and available for crop use well into the growing season, thereby alleviating the overstimulation hazard from fall N application depicted in Figure 1. It also precludes disease problems incidental to excessive fall vegetative growth with fall applied N in some years.

Phosphorus and other immobile nutrients, on the other hand, must be applied at or before planting in order to be present in the crop rooting zone as growth commences. There is minimal leaching of such elements into the soil if broadcast after planting, and since almost no root activity occurs at the soil/air interface little other than a small amount of foliar absorption is likely to occur.

Chemical Carrier of Nutrient. Time and space do not allow complete treatment of the question of nutrient carrier since there is such a very large number of products on the market. Among the more common N products such as anhydrous ammonia, ammonium nitrate, ammonium sulfate, calcium ammonium nitrate, urea, and nitrogen solutions of one or more of these carriers, little or no difference in agronomic effectiveness is likely to be measured so long as each carrier is used according to its own limitations. Recently developed sources of a controlled release nature, however, may prove quite superior or inferior depending on environmental conditions.

Phosphatic materials on the fertilizer market vary markedly in their relative availability to the wheat crop. Their effectiveness is also very much influenced by soil character. Some materials that are highly effective on acid soils are much less so on calcareous soils (e.g. DAP, ACSP, CMP in Table 2). Associated NH_4^+ and high water solubility combine in assuring immediate plant availability and maximum plant uptake with most effective placement. Particle size of the P carrier is important in the fact that coarse granulation is advantageous for high solubility materials for minimizing fixation, while very fine division and thorough mixing with soil is essential for carriers low in water solubility. Under reducing conditions of very strong acidity some materials like basic slag in a mixed treatment may prove fully equal to any other listed. Superiority of the slag has been measured occasionally in which case base and trace element 'impurities' must be presumed to have contributed.

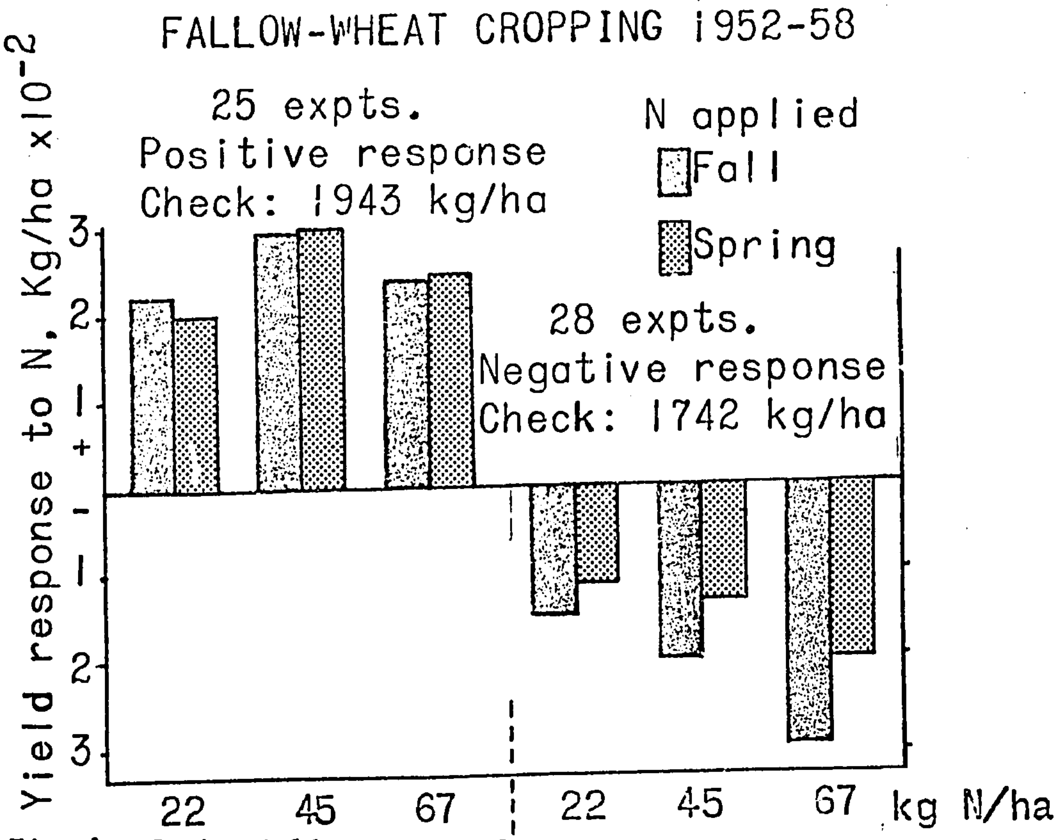

Fig. 1. Grain yield response of winter wheat to fertilizer N applied in the fall and spring under fallow-wheat cropping at 77 locations in western Nebraska, 1952-58. All N treatments broadcast as ammonium nitrate; 24 locations (not plotted) evidenced no response to N (4).

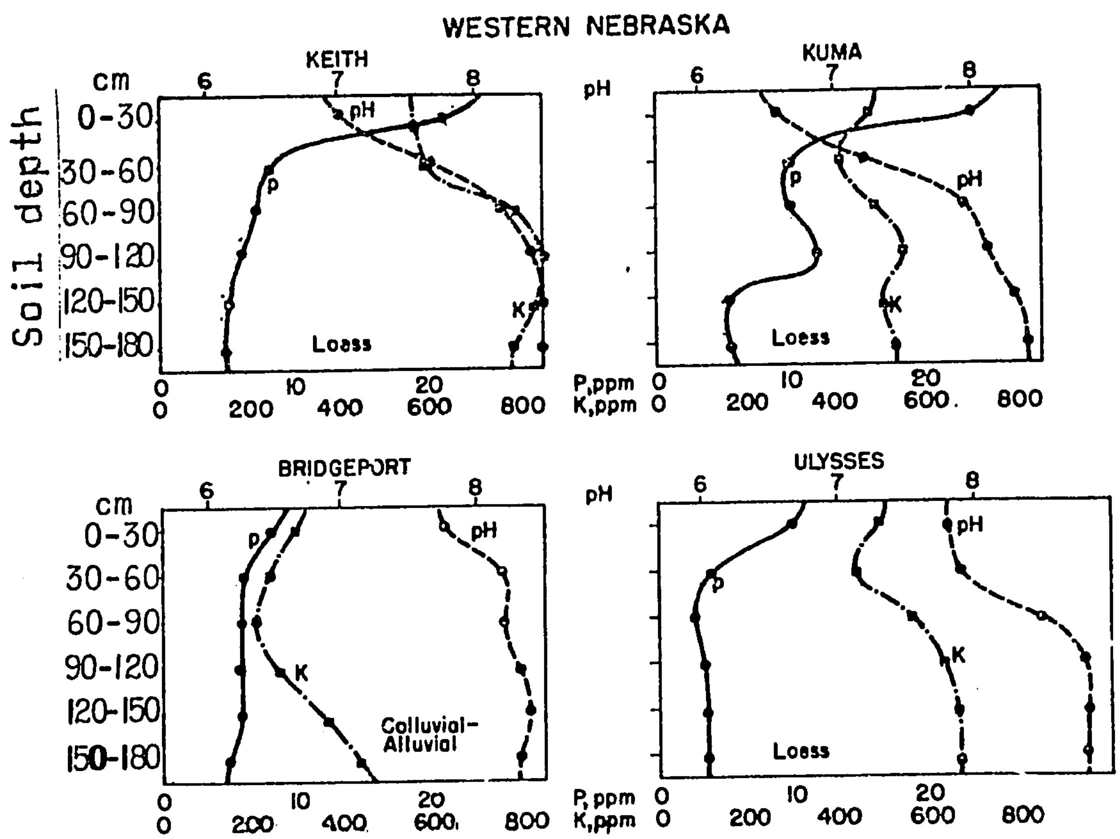

Fig. 2. Soil pH, available P (Bray & Kurtz #1), and exchangeable K for the 180 cm profile of representative soils of western Nebraska.

In the case of carriers of most nutrients a high degree of water solubility will usually portend ready plant availability and conversely. There are exceptions, of course, as with elemental S used as S fertilizer, basic slag for P, ZnO for Zn, etc. With all of these, however, the material must be very finely divided and mixed well into the soil rather than banded for maximum crop utilization. Such fine materials are difficult to apply.

Table 2. Relative availability of phosphatic fertilizer materials for annual crops grown under Nebraska conditions.

Annual crops grown on moderately acid soils
APP, MAP, DAP ≥ PA, CSP, ACSP, OSP, wsNP, CMP > DCPdi, lwsNP > RhP, BS, DCPan, FTP > RP > 0
Annual crops grown on calcareous soils
APP, MAP, PA ≥ DAP, CSP ≥ ACSP, OSP > NP, CMP, RhP, DCP > FTP, BS, RP = 0

Names abbreviated as follows: Ammoniated PolyPhosphate, MonoAmmonium Phosphate, DiAmmonium Phosphate, Phosphoric Acid, Conc. SuperPhosphate, Ammoniated Conc. SuperPhosphate, Ordinary SuperPhosphate, Nitric Phosphate (water soluble, low water solubility), Calcium MetaPhosphate, DiCalcium Phosphate (dihydrate, anhydrous), Rhenanian Phosphate, Basic Slag, Fused Tricalcium Phosphate, Rock Phosphate

Fertilizer Placement. Proper fertilizer placement is necessarily concerned with achieving high efficiency in crop utilization of the applied nutrient and with prevention of deleterious salt effects to germination. A carrier like anhydrous ammonia must be injected sufficiently deep into the soil with immediate closure of the injection slot to prevent serious gaseous loss to the atmosphere. Urea applied to calcareous soil requires some incorporation to prevent ammonia volatilization loss from the unstable ammonium carbonate produced by the enzymic hydrolysis of this carrier. All of the common N materials are possessed of a high salt index such that care must be exercised to assure limited contact between fertilizer and seed. As little as 10 kg N/ha placed in the row can have damaging effects on wheat germination if soil moisture is limited and rain is long delayed subsequent to planting. It is also important that very small amounts of most trace element carriers be allowed to enter the seed row because of toxic effects on seedlings.

Phosphate banded in or very near to the seed row of wheat has commonly been found to give greatest yield effect per unit of applied P in acid soils. The enhanced response can be attributed to the positional availability and rapid early uptake of this nutrient (as is required for best growth of the crop) and to retarded fixation loss in some soils. Such banding has not proved to be as necessary for maximum utilization efficiency on calcareous soils.

Hazards of Excessive Fertilizer

Crop Lodging. One of the major problems resulting from overfertilization of the winter wheat crop has been that of lodging. Especially has nutrient N been suspect in this regard with traditional varieties of wheat grown in the drier climatic regions. Excessive N favors rank leaf and stalk growth which with increased shading causes succulent and weak stalks that do not stand well under beating rain and wind action. Kernels of wheat on lodged plants do not fill well and portions are commonly lost in the harvesting operation. The development of stiffer strawed varieties in recent years, especially dwarf types, has alleviated the problem to some extent. Lodging from excessive nutrient does remain a problem, though, for most regions where strong winds may accompany rain received after heading of the crop.

Imbalances Created. Excessive amounts of any one of the soil-derived elements of plant nutrition can have deleterious effects on crop growth from the standpoint of an imbalance in the nutrients required if not outright toxicity. It is to be expected that force-feeding the plant excessive amounts of a given nutrient must necessarily dilute the amount of some other nutrient taken up, and if the diluted one chanced to be at a marginal level initially, an induced deficiency would result. The literature reports numerous examples of nutrient deficiency created by excessive application of another element, e.g., Zn and Fe by P, Fe by Zn, Fe by Cu, Mg by K, etc. It behooves the plant breeders in establishment of nurseries for evaluation of genetic materials to know something about nutrient levels in the soil for preventing problems of this nature from blanket fertilizer treatments. The use of so-called 'balanced fertilizers' is not necessarily the answer since balance must be accomplished between soil nutrient delivery capacity and nutrients added.

Overstimulation. Farmers as well as agricultural technicians have commonly experienced the overstimulation of crops accompanying high fertility in the drier regions. Their apprehension stems from the nutrient supply causing excessive vegetative stimulation at the expense of grain yield as moisture runs out. The problem in this respect has been most acute with N which has greatest stimulative action on vegetative development. The hazard has frequently been accentuated with fallowing which in itself is responsible for substantial mineral N accumulation in soil.

More often than not, where overstimulation probability is the accepted reason for excluding N treatment, the experience has come from application at rates proved economic for more humid regions. Reducing rate to a more compatible level with the moisture supply available will frequently result in positive fertilizer benefit. It is the author's belief, for example, that a N treatment of 10-20 kg/ha would prove economic in most years on the majority of soils of even the central Anatolia plateau of Turkey.

A further aspect of N management is crucial here in respect of timing. Nitrogen applied in the fall at or before planting is likely to stimulate excessive fall and early spring vegetative growth and be responsible for considerable moisture depletion. Such depletion can be at the expense of yield in the following summer if seasonal rainfall is deficient (note Figure 1). Delayed spring application, on the other hand, will not have as great an effect on vegetative development and may well result in sufficient moisture remaining for fulfilling grain yield requirements. The data of Figure 3 support this contention in showing less water consumed and a greater water use efficiency by the crop with spring than with fall N treatment.

Water Use Efficiency

The fact that crops make more efficient use of water in producing grain as soil fertility increases from a deficiency state is well established (8). This benefit has been measured commonly wherever fertilizer treatment increased yield of crop. The registered effects are the result of more efficient production and storage of carbohydrates in the grain-forming process when nutrients accessible to the crop are adequate. Note in Table 3 that yield increased with increasing amounts of available water at planting, and with rate of N application. Water use efficiency increased correspondingly from applied N but only as water was nominally available, reaching its maximum with the higher N rates and the 15 cm preplant water application (7). This study with continuous cropping in a semiarid region indicated the need for 22 kg fertilizer N/ha for each 7 cm available preplanting soil moisture on the soil involved.

Table 3. Effect of preplanting soil moisture and rate of N fertilization on yield and water use efficiency of winter wheat at North Platte, Nebraska, 1954-56.

N applied,	Available soil water at seeding, cm*			
kg/ha	0	7	15	21
	GRAIN YIELD, kg/ha			
0	473	1013	1283	1350
22.5	675	1418	1890	1958
45	608	1688	2160	2363
90	540	1688	2498	2633
	WATER USE EFFICIENCY, kg/ha-cm			
0	16	26	32	30
22.5	22	36	45	41
45	19	44	48	47
90	16	41	54	51

*Yield response values are average for spring and fall applications of N.

Other studies throughout Nebraska on representative soil and cropping situations have demonstrated a mean production of 70 kg wheat/ha-cm of water by the fertilized crop compared with 62 kg/ha-cm or an increase of 12% in water use efficiency at the same time that yield increased an average 21% (Fig. 4). In some cases fertilizer treatment had a detrimental effect on water utilization, associated with lack of positive yield response, while in others with very great fertilizer response, water effectiveness was enhanced more than 100% by treatment (6). Nebraska results do not corroborate some reports in the literature suggesting that the greater production per unit of water consumed by fertilized crops is accomplished without noticeable increase in total water consumption. As noted in Fig. 4 we found an average additional 2.5 cm of water consumed by the fertilized crop. Explanation for the greater total use is given as a more active root system with greater moisture extraction capability in the area of root proliferation as well as deeper root extension through fertilization for extraction of any existing deep subsoil moisture. Thus, the residual soil moisture following a well-fertilized crop is likely to be slightly less than that remaining without fertilization.

An appropriate summation of this section would be that fertilizers will not substitute for water, but where needed they will assist the growing crop in making better use of that which is available. For soils of moderate fertility level, the increased efficiency from fertilization will approximately equal the proportionate increase in yield, but not quite due to the small amount of extra water consumed. Balancing the level of fertility for the wheat crop with the moisture supply likely to be available for its production thus becomes of the essence.

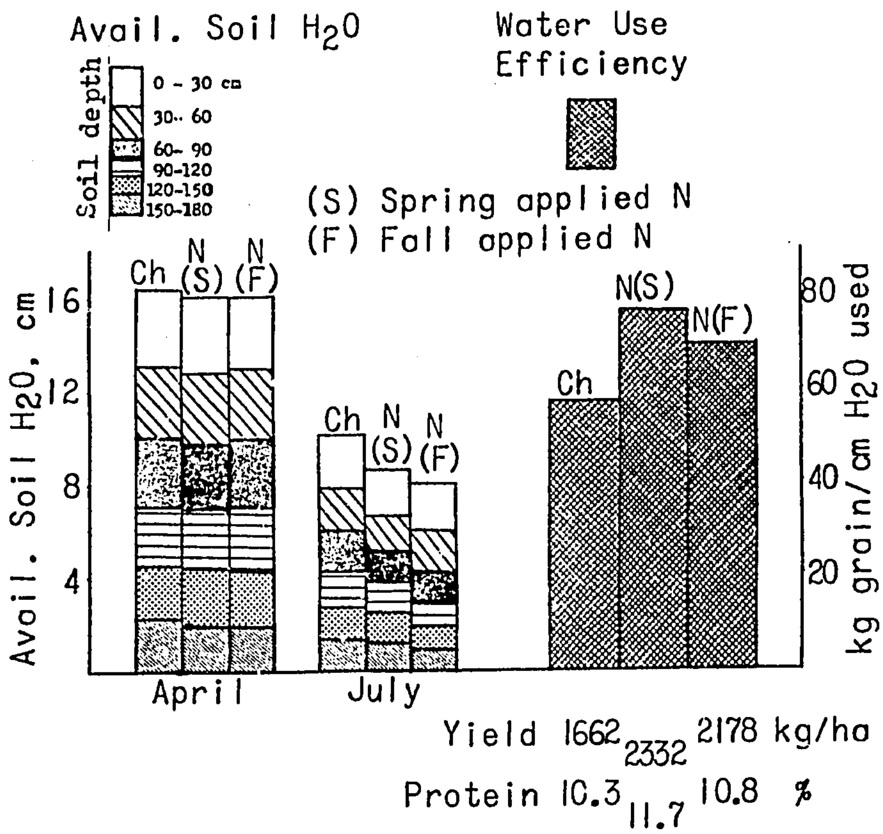

Fig. 3. Grain yield, protein percentage and water use efficiency in 16 field experiments with winter wheat in western Nebraska as affected by time of applying 45 kg N/ha, 1962-65.

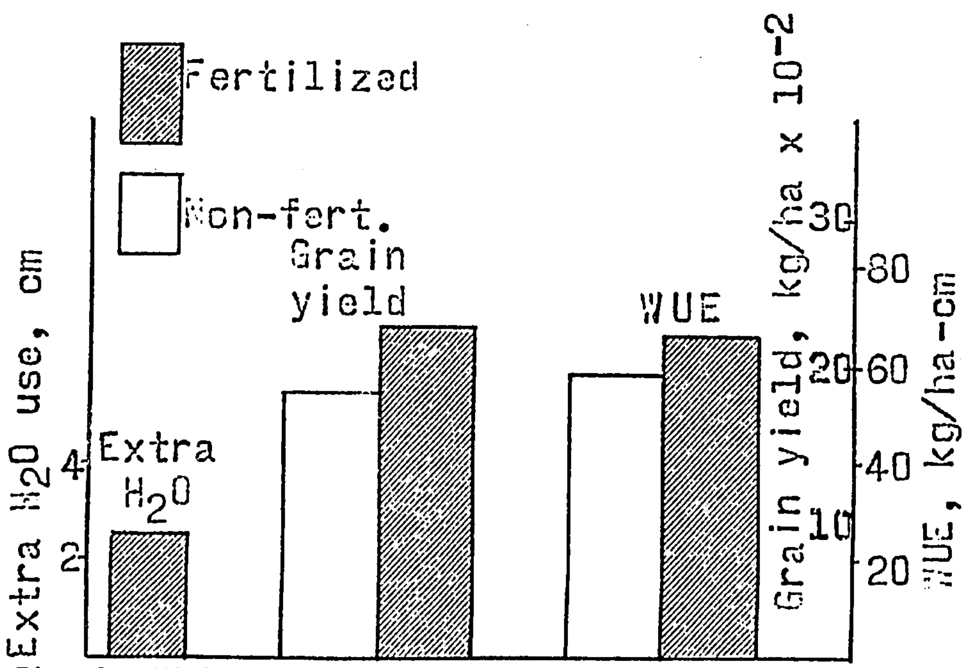

Fig. 4. Yield and water use efficienty of winter wheat (WUE) in Nebraska as influenced by optimal fertilizer treatment in 41 field experiments of 1962-64.

Fertilizer Use and Crop Quality

Wheat has long been recognized as one of the important quality items in man's diet. This has been due in considerable part to the generally higher protein content of the grain than occurs in the majority of other food grains. Not to be lost sight of as we consider fertilization of the wheat crop is the basic fact that protein yield in the crop is fundamentally a nitrogen nutrition factor. Various other nutrients contribute, of course, but none with the controlling influence of N. The degree to which the soil and applied fertilizer supply this required ingredient largely determines ultimate protein level. Positional availability of the nutrient becomes a significant contributing factor, especially under dryfarming conditions where root activity from the surface downward declines as the stored soil moisture is progressively depleted. Other environmental factors may contribute substantially to protein percentage, with the usual observation that as N is nominally available and all supporting conditions otherwise are optimum for yield, protein content is minimal and conversely.

Studies reported by Johnson (4) indicate that increased total protein of the grain associated with added fertilizer N is no assurance of a better quality product for man. He notes a declining proportion of lysine among the amino acids as protein percentage increases from N fertilization, a matter of no concern to ruminants but troublesome to monogastric animals including man. Other studies on biological value of plant proteins have stressed the importance of sulfur-containing amino acids, perhaps exceeding the significance of lysine when nutritional value of a given food product from different sources is investigated. Unanswered is the question in-how-far the essential amino acid index (EAA) of wheat at high levels of N nutrition might be improved by enhancement of the crop's S nutrition status during the critical stages of protein accumulation and storage.

The time of N fertilizer application can have substantial bearing on crude protein in the grain of the finished crop. Most studies with winter wheat have indicated a progressively higher protein percentage with delay in time of N application, so long as moisture was received to carry the delayed application to the root system or when the N was applied foliarly, to the point where the total expressed N effect was on protein and not at all on yield.

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PHOTOPERIODISM AND COLD TOLERANCE IN WINTER WHEAT

by

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In pre-Strampelli winter wheat breeding even in South European countries like Yugoslavia or Italy, there were no winter wheat varieties tending to the day neutral type (Martinić, 1966 and unpublished data). Nevertheless, the European winter wheats belonging to the typical long day type, quantitatively differed in their response to photoperiod (Schmalz 1953, Dantuma 1958, et al.).

It was believed for a long time that high response to photoperiod was a prerogative for good cold tolerance and winter hardiness, especially for Central and North European varieties. (Schmalz 1953, 1957, Hansel 1954, et al.). Therefore, breeding methods for screening varieties and early generations for desired photoperiodism and winter hardiness were developed (Rudorf 1938, Schmalz 1953, et al.). Nevertheless, good cold tolerance combined with less pronounced day length response and only slight vernalization requirement in traditional varieties of Southeast Europe, was also a well known fact (Hansel 1954, Rimpau 1958, Dantuma 1958, et al.).

Dantuma (1958) supposed that in the Netherlands, late spring development although it helped varieties to be more winter hardy, was responsible for their failure to reach the greatest productivity. He further suggested crosses between West European varieties and East European and American winter hardy types for creation of new winter hardy forms with early spring development. Wienhues (1961) also supposed that day neutral types like the French variety Etoile de Choisy, should allow further progress in yield in mild West European regions, provided neutrality was combined with adequate winter hardiness. The idea about the relationship between early spring development and yield of kernels might be of an earlier date, but, it was recognized in Europe for the first time by the famous Italian wheat breeder Nazareno Strampelli about fifty years ago (Strampelli 1932, Martinić 1966). Later on, "Strampelli type" varieties spread to many South European, Mediterranean and other regions both for direct use and for breeding purposes. The progress in wheat production that began in Yugoslavia about 1958 was primarily based, as far as varieties were concerned, on the "Strampelli type". These wheats and their derivatives differed markedly from traditional North, West and Southeast European varieties in their response to photoperiod (Wienhues 1961, Dobben van 1965, Martinić 1964, 1966, 1971, et al.). Thus, two clearly distinctive groups of winter wheat varieties existed in Europe for quite a long period of time. First, varieties that were low responding to photoperiod spread into the Southern regions and second, high responding varieties spread into Central and Northern Europe. Nevertheless, within the two groups, there are quantitative differences in response to photoperiod. Furthermore, useful correlation breakers with low response to photoperiod and satisfactory cold tolerance for many regions also have been developed.

Photoperiodism in Common Wheat

Since Gardner and Allard discovered the response of cultivated plants to photoperiod, hundreds of papers have been written on photoperiodism of spring and winter wheat varieties. It was found that the sensitivity of varieties to photoperiod was primarily dependent on their region of origin, although in some cases, exceptions were known. Varieties with high sensitivity to day length differ in their "critical day length" in a range from 12-13 to 16-18 hours, being higher for the varieties from more northern regions and lower for those from the southern parts of the lower latitudes. (Schmalz 1953, Dantuma 1958, Van Dobben 1965 and many others). Varieties with low sensitivity also differ in their "critical day length", but at a lower level varying from 12 to 6 hours (Wienhues 1961, Van Dobben 1965, De Voss 1971, et al.). Practically, this means that such varieties are able to head even in very short winter days as far as their photoperiodism is concerned.

Naturally, the development of varieties does not depend on their sensitivity to day length only, but also on many other very decisive factors, such as temperature from 1-10°C to stimulate the vernalization process in winter wheats, higher temperature that influences growth such as light quality and intensity, moisture circumstances, etc. Thus, many internal and external factors and their interactions have made possible the successful growing of varieties with low sensitivity in many regions of the world where such varieties had never been known before (Martinić 1964, 1966, 1971). Nevertheless, in this author's opinion as well as that of many others, all common wheat varieties irrespective of whether they belong to low or high sensitive groups are, theoretically, long day plants, and the phenomenon is of a quantitative nature. A few apparent exceptions may be ascribed more to the criteria used for the evaluation and characterization than to the real "day length neutral" nature of the varieties. I hasten to add, that it is questionable whether such a theoretically "day length neutral type" could be of greater practical importance than a range of known and well used low sensitive spring and winter wheats.

Cold Tolerance in Common Wheat

Cold tolerance in winter wheat varieties is usually in good agreement with their winter hardiness in the field (Weibel and Quisenberry 1941, Levitt 1956, Dantuma 1958, et al.), although this agreement is far from perfect (Roberts and Grant 1968, and other authors). Owing to the very complexity of winter hardiness, cold tolerance seems to be, at least in some regions, overestimated.

Cold tolerance is a heritable trait and, in some cases, the inheritance seems to be rather simple. At least three chromosomes (Low and Jenkins 1970) and undoubtedly, plenty of alleles are involved. Large genetic variation of cold tolerance within the species, especially in winter types, is known and available. However, many other factors are involved in the phenotypic expression of cold tolerance and winter hardiness (Levitt 1956, Lamb 1967, et al.). Furthermore, it needs to be pointed out that the circumstances under which the plants are grown and hardened prior to the cold treatment and the developmental stage of plants, are of the utmost importance.

Irrespective of genetic variation depending on the genotype treated, varieties show good cold tolerance from the coleoptile stage up to 5 leaves, expressing the lowest tolerance to the treatment at the stage of 2-3 leaves when the whole reserve of endosperm has been exhausted (Hänsel 1961). This statement is in accord with the two maxima of cold resistance found by Roberts and Grant (1968). They also found varietal differences in the duration and timing of the second resistance maximum that falls in the tillering stage. There is general agreement that, with the beginning of the generative stage when shooting starts, the resistance to cold sharply falls.

Tolerance to spring frost in the generative stage does not appear to be linked with cold tolerance in the vegetative stage. Rather small differences between spring and winter wheats in late frost tolerance are found (Single 1968.) Early heading could be very dangerous in regions where late spring frost occurs (Lamb 1967, et al.).

As shown by many authors, the stages of the life cycle of varieties could decisively influence their cold and frost tolerance irrespective of genotypic hardiness of varieties. But, the desired level of tolerance or resistance varies with different regions and the phenotypic expression suitable for a region may be obtained through interactions of numerous internal and external factors which influence cold and frost tolerance of common wheat.

Photoperiodism and Life Cycle of Varieties

The sharp fall of cold tolerance with the beginning of shooting stage and the possibility of avoiding late frost injuries by the growing of late varieties seemed to justify the breeding of varieties with prolonged vegetative growth in early spring combined with late or early heading, depending on the region for which they were bred. "High critical day length" was a criterion for lateness in many programmes. As a matter of fact, the earliest varieties usually possessed low and the latest ones high sensitivity to photoperiod.

Fig. 1 shows the relative number of days to heading (y_1) of some fall sown traditional (B) and modern wheat varieties and strains (A) grown in the field near Zagreb (45° 45' N, alt. 156) Yugoslavia, in relation to the number of days to heading (x_1) of 55-day vernalized seeds on the same experimental field and treated for 50 days with a shortened photoperiod of 11.30 hours (for exact procedure see Martinić 1966 or 1971). It is seen that the correlation coefficient of 0.80 for both groups of varieties fits well the results of Yasuda and Shimoyama (1965) and others, when the sensitivity criterion was number of days to heading in shortened photoperiod of vernalized seeds (x_1). Nevertheless, correlation breakers like Kavkaz (Kv) of the Krasnodar station (USSR) are clearly distinguished even by this criterion.

When, as shown in Fig. 2, the criterion for photoperiodism was the delay of heading in days (x_2) caused by the growing of varieties in a shortened photoperiod, the low responding varieties (A) were better distinguished from high responding ones (B) than was the case with the usual criterion (x_1). The correlation coefficient for x_2 for low sensitive varieties (A) was too low ($r = 0.172$) to be significant and, within the group, varieties were too clearly different from one another to be taken together. On the contrary, using the first criterion, the correlation coefficient for the varieties of the group A was lower ($r = 0.553$) than that of both groups ($r = 0.800$) but still significant at the 1% level (Fig. 1). By using the second criterion (Fig. 2), the positions of B varieties were also considerably changed. But, the number of varieties in group B is far too small to be representative and the heading date as such depends, especially under field conditions, on some other known and unknown factors to be treated as perfect criterion for evaluation of varietal differences in sensitivity to day length. For the time being, the second criterion is useful especially if delay of heading (Fig. 2) instead of the number of days to heading (Fig. 1) in the shortened photoperiod, is used.

However, many "exceptions" or "correlation breakers" which often are found, allow the conclusion that the well known correlation between photoperiodism and life cycle which, in the past in many regions with primitive agricultural practice, developed through natural selection. Today in modern practice, it primarily depends on the goals of breeding programmes and methods used. If such programmes reasonably favour the "exceptions", in a rather short period of time a new population of spring and winter wheat varieties, without clear relation between the two above-mentioned traits i.e. life cycle and photoperiodism could be created.

Photoperiodism and Cold Tolerance

Forty-one winter wheat varieties and strains and the variety Leone, an intermediate type, were used for a study of the relationship between sensitivity to day length and cold tolerance. As shown in Figs. 3 and 4, 35 of them had low sensitivity to photoperiod (group A) and, of the greatest importance for interpretation of the results, were (Rn-12) Ranaja 12, (Be-1) Bezostaja 1, and (Kv) Kavkaz from USSR, (Et) Etoile de Choisy from France, (SP) San Pastore and (Le) Leone from Italy, and (Sv) Sava and (ZD) Zlatna Dolina, two new promising Yugoslav varieties. The B-group of varieties with high sensitivity to photoperiod is represented by (M-808) Mironovskaja 808 from the USSR, (GS) Gaines and (Min) Minhardi from the USA, (ND) Nord Desprez as the representative of the North European varieties, (U-1) Osiječka Šišulja, a traditional variety bred in Yugoslavia about 1935, (B-1205) Bankuty 1205 from Hungary, introduced also about 1935 and along with the U-1 widely grown in Yugoslavia up to 1958, at which time they were replaced by new modern varieties (Borojević and Potočanac, 1966) with low sensitivity to shortened day length (Martinić, 1966).

The cold tolerance of the varieties and lines was examined in freezing chamber of the Institute of Agricultural Research at Novi Sad, by Dr. Mišić (1965). The varieties were hardened under natural fall conditions in Novi Sad. During winter time in the freezing chamber they were treated in the vegetative stage with low temperature for 48 hrs at 0°C, 24 hrs at -5°C, 12 hrs at -10°C and finally for 6 hrs at -15°C. The number of plants surviving the treatment was the criterion for the evaluation of cold tolerance of varieties. After several treatments, varieties and strains were systematized by Dr. Mišić (personal communication) and in the end their cold tolerance was expressed in a score from 1 (no survival) to 10 (100% survival) when treated as just described.

As shown in Fig. 3, when both groups (A and B) of varieties were evaluated as "one sample" the correlation coefficient $r = 0.495$ was significant at the 1% level, supporting to some extent the positive correlation between cold tolerance (y_2) and sensitivity to photoperiod expressed in number of days to heading in shortened photoperiod (x_1). On the contrary, the smaller correlation coefficient ($r = 0.258$) for low sensitivity group A of varieties was not significant at 5% level and it was tending to 0 ($r = 0.172$) when the second criterion for photoperiodism, i.e. the delay of heading in shortened photoperiod (x_2, Fig. 4) was used. It is obvious from Figs. 3 and 4 that, in many modern varieties and strains, high tolerance to freezing temperature of -15°C in vegetative stage after hardening in natural conditions, has been combined with low sensitivity to shortened photoperiod.

Discussion and Conclusion

Although there are a number of varieties in which cold tolerance is built in along with low sensitivity to day length, the growing of such varieties as Bezostaja in Svalof, Sweden is too hazardous (Dr. Olsson, personal communication, 1971). On the other hand, in Sapporo, Japan in the first IWWPN much better survival of Bezostaja (85.5%) than that of highly sensitive varieties like Bankuty 1201 (1.8%), Heine VII (5.5%) and some others, along with that of low sensitive spring variety Lerma Rojo 64 (0% survival), was observed (Stroike et al. 1971).

Therefore, further investigations are necessary in order to enable an answer to the question of whether it is possible and reasonable to build into new low sensitive varieties such a level of winter hardiness that will allow them to avoid risk when grown in more northern regions like South Sweden where winter types with high sensitivity are successfully grown. What practical use such a variety would have in northern regions is, at least to me, still an open question. The advantages of low sensitivity varieties with very different cold tolerance and vernalization requirement in the regions of about or below 45° are, today, well established (Strampelli 1932) by the results of several modern winter wheat breeding programmes (Martinić 1966 1970, 1971).

Nevertheless, the superiority of new types with low sensitivity in adaptability, stability of yield, and grain yield capacity can not be adequately explained only by the shorter life cycle which allows the variety to avoid the risks of diseases and drought in Southern hot summer regions (Martinić 1971). Although the cold tolerance of several low sensitivity varieties is higher than required for many regions, it is not the only factor determining the winter hardiness of varieties. As has just been shown from the results of the present study, the correlation between day length sensitivity and life cycle of low sensitive varieties, when fall sown in the field, is very low and not significant at least for Yugoslav growing conditions.

Early fall development is well controlled by the vernalization requirement of winter types in Yugoslavia (Martinić 1969) as is early spring development in Australia (Pugsley 1967). Undoubtedly, many other factors govern the life cycle of varieties in the fall and spring which can compensate the effect of day length on development and assure that plants will remain in the best developmental stage for overwintering. In some winter wheat regions at least, late fall sowing controls too early development and allows successful production, as winter crops, of low sensitive spring or dual purpose weak winter hardy varieties. Thus, there really are at the disposal of breeders plenty of combinations for creation of a desired genotype, as far as photoperiodism and cold tolerance are concerned.

To conclude, we have good reasons to hope that in a few years time the IWWPN may render possible a better interpretation of the above-mentioned traits and their interrelations. Varieties grown in the Nursery will need to be analyzed uniformly in a controlled environment for characterization of their day length sensitivity, cold tolerance, vernalization requirement, and life cycle.

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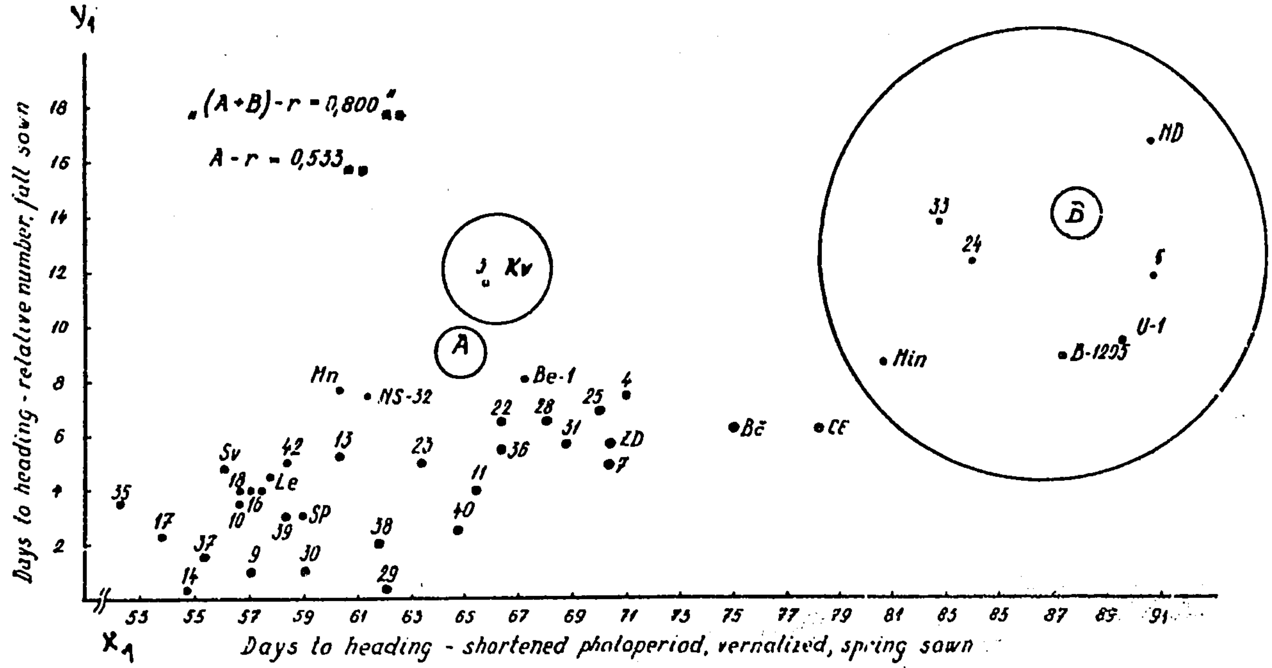
y_1
Days to heading - relative number, full sown
"(A+B)-r = 0,800"
A - r = 0,533
A
B
Kv
Mn
NS-32
Be-1
Sv
Le
SP
ZD
Bč
CE
ND
U-1
B-1205
Min
x_1
Days to heading - shortened photoperiod, vernalized, spring sown

Fig. 1

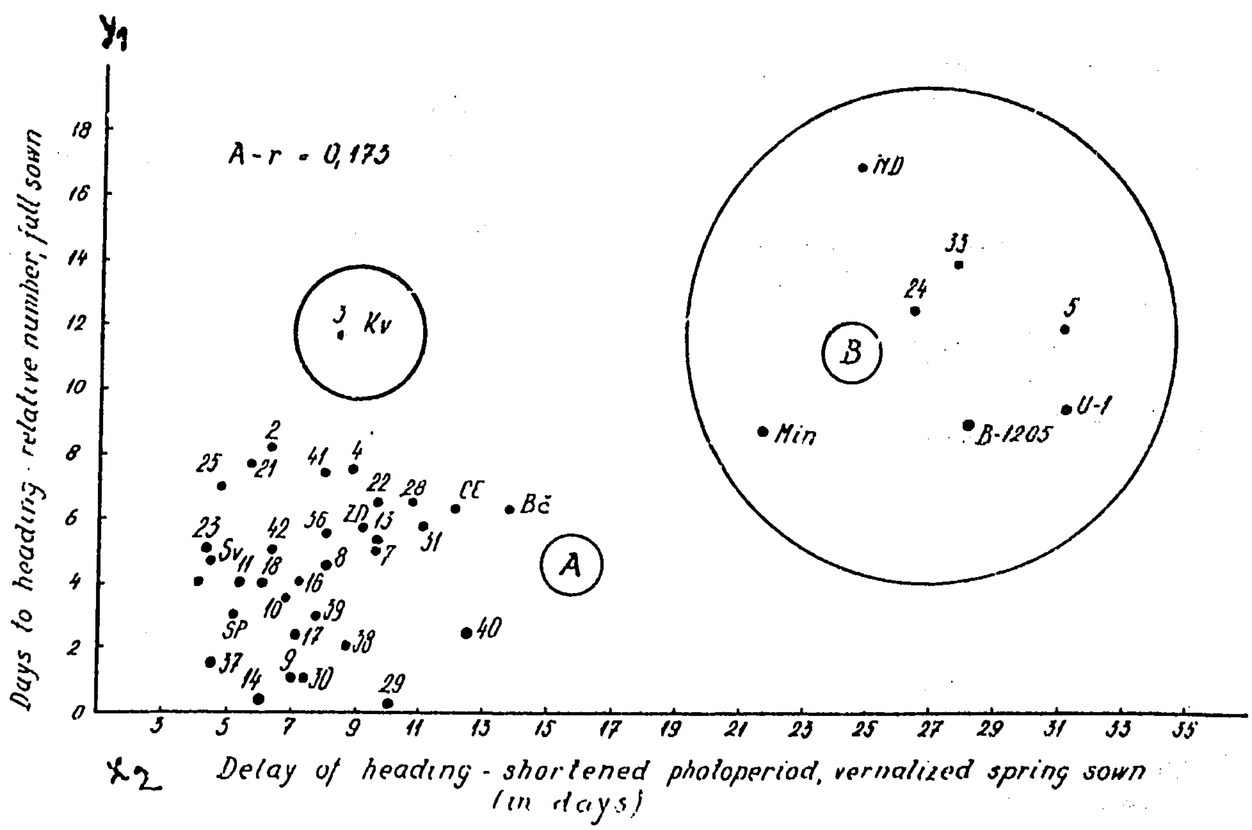
y_1
Days to heading - relative number, full sown
A - r = 0,175
Kv
A
B
ND
Min
B-1205
U-1
CE
Bč
ZD
Sv
SP
x_2
Delay of heading - shortened photoperiod, vernalized spring sown
(in days)

Fig. 2

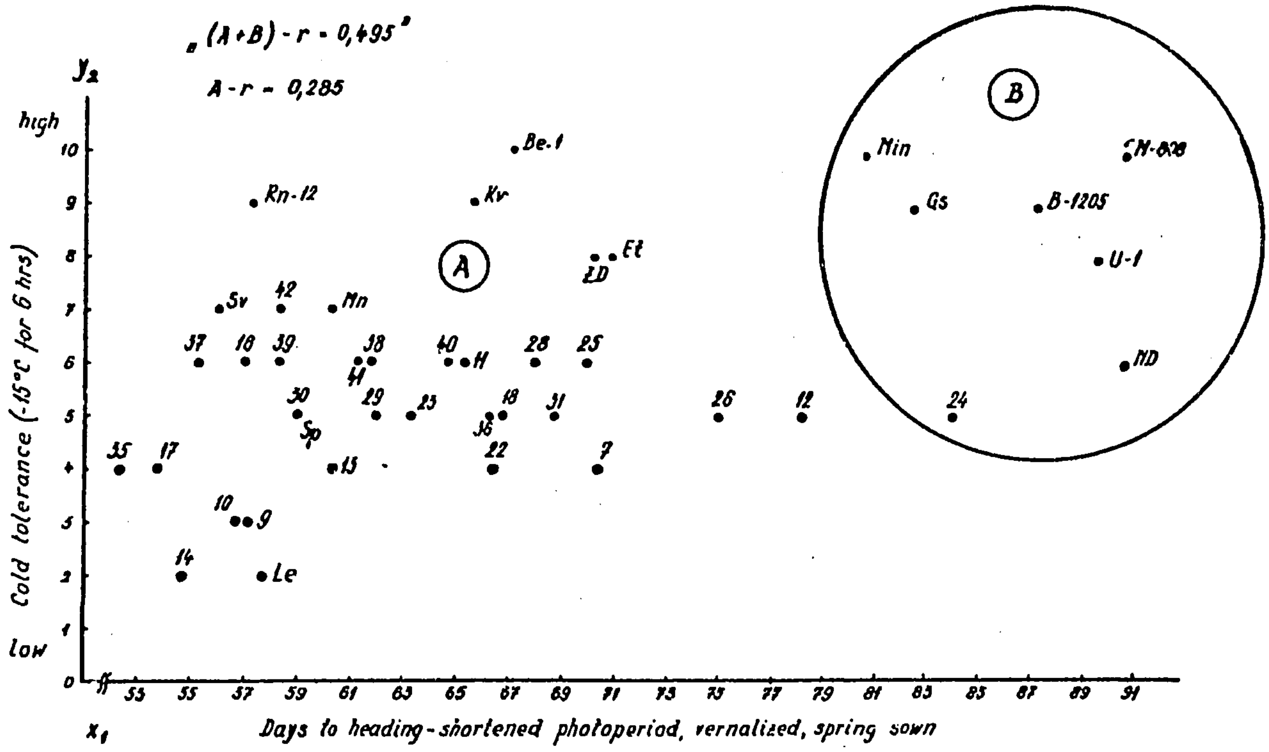
(A+B) - r = 0,495
A - r = 0,285
high
low
Cold tolerance (-15°C for 6 hrs)
Days to heading-shortened photoperiod, vernalized, spring sown
A
B

Fig. 3

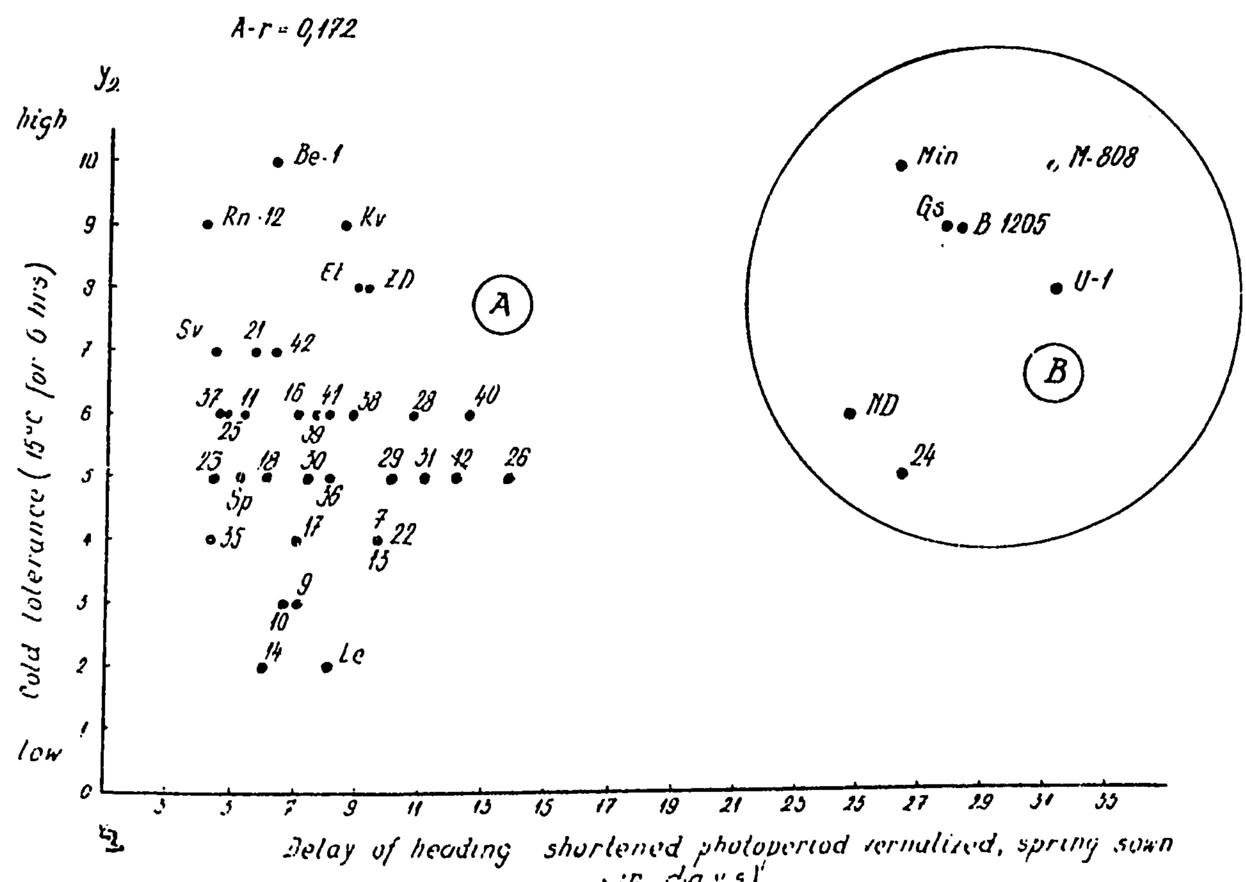
A-r = 0,172
high
low
Cold tolerance (15°C for 6 hrs)
Delay of heading shortened photoperiod vernalized, spring sown (in days)
A
B

Fig 4

Z. Martinić, Zagreb

Description of Figures

Figure 1 - Days to heading of winter varieties and lines (Y_1) is highly correlated with their response to photoperiod when days to heading in shortened photoperiod (X_1) is used as a criterion for photoperiodism. The Kavkaz variety of the Krasnodar Station (Kv) is clearly distinguished as a correlation breaker even by this criterion.

Figure 2 - When delay of heading caused by shortened photoperiod (X_2) is used as the criterion for photoperiodism, insensitive (A) and highly sensitive (B) varieties to photoperiod are easily distinguished. The correlation coefficient between life cycle until heading and photoperiodism approaches zero between this criterion.

Figure 3 - Positive correlation between cold tolerance (Y_2) and the X_1 criterion for photoperiodism is supported only when A and B varieties are evaluated together. Several correlation breakers, at this level of cold tolerance, are clearly distinguished.

Figure 4 - When delay of heading (X_2) is used as the criterion for photoperiodism, the correlation coefficient between cold tolerance (Y_2) and photoperiodism for varieties with low sensitivity to photoperiod (A) tends to 0. The A and B varieties are too clearly distinguished.

Varieties and lines in Figures 1 - 4

No.	or Abbr.	Name	Country	Photoperiodism
1	Rn-12	Ranaja 12	USSR	A
2	Be-1	Bezostaja 1	"	A
3	Kv	Kavkaz	"	A
4	Et	Etoile de Choisy	France	A
5	M-808	Mironovskaja 808	USSR	B
6	ND	Nord Desprez	France	B
7	--	Autonomia	Italy	A
8	Le	Leone	"	A
9	--	Fiorello	"	A
10	--	S-13	"	A
11	--	Libellula	"	A
12	CE	Elia	"	A
13	--	Zagorka	Yugoslavia	A
14	--	Zg-5900/66	"	A
15	ZD	Zlatna Dolina	"	A
16	--	Sanja	"	A
17	--	Zg-7920/66	"	A
18	--	Mura	"	A
19	B-1205	Bankuti 1205	Hungary	B
20	U-1	Osiječka šišulja	Yugoslavia	B
21	--	Mirna	"	A
22	--	Slavonka	"	A
23	--	Bl-5328/68	"	A
24	--	Zekar	"	B
25	--	H-52	"	A
26	Bč	Bačka	"	A
27	Sv	Sava	"	A
28	--	NS-32	"	A
29	--	NS-171/1	"	A
30	--	NS-171/0	"	A
31	--	NS-440	"	A
32	Min	Minhardi	USA	B
33	Gs	Gaines	"	B
34	SP	San Pastore	Italy	A
35	--	NS-447	Yugoslavia	A
36	--	NS-439	"	A
37	--	NS-622	"	A
38	--	NS-735	"	A
39	--	NS-732	"	A
40	--	NS-602	"	A
41	--	Panonija	"	A
42	--	NS-720	"	A

A - low sensitivity to photoperiod
B - high sensitivity to photoperiod

LIMITING FACTORS IN WHEAT ADAPTATION

by

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The most important limiting factors for optimal development of wheat genotypes are those whose effect cannot be compensated by the wheat properties among themselves or by other environmental factors. For example, the effect of unfavourable conditions during the spikelets development may be compensated by the effect of favourable conditions during the fertilization or grain filling period. But 30 percent of winter survival due to the effect of low temperature cannot be compensated by tillering and a variety must possess genetic resistance to low temperatures.

The characters upon which the genetic potential for yield depends, such as number of spikes per unit area, number and weight of kernels per spike, etc., are similar in the majority of wheat breeding programs nowadays. But the characters by which a variety has to oppose the limiting factors of environment are different in various regions. This subject will be discussed on the basis of the data from the International Winter Wheat Performance Nursery (IWWPN) during 3 years in Novi Sad and 1 or 2 years in other localities in Europe.

Water supply

If the rainfall is in excess, the variety must be resistant to lodging (Fig.1). The resistance to lodging is achieved by breeding for short stature of plant rather than for tall and thick stalk. In the First and the Second IWWPN most varieties with tall straw were tested and during 3 years in Novi Sad, quite severe and rather early lodging has occurred. Therefore no correlation was found between the percent of lodging and the yield of grain (Tables 1 and 2). However in Milano, Wageningen and Svalöf, where greater differentiation in time and intensity of lodging took place in 1969, both simple and partial coefficients of correlation were significantly negative in regard to the yield (Table 3). In other of our experiments where dwarf, short and tall varieties were tested, a negative correlation between the percent of lodging and yield was also shown (Borojević and Cupina 1969).

If there is a shortage of water, the variety has to be resistant to drought, counteracting it either by efficient development of root system in the case of early drought or by efficient photosynthetic apparatus in the case of late drought. The variety Bezostaia-1 and several varieties from Nebraska and Kansas possess such capacity which has brought them among the leading varieties in southern Europe (Table 1) and in dry regions in Turkey, Iran, and the Central USA.

Table 1. The grain yield of varieties in q/ha in the IWWPN for a 3-year period in Novi Sad, Yugoslavia.

Variety	1969	1970	1971	$\bar{X}$
1. Arthur	61.8	58.1	58.0	59.3
2. Benhur	57.2	52.6	53.1	54.3
3. Yung Kwang	56.3	48.5	58.1	54.3
4. Timwin	52.0	52.4	58.1	54.2
5. Parker	57.6	49.1	53.2	53.3
6. Bezostaia-1	58.9	45.2	54.6	52.9
7. Atlas 66	52.5	51.5	49.1	51.0
8. Scout 66	57.7	46.5	47.6	50.6
9. Backa	50.9	--	56.8	53.8
10. Gage	54.3	50.2	--	52.2
11. NB67730	57.4	43.7	--	50.5
12. Stadler	53.0	48.1	--	50.5
13. Lerma Rojo 64	56.7	40.2	48.8	48.6
14. San Pastore	56.9	40.6	47.2	48.2
15. Fertodi 293	46.2	45.6	52.1	48.0
16. Sturdy	52.3	42.2	47.7	47.4
17. Blueboy	49.1	35.0	56.6	46.9
18. Purdue 4930	53.3	45.0	--	49.1
19. Riley 67	51.7	48.0	--	49.8
20. Bankuti 1201	49.5	48.2	--	48.8
21. Triumph 64	68.2	44.6	41.8	44.9
22. Yorkstar	37.3	34.7	52.2	41.4
23. Shawnee	47.5	46.5	--	47.0
24. Lancer	48.5	35.4	--	41.9
25. Heine VII	35.3	29.9	50.3	38.5
26. Felix	27.6	18.0	53.3	33.0
27. Gaines	37.6	34.9	--	36.2
28. Winalta	37.4	31.0	--	34.2
29. Capelle D'Esprez	35.5	30.6	--	33.0
30. Odin	23.3	28.7	--	26.0

Table 2. Simple (r_a) and partial (r_b) coefficients of correlation between yield of grain and other characters for 30 wheat varieties grown in the IWWPN during 3 years in Novi Sad.

		1969	1970	1971
Yield of grain:				
% lodging	r_a	0,601^{xx}	0,328	0,169
	r_b	0,292	0,100	0,100
flowering (days)	r_a	-0,827^{xx}	-0,644^{xx}	-0,392^{x}
	r_b	-0,537^{xx}	-0,409^{x}	-0,032
ripening (days)	r_a	--	-0,311	-0,393^{x}
	r_b	--	0,367^{x}	-0,100
leaf rust (severity)	r_a	-0,540^{xx}	-0,576^{xx}	-0,138
	r_b	-0,374^{x}	0,100	0,164
test weight	r_a	0,810^{xx}	0,798^{xx}	0,130
	r_b	0,298	0,548^{xx}	-0,110

-- no data recorded

Extreme temperatures

To survive temperatures below -15°C or lower, when they are without the snow cover, wheat varieties must possess genetic resistance to low temperatures (Fig. 1). In localities where low temperatures were limiting, as in Svalöf, a highly significant positive correlation between the percent of winter survival and yield was found, while in localities with mild winter (Rieti, Milano), there was no correlation between these two parameters (Fig. 2 and Table 3).

The deleterious effect of high temperatures may be reduced by earliness or by genetic resistance to high temperatures. It is possible to escape high temperatures by earliness in continental and semi-arid regions where they do not coincide regularly with grain filling stage, but in arid climates, the resistance to high temperatures during the ripening stage is a necessary genetic attribute of a variety. The resistance to that kind of drought was not measured in the IWWPN, but from the performance of the varieties from Nebraska, Kansas, Texas, it is evident that the genetic resistance to drought plays a very important role in yield formation.

Response to daylight

The length of day may be also a limiting factor in the adaptation of certain wheat genotypes (Fig. 1). If the long day requirement is combined with moderate temperatures, which is the case in North and West European Countries, a positive correlation is found between the time of flowering or ripening and

Table 3. Simple (r_a) and partial (r_b) coefficients of correlation between yield of grain and several other characters for 30 wheat varieties grown in the IWWPN in Europe in 1969.

		Fundulea, Romania	Novi Sad, Yugoslavia	Rieti, Italy	Milano, Italy	Wageningen, Netherlands	Svalöf Sweden
Yield of grain % lodging	r_a	X	0,601^{xx}	X	-0,462^{xx}	-0,448^{xx}	-0,123
	r_b		0,292		-0,431^{x}	-0,311	-0,411^{x}
% winter survival	r_a	X	X	X	X	0,312	0,638^{xx}
	r_b					0,205	0,630^{xx}
flowering (days)	r_a	-0,589^{xx}	-0,827^{xx}	-0,712^{xx}	-0,091	0,352^{x}	0,740^{xx}
	r_b	0,405^{x}	-0,537^{xx}	-0,537^{xx}	-0,559^{xx}	0,326	0,401^{x}
ripening (days)	r_a	-0,677^{xx}	-	-0,279	0,127	0,113	0,547^{xx}
	r_b	-0,138		0,561^{xx}	0,523^{xx}	0,044	0,562
leaf rust (sev.)	r_a	-0,213	-0,540^{xx}	-0,518^{xx}	0,071	-	-0,230[1]
	r_b	0,000	-0,374^{x}	0,000	-0,429^{x}		0,406^{x}[1]
stem rust (sev.)	r_a	-0,584^{xx}	-	-0,431^{x}	0,093	-	-
	r_b	-0,212		-0,274	-0,415^{x}		
% protein	r_a	0,054	-0,199	0,224	-0,502^{xx}	-0,565^{xx}	-0,457^{xx}
	r_b	-0,017	-0,247	-0,430^{x}	-0,680^{xx}	-0,327	-0,694^{xx}
test weight	r_a	0,746^{xx}	0,810^{xx}	0,804^{xx}	-0,078	-0,223	0,689^{xx}
	r_b	0,489^{xx}	0,298	0,619^{xx}	-0,361^{x}	0,187	0,563^{xx}

- no data recorded
X data not differentiating
1 refers to mildew

W H E A T   A D A P T A T I O N

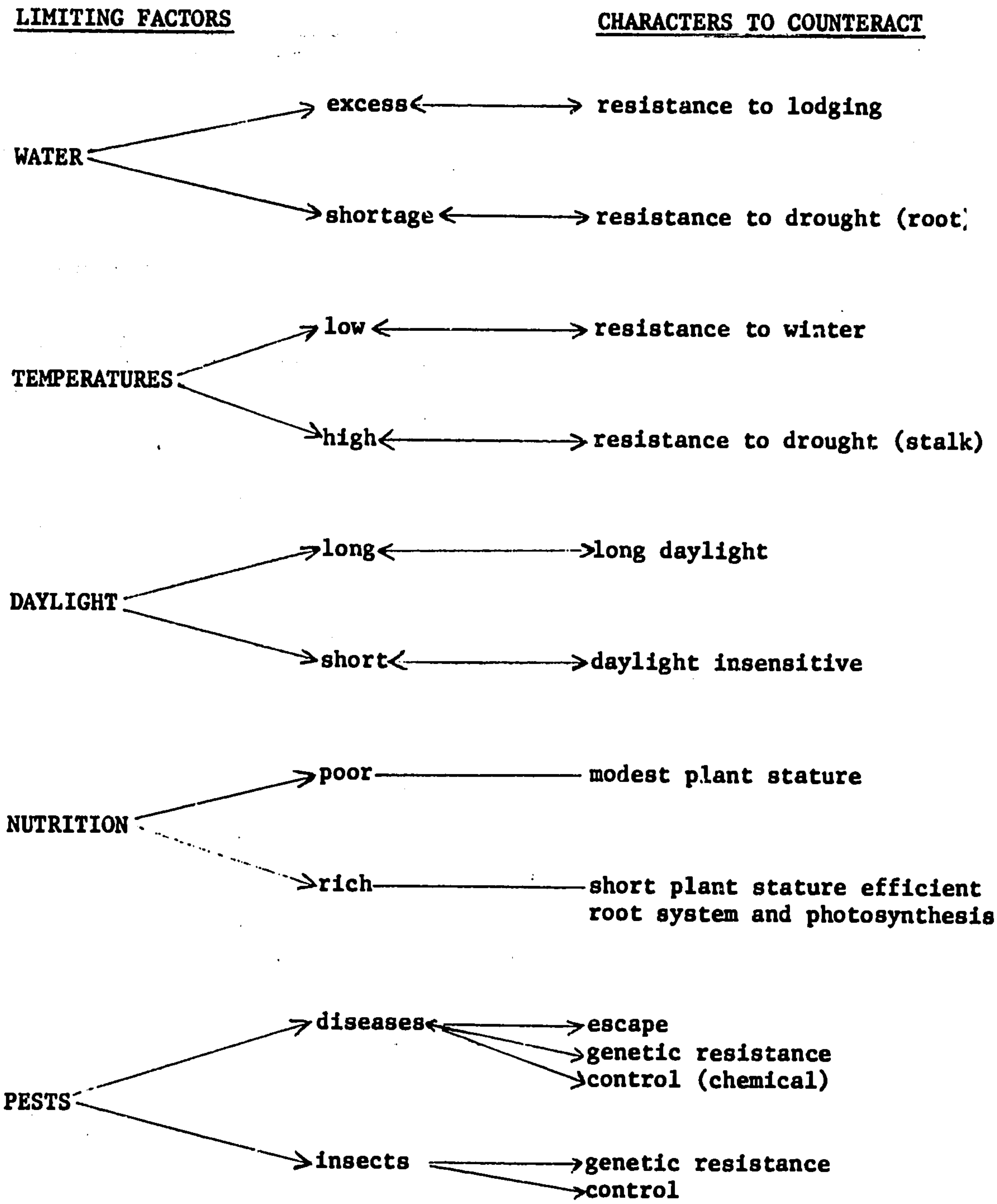

Fig. 1

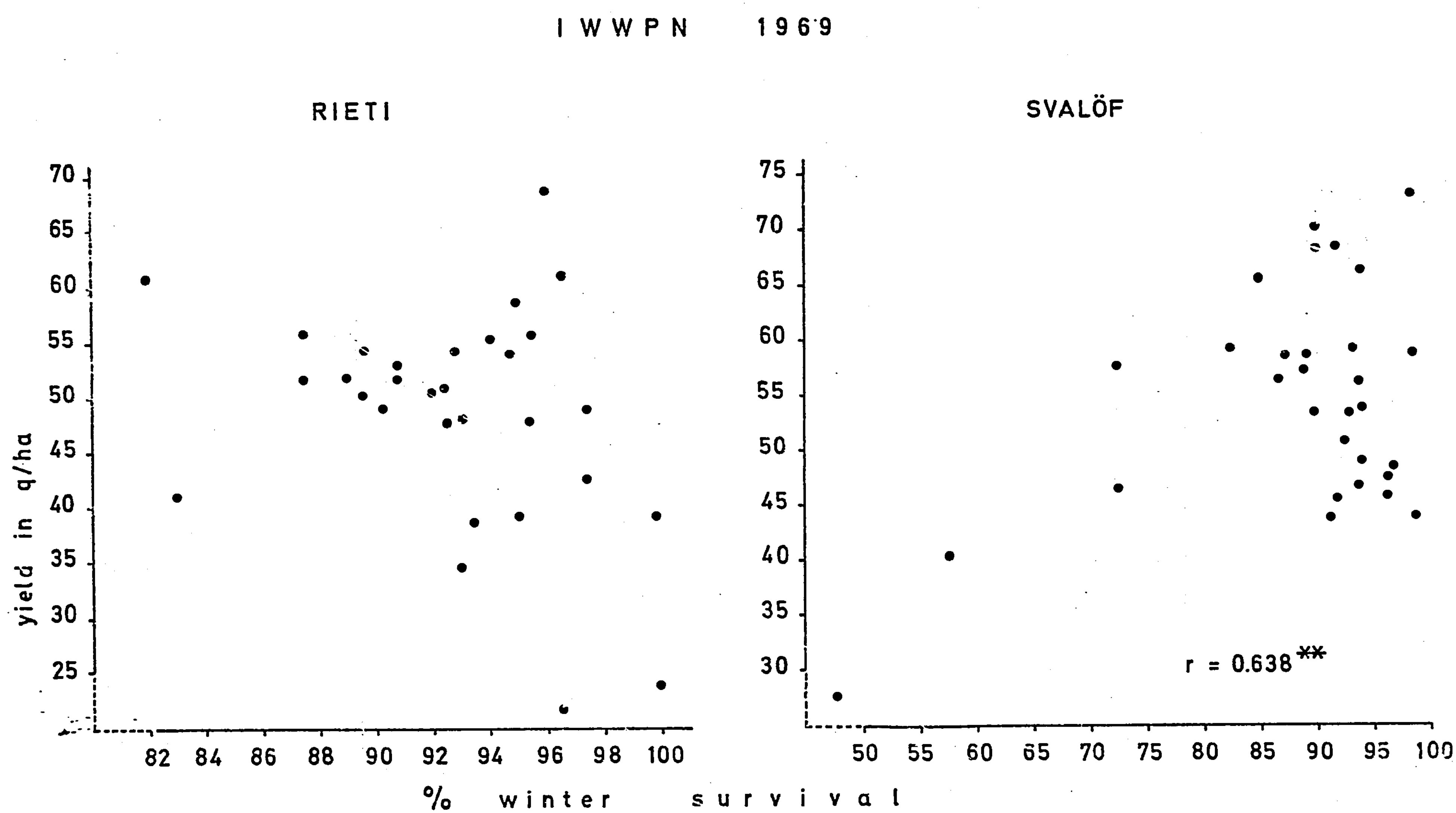

Figure 2.

yield of grain (Fig. 3 and Table 3). On the contrary, when shorter daylength and high temperatures interfere with the flowering stage, a negative correlation with regard to yield is shown as in Yugoslavia (Fig. 3 and Table 2) and in Italy (Table 3). Although a high positive correlation exists between the flowering and ripening time (Table 4), the coefficient of correlation between the flowering time and yield on one side and the ripening time and yield on the other, were not in full agreement. The partial coefficient of correlation between the ripening time and yield was even positive for Rieti and Milano (Table 3) showing that in 1969 most varieties had a normal ripening period.

Daylight neutral varieties overcome the large differences in the latitude. Therefore, the Mexican daylight insensitive varieties perform well in all latitudes where the resistance to winter is not the limiting factor, whereas the Swedish and German varieties with long day requirement perform poorly under the conditions of shorter days (Table 1). One of the reasons for the extremely good performance of Bezostaia-1 in almost all latitudes is its less sensitive response to daylength, which is also the case with most high-yielding Italian and Yugoslav varieties (Martinić, 1970).

Nutritional requirements

The localities where the IWWPN is conducted, besides differences in climate, show a wide range of conditions in soil quality, use of mineral fertilizers, etc. While the average yields in Kabul and Svalöf were over 50 q/ha in Oklahoma and Eskisehir they were below 30 and 20 q/ha respectively (Stroike et al. 1971).

Intensive varieties cannot express their yield potential under poor conditions, while extensive varieties are not suitable for highly intensive agriculture. Therefore, the average yield from many localities when the growing conditions are very different, may lead to wrong conclusions in regard to the real value of a variety.

If the growing conditions are poor and cannot be much improved, varieties with modest nutritional requirements, economical root system and smaller photosynthetic apparatus, will have the advantage. If the nutrition is abundant, larger leaf area and bigger root system may have an advantage, provided there is resistance to lodging by dwarf or stiff straw (Fig. 1).

Attack of pests

A variety can oppose the attacks of pathogenic organisms and insects by earliness, by genetic resistance or by chemical control (Fig. 1). If a variety possesses genetic resistance, its vegetation period may be prolonged which contributes considerably to an increase of yield (Scout, Parker, Table 1).

The contribution of disease resistance to yield formation is demonstrated by the negative correlation between the percent of severity of leaf rust and yield for 2 years in Novi Sad (Table 2). This, however, was a combined effect of genetic resistance and escape by earliness. In other localities a negative coefficient of correlation both for leaf and stem rust with regard to yield was also observed (Table 3).

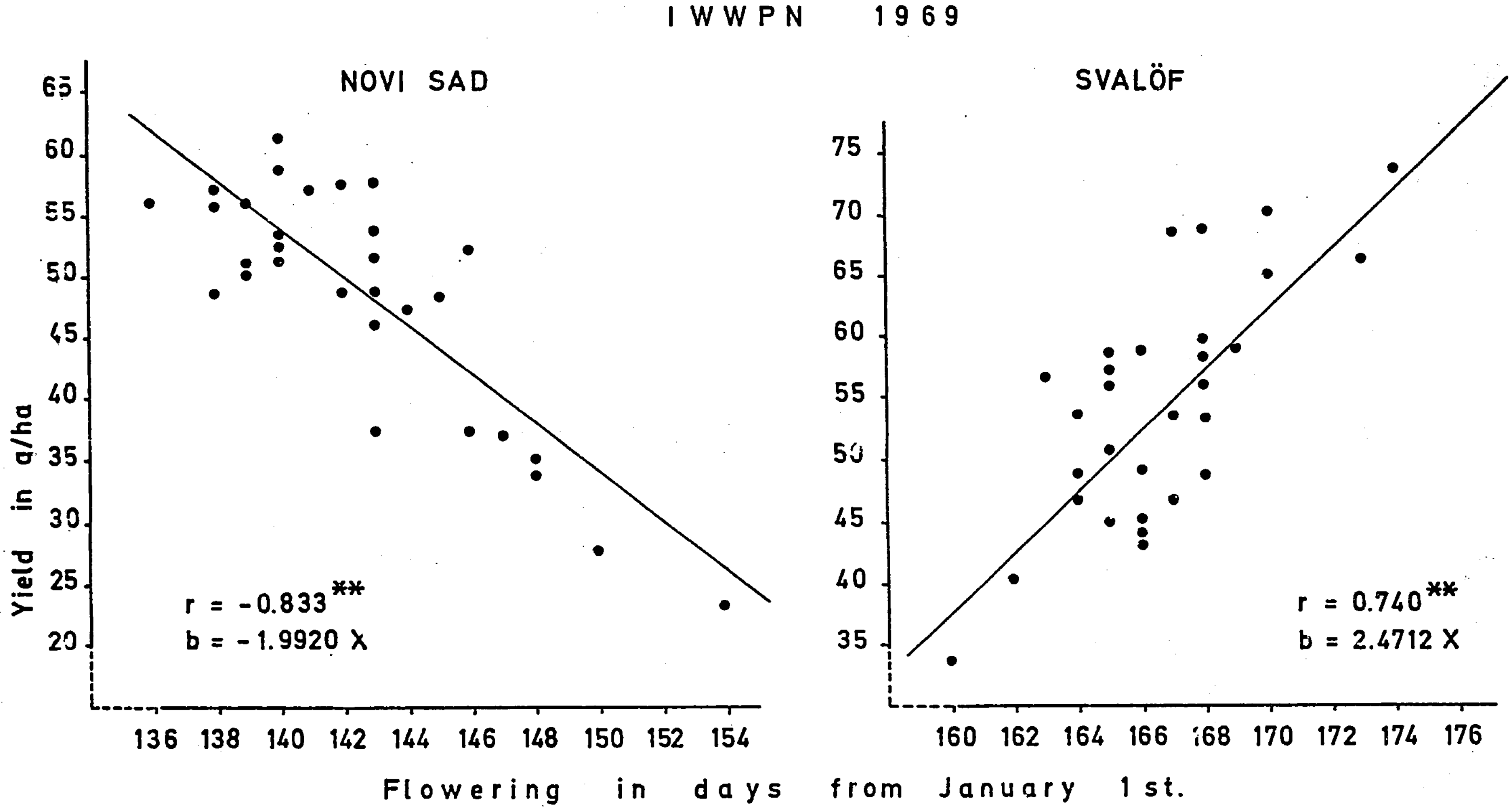
IWWPN 1969
NOVI SAD
SVALÖF
Yield in q/ha
r = -0.833**
b = -1.9920 X
r = 0.740**
b = 2.4712 X
Flowering in days from January 1st.

Figure 3.

Relationship between the characters

To better reveal the limiting factors in yield formation it seems useful to examine the interdependence between the characters themselves.

The relationship between resistance to lodging and the length of vegetation period was different in various years in Novi Sad but in general showing a lesser percent of lodging of earlier varieties which in 1969 was statistically significant (Table 4).

High percent of lodging did not cause a heavy attack of leaf rust in Novi Sad (Table 4), but this may not be so at other locations (Tables 5 and 6).

The vegetation period expressed as flowering and ripening time in days from January 1st showed highly significant positive correlations with the severity of leaf rust for 2 years in Novi Sad (Table 4). This again shows that early varieties may escape attack while the later ones should be resistant (Tables 5 and 6).

The protein content and the test weight are also highly dependent upon the length of vegetation period and the severity of diseases. Highly significant negative coefficients of correlation between test weight and flowering or ripening time and leaf rust attack during 3 years in Novi Sad (Table 4) proved that the vegetation period was limited considerably by high temperatures, shortage of water and disease attack.

Table 4. Simple coefficients of correlation between various characters for 30 wheat varieties grown in the IWWPN during 3 years in Novi Sad.

	Flowering	Ripening	Leaf rust	% Protein	Test weight
		1969			
% lodging	-0.542^{xx}	-	-0.272	-0.009	0.530^{xx}
flowering (days)			0.333	0.321	-0.742^{xx}
leaf rust (severity)				0.334	-0.550^{xx}
% protein					-0.179
		1970			
% lodging	-0.105	0.016	-0.079	+	0.351^{x}
flowering		0.801^{xx}	0.716^{xx}		-0.711^{xx}
ripening			0.455^{xx}		-0.463^{xx}
leaf rust					-0.684^{xx}
		1971			
% lodging	-0.210	-0.156	-0.026	+	0.182
flowering		0.955^{xx}	0.650^{xx}		-0.491^{xx}
ripening			0.632^{xx}		-0.497^{xx}
leaf rust					-0.272

- no data recorded
+ data for protein not yet obtained

Table 5. Simple coefficients of correlation between various characters for 30 wheat varieties grown in the IWWPN in Europe for 1969.

	Ripening	Leaf rust	Stem rust	% Protein	Test weight
		Fundulea			
flowering (days)	0.954^{xx}	0.273	0.750^{xx}	-0.011	-0.918^{xx}
ripening (days)		0.257	0.741^{xx}	0.000	-0.946^{xx}
leaf rust (severity)			0.203	0.132	-0.293
stem rust (severity)				-0.030	-0.730^{xx}
% protein					0.084
		Rieti			
flowering	0.783^{xx}	0.535^{xx}	0.398^{x}	-0.057	-0.670^{xx}
ripening		0.280	0.305	0.217	-0.334
leaf rust			0.000	-0.437^{x}	-0.621^{xx}
stem rust				-0.312	-0.445^{xx}
% protein					0.498^{xx}
		Milano			
% lodging	-0.065	-0.232	-0.429^{x}	0.468^{xx}	0.443^{x}
flowering	0.857^{xx}	0.061	0.559^{xx}	-0.445^{x}	-0.567^{xx}
ripening		-0.080	0.372^{x}	-0.376^{x}	-0.418^{x}
leaf rust			0.494^{xx}	-0.484^{xx}	-0.412^{x}
stem rust				-0.704^{xx}	-0.763^{xx}
% protein					0.546^{xx}

Table 6. Simple coefficients of correlation between various characters for 30 varieties grown in the IWWPN in Europe for 1969.

	Lodging	Flowering	Ripening	Mildew	% Protein	Test weight
		Wageningen				
% winter survival	-0.101	0.136	0.146		-0.352^{x}	-0.297
% lodging		-0.048	-0.003		0.525^{xx}	0.374^{x}
flowering			0.347^{x}		-0.220	-0.416^{x}
ripening					0.006	-0.329
% protein						0.298
		Svalöf				
% winter survival	0.265	0.485^{xx}	0.187	-0.478^{xx}	0.112	0.695^{xx}
% lodging		-0.138	-0.406^{x}	-0.283	0.462^{xx}	0.083
flowering			0.819^{xx}	-0.440^{x}	-0.470^{xx}	0.380^{x}
ripening				-0.374^{x}	-0.355^{x}	0.262
mildew (severity)					-0.354^{x}	-0.263
% protein						-0.054

Conclusion

Testing of different varieties in various climatic and edafic regions brings the limiting factors to our attention more clearly than testing in one region, and shows their relative importance in each region as well as the characters of a variety by which those factors should be opposed.

Differences in the data obtained from such trials suggest that the merit of a variety must not be evaluated on the basis of average performance from all regions, but first of all on the average for several years in one region or locality. It is useful to know that Bezostaia-1 occupies the first place among all localities tested during 3 years, but this ranking does not mean much for Milano or Cambridge, because this variety was not among the leading ones there.

However, our knowledge about the performance of Bezostaia-1, Scout, Odin, San Pastore and other varieties means very much for further wheat breeding. We have better evidence of which are the determining yield components in each region, how they are formed under the limiting factors in the region that we are interested in, which characters, and to what extent they may compensate for those which were limiting in their development. On the basis of such knowledge, we can make a more definite model of high-yielding varieties which should be actually an ecological model (Mac Key 1970, Borojević 1971). In order to aid this work, the IWWPN should include the best representatives of the present day genotypes and to test them in the best representatives of ecological regions in the winter wheat growing areas of the world.

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WINTER WHEAT
SUMMER FALLOW RESEARCH IN CENTRAL ANATOLIA

by

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Turkey

Central Anatolia in general is a large plateau surrounded by high mountains. With hot, dry summers and cold winters it exhibits a continental climate. The distribution of the average annual 380 mm rainfall is 19%, 30%, 34%, 17% in the fall, winter, spring and summer respectively. From the beginning of the fall tillage through the spring tillage operations, 70% of the annual rainfall is received. However, variations from this pattern are not unusual. This fact affects the agricultural practices and the yield in the area as will be explained later. The wettest month of the year is May, or December. Relative humidity is the lowest in July and August. Snow covered and frosty days occur between November and April. Soil may freeze down to 30 cm in some regions.

Some Meteorological Values for Central Anatolia

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total or mean
Average Rainfall, mm												
43.2	41.6	39.9	39.2	49.6	31.9	9.0	5.8	15.1	23.0	33.6	49.7	381.7
Average Temperature, C°												
0.7	0.4	4.2	10.3	15.2	19.0	22.1	22.1	17.4	12.0	6.6	1.8	12.9
Highest Temperature, C°												
19.0	23.8	29.1	31.1	34.8	37.6	41.7	41.8	37.2	33.6	26.2	21.8	41.8
Lowest Temperature, C°												
-32.5	-34.4	-26.6	-11.0	-5.5	-0.6	2.9	2.2	-5.4	-9.7	-24.4	-30.2	-34.4

Source: Çölaşan, Umran, E. (1970) Türkiye Iklim Klavuzu.
37. Sokak No. 36/2 Bahçelievler, Ankara

Generally, the arable soils in Central Anatolia are classified as Brown, Reddish Brown and some Sierozem Great Soil Groups. These soils are moderately deep, but on the steeper slopes they may be shallow. The texture of surface soils ranges from clay loam to silty clay loam, but deeper in the profile the clay content may increase up to 50-60%. The pH is always above 7.0. The soils are calcerous and lime content increases with the depth. Organic matter content is slightly above 1% at the surface and decreases with depth in the soil profile.

Why fallow? Is fallow necessary in Central Anatolia? In the past, several Turkish researchers have sought the answers to these questions. Evliya in 1937 (4), after comparing the moisture situation in two fields at the same time, one after the harvest, the other during the fallow, came to the following conclusions: The field after the harvest did not have available water within 0-30 cm from the surface, whereas available water was found in the fallow field 6-7 cm from the surface. This was residual water from the previous year. The moisture in the fallow field was 2.7 times greater than in the harvested field. He further concluded that the residual moisture conserved during the fallow year was a suitable medium for early emergence and strong root development of young seedlings as well as providing available phosphorous from the slightly soluble phosphorus. In his report, he stated some principles of fallow procedures, which are valid even today.

Evliya in 1940 (5) reported that conserving soil moisture was not the main reason for fallowing. The water that plays an important role in plant production is the moisture present in the soil profile during the spring of the crop year and the precipitation that is received afterwards. During the fallow year, the soil was given an opportunity for natural fertilization. In other words, if the soil was to be fertilized artificially, there would be no need to fallow the land. He came to these conclusions after conducting a series of field trials.

Gerek (8), to investigate Evliya's suggestions (5), conducted 10 years of field trials using N.P.K. fertilizers at different rates and compared summer fallow wheat yields with annual cropping. According to his findings, yields after fallowing were higher than annual yields and more economical.

Later, Çagatay (3), investigated moisture accumulation and moisture movements in level and sloping fields under both fallow and crop situations. Because he found very little differences in the moisture contents of fallow fields and the cropped fields in the spring, he concluded that to fallow a field only for moisture conservation was not rational. The useful water for plants is supposedly the available water present in the soil in March plus precipitation from that date to harvest. For this reason, plants were not using the water that was conserved in the previous fallow year. And if the precipitation at seeding time is enough to wet 15-20 cm surface layer, then, there would be no difference between fallowed and non-fallowed land. But he also concluded that the moisture content within 10 cm from the surface of the soil at seeding time would indicate whether the fallow practices were done properly. Later, some other research with regard to the summer fallow practices added more information to the early studies.

Although moisture content in March in the soil profile and precipitation are vital for crop production (2, 5, 13), the surface moisture at seeding time for early germination is also very important for two reasons. First, a drought period in summer and fall (13) could have been controlled, and early germination would offer less chance of damage from possible April and May droughts. Secondly, since it has been proven that plants get almost half of their total N and P needs by the tillering stage (1) they would be in a condition to resist the cold winters and dry springs, provided the tillering is completed in the fall. Also, it was suggested that precipitation at seeding time which wets the soil surface only a few centimeters but is enough for germination, may cause the seedlings to die from lack of moisture in the lower part of the profile (7). Thus, sufficient moisture in the soil for germination of seeds and for tillering of young plants before the winter is quite important (2).

The mobilization of nitrogen in fallow fields in Central Anatolia were part of a study (6). There was more N in the fallow area than in the field after harvest. Fields which were recently cultivated had higher organic matter and nitrification rates than the fields under cultivation for centuries.

Some recent studies were made concerning the amount of moisture conserved by fallowing in Central Anatolia. Özbek et al. (15) found that fallow efficiency for moisture conservation was between 12.9-29.0% in Central Anatolia. For Eskisehir it was 21% (7). We have found this value to vary according to soil depth, climate, and summer fallow practices. In 1968-1969 the fallow efficiency at the Polatli State Farm was found to be 16.3% with spring moldboarding and onewaying compared with 24.3% with fall chiseling, spring sweeping, and rodweeding (15). In 1969-1970 at the Altinova State Farm where 8 different fallow tillage systems were applied, the fallow efficiency was between 12.2 and 20.9%. The highest value was obtained by spring sweeping twice and rodweeding. Because of more precipitation received in 1970-71, the values were determined to be between 24.6-30.2%. The highest value was obtained from fall chiseling, spring sweeping and rodweeding. Fallow efficiency values obtained from Ankara, Polatli, Altinova and Gözlü Locations in Central Anatolia were between 1.8-36.0% in 1969-70 and 8.8-29.5% in 1970-71. (Unpublished data from cooperative project between Soil and Fertilizer Research Institute and Wheat Research and Training Center, 1969-71.) The changes were mostly due to soil depth and tillage practices in addition to the climatic conditions.

Actual evapotranspiration values calculated for several areas of Central Anatolia show that 380-580 mm of water are required to produce a reasonable wheat yield (12-16). However, the wheat does not receive all of the 380 mm of annual precipitation because the cropping period covers only 280-300 days. Therefore, the additional water required for a reasonable wheat yield must be obtained from the moisture stored in the soil profile during a fallow period.

In conclusion, previous studies have shown:

1. That moisture is being stored in the soil profile (2,4,7,9,10,13,15,16).
2. That some plant nutrients are being made available (2,5,6).
3. That the practice of fallowing is necessary in Central Anatolia to maintain a reasonable wheat yield (2,4,7,8,9,10,13).

Even though fallowing is the usual practice in Central Anatolia, recent studies have shown that the potential for higher yields is much greater than is presently realized.

If summer fallowing is considered as essential for maintaining good wheat yields in Central Anatolia, then the question of the best fallow management techniques to be used needs to be answered. Research to answer some of these questions began in Eskişehir (9,10,13) and Ankara (2) in 1931. The Eskişehir study was completed in 1950. Kiraç (13) published a preliminary report in 1935 and later Gerek (9,11) published the complete report in 1960.

In the Eskişehir study, moldboard ploughing at 15 cm depth in March was taken as the standard treatment and all other treatments were compared to it. Some important highlights of the Eskişehir study can be summarized as follows: Time of tillage was more important than depth of tillage. If for some reason, a follow-up tillage could not be made, then late tilling would be preferable. This would be in April for low lands and in May for sloping lands. Without follow-up tillage, suitable and early tillage is useless. Late tilling should be shallow. Follow-up tilling should not be made with the same implement that was used for initial tillage. Fall tillage did not give good results.

The Ankara studies as reported by Berkman in 1960 (2) can be summarized as follows: For a good crop, seeding has to be done in the fall. Fallow fields should be tilled about March as soon as suitable tilth is obtained at the soil surface. Early tilling makes weed control compulsory. Weed control should be made with the implements that cut the soil rather than turn it over. If no weed control is planned, then late tilling is preferable. Soils should be tilled deeper in rainy years than dry years. The tilling depth should never exceed 20 cm. Seeding should be made 5-6 cm below the soil surface at the rate of 150-250 seed/m^2. For late seeding this amount may increase up to 350 seeds/m^2.

To determine the most suitable tillage implements in Central Anatolia, Mutaf (14) conducted three years of experiments. The front cutter moldboard was found to be the best of 9 implements tested.

In the late 1960's and early 1970's a number of Institutions were working on summer fallow research. They are listed below as follows:

Within the Ministry of Rural Affairs, Topraksu General Directorate
- Soil and Fertilizer Research Institute
- Central Topraksu Research Institute
- Eskişehir Topraksu Research Institute
- Konya Topraksu Research Institute;

Within the Ministry of Agriculture, General Directorate of Agriculture
- Wheat Research and Training Center in cooperation with the Rockefeller Foundation;

Ankara University, Faculty of Agriculture
- Department of Plant Breeding
- Department of Soil Fertility and Radiophysiology;

AID in cooperation with the Ministry of Agriculture.

Because of the nature of summer fallow research that covers full period of fallow and crop year, there is no complete report published by the above-listed Institutions. But unpublished data for one period by the Eskişehir Topraksu Research Institute reveals that fall moldboarding, spring sweeping with rotary hoe pulled behind, and rodweeder combinations gave significantly higher yields than the other tillage treatments at the Polatli State Farm. As was mentioned before, with fallow that year at the same location, the fall chisel treatment conserved the most moisture (16).

The Soil and Fertilizer Research Institute began a tillage experiment at the Altinova State Farm in 1969. This experiment included chisel, and moldboard as the initial tillage implements in the fall and in the spring. Sweep, oneway, disc harrow, rodweeder, and spike tooth harrows were used as secondary and summer tillage implements. Disc drill (17 cm) and deep furrow drill (35 cm) were used with local and foreign variety wheats at the seeding time. In addition, a no tillage treatment in which herbicides were used to control weeds was included in the trials. A total of 8 treatments with 4 replications, in a randomized design using various combinations of the above tillage implements were applied.

The experiment was designed to fulfill three basic conditions or principles in the Central Anatolia summer fallow area as follows:

1. To prevent run-off and increase filtration in order to get most of the precipitation during fall, winter and early spring into the soil profile.
2. To decrease the evaporation from the soil and to control the weeds after spring and during the summer season.
3. To conserve moisture during the fallow season to insure a moist layer of soil at a suitable planting depth for early, rapid germination at the time of seeding.

These principles were agreed upon by the Wheat Research Center in cooperation with the Rockefeller Foundation.

Evaluation of the experiment was made through:

A. Moisture determinations
B. Yield
C. Economics of the tillage practices

Because the moisture factor is yield-limiting in Central Anatolia, the details of the moisture determinations are given below:

In the Fallow Year:

1. Moisture in the soil profile at the beginning of fall tillage.
2. Moisture in the soil profile in the spring prior to spring tillage
   a. the increase in soil moisture content between the two periods (in mm and %).
   b. benefit from the precipitation, %.
   c. available water in the soil profile (in mm and %).
3. Moisture in the soil profile at the seeding time
   a. the decrease in moisture content, in mm and %.
   b. available water, in mm and %.
   c. depth of moist zone and moisture content at this depth.

In the Cropped Year:

1. Moisture in the soil profile in the spring.
2. Moisture in the soil profile at the harvest (ET values).

Our field experiment at the Altınova State Farm which was conducted in the 1969-70 fallow season and the 1970-71 crop year with the above-given methods can be summarized as follows:

A. Moisture observations:
1. Fall tillage did not improve water conservation in the soil profile. Instead, no-fall-tillage treatments had more benefit from the precipitation between fall and spring tillage times.
2. After 185.3 mm fall, winter and early spring precipitation the soil profile was wet down to 70-120 cm depth during 190 days.
3. At seeding time, the treatment involving spring sweeping twice with a rotary hoe pulled behind and summer rodweeding had the most moisture in the soil profile. This moisture was also closer to the soil surface than in the other treatments. Fallow efficiency of this treatment was significantly higher than in the other treatments (20.9%).
4. Fallow efficiency values ranged between 12.2-20.9% within the 8 treatments.
5. In the spring of the cropped year moisture penetrated deeper in the soil profile than during the fallow year.
6. Calculated ET values ranged between 381.1 and 427.2 mm.

B. Yield:
Because of the very favourable rains after seeding through harvest there were no significant differences found within the treatments. During 281 days of the cropped year 374 mm of precipitation was received. The average yield of the experimental site was 320 kg/de in comparison to 263 kg/de yield of same field that was state farm harvested.

C. The most expensive treatment was the chemical fallow costing 21.8 TL/de/ The least expensive treatment was spring chiseling, sweeping and rodweeding costing 9.75 TL/de.

Moisture observations from the same experiment during 1970-71 fallow season were:
1. Unlike the previous year, soil profiles were wet down to 150 cm with 237.7 mm precipitation in 217 days from the beginning of fall tillage through the spring tillage.
2. Fall chiseling conserved more moisture than fall moldboarding and no-fall-tillage treatments.
3. At the time of seeding fall chiseling, spring sweeping and rodweeding had significantly higher fallow moisture efficiency than the other treatments (30.2%).
4. Fallow efficiency values ranged between 24 6 and 30.2%

The yield will be evaluated after the 1972 harvest.

Literature

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OVERVIEW OF THE NUTRITIONAL PROBLEM

by

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The first international recommendations on protein requirements were made in 1935 by the Technical Committee on Nutrition of the League of Nations. It did not specifically include advice on the quality of protein except to say that it "should be derived from a variety of sources and that it is desirable that a part of the protein should be of animal origin". These recommendations were mainly based on observations on food consumption in healthy, active populations in developed countries, and were focused on the nutritional needs of the poor in affluent industrialized societies.

World-wide awareness of the problem relating to protein malnutrition in developing countries is very recent. It was only after the Second World War that FAO initiated the first attempt to assess the amount of food available in terms of calories in various countries in relation to calorie needs. This first world food survey showed that there were shortages of calories over large areas of the world, a situation which persisted during the succeeding twenty years, in spite of the slowly growing awareness of the nature of the problem.

During this period, however, new knowledge on protein requirements for satisfactory physical and mental development has been accumulated, as was reflected--among other things--in the recommendations of the FAO Committee on Protein Requirements in 1955 and of the FAO/WHO Expert Group on Protein Requirements in 1963. Protein have received increasing attention in recent international discussions of the world food and population problems. Proteins are essential to life and their main role is growth and maintenance. They are made up of a combination of amino acids, of which over 20 have been identified. The human body requires a minimum daily intake of proteins in which at least 8 amino acids--the so-called essential amino acids--must be present in certain quantities because these cannot be synthesized by the human body. Plants, on the other hand, can synthesize all 20 amino acids, so that animals and man ultimately rely on plant proteins for life.

The Advisory Committee on the Application of Science and Technology to Development, in its report of May 1967 under the title "Feeding the Expanding World Population: Internation Action to Avert the Impending Protein Crisis", used the expression "protein gap" to refer to the difference between protein requirements and protein intake. Since then serious efforts, at both national and international levels, have been directed towards closing this gap.

The protein problem is also linked to calorie supply. When the diet is deficient in calories, as it is in many developing countries, proteins are diverted from their normal functions of providing for maintenance and growth to supplying energy for other functions.

Therefore, the nutritional quality of food is dependent on many factors in addition to the content and type of its proteins. These include the content of carbohydrates and fats (mainly to supply energy for physical activity or, to a lesser extent, energy for growth, metabolism and mental energy), as well as being dependent of the presence of minerals and vitamins. However, protein content alone is widely used as a general indication of nutritional adequacy of diets. The expression "protein gap" is commonly used to refer to the difference between the actual protein content of diets (and therefore the intake of protein by man) on the one hand, and the protein requirement in the diet to make it nutritionally adequate on the other. However, as previously indicated, the protein adequacy is not independent of its calorie content.

Estimates of the size of the protein gap in various countries have been derived from food balance studies. They provide the best information available on average national supplies (production + imports - exports) and requirements. Individual supplies and requirements differ from national averages by reasons of differences in body weight, age, sex, and metabolic efficiency, as well as differences in distribution of food because of economic and social differences between groups, differences between families within groups, and differences within families. Protein absorption is also limited in low income groups due to the prevalence of infection and parasitism, and this necessitates increased protein requirement. To allow for such individual differences, average national requirements were adjusted by an increase of 20% for the purpose of the FAO Indicative World Plan and its related proposals for action programs.

It is recognized that such food balance studies have serious limitations because of their complexity, the difficulties involved in obtaining reliable basic data in the first place, and the additional difficulty of deducing protein-calorie relationships at the family and individual level from average figures on the national level. Nevertheless, the IWP study showed that on the basis of available information for 1960-62, 77 countries in the developing regions could be classified broadly on the basis of protein deficiency--the gap between protein requirement and national supply (domestic production + imports - exports) into three groups:

<u>Group A</u>: Protein gap ranging from 1 to 30 grams/caput/day
Total = 43 countries: Africa = 21, Near East = 5, Far East = 6, Latin America = 11.

<u>Group B</u>: No significant protein gap.
Total = 5 countries: Africa = 2, Near East = 1, Far East = 1, Latin America = 1.

<u>Group C</u>: Protein supply in excess of requirements.
Total = 29 countries: Africa = 9, Near East = 5, Far East = 4, Latin America = 11.

However, within the 43 protein deficit countries in <u>Group A</u>, 11 had also a calorie deficit ranging from 300 to 600 calories/caput/day, and 20 countries a calorie deficit of up to 300 calories/caput/day, while no information on calorie status was available in 7 countries. In <u>Group B</u>, 3 countries had a calorie deficit of up to 300 calories/caput/day. Even among the 29 countries in <u>Group C</u> which had an excess of protein over requirement, 2 had a calorie deficit of between 300 to 600 calories/caput/day and 14 of up to 300 calories/caput/day.

It is emphasized again that national protein-calorie data cannot by itself be used as a direct indication of protein-calorie relationship at the individual level. All that can be said is that there is more likelihood of a high incidence of clinical deficiency in countries with a protein deficit and a high calorie deficit than in other countries, while there may also be a substantial amount of over or incipient protein malnutrition even in countries with an adequate protein supply if they do not have an adequate calorie supply, quite apart from the fact that the available protein may not be getting to the vulnerable groups that particularly need it. It has been estimated that in India 25% of the population may be suffering from clearly identified symptoms of malnutrition, in addition to a great mass of undiagnosed marginal protein malnutrition. The deficiency is manifested in high child mortality, retarded physical and mental growth in children, impaired gene function and other sub-clinical effects on the population.

In its latest agricultural commodity projections for 1970-1980, FAO in 1971 analyzed the impact of the so-called "green revolution", not only on the food supplies but also on nutrition in the light of new data on energy and protein requirements prepared by the FAO/WHO Ad Hoc Committee of Experts on Energy and Protein in 1971.

The analysis showed the bundle of changes, including the greater use of high-yielding varieties of cereals, more fertilizers and water, and, generally, a higher standard of cultivation, should be expected to lead to a sustained and historically high average rate of growth of 3.4% p.a. of cereal production in developing countries from 1970 to 1980. Wheat would rise by 4.2% p.a., rice by 3.1% p.a. and coarse grains by 2.9% p.a. with yields contributing 60, 55 and 71% respectively to the additional production of 138 million tons of cereals. These trends in cereal production are the core of a projected increase in the total food production of developing countries of 39% over the projection period compared with the estimated population growth of 31%.

The projections indicate that by 1980, when the world will demand some 27% more food than in 1970, the average quantity of food consumed per caput would have risen by 8% in developing countries as measured by a price-weighted index and by 5% in terms of both calories and proteins. While this would represent a certain improvement, the number of people with a calorie intake below requirements might not have changed much. It will be seen in Tables 1-3 that as a result of the green revolution higher rates of growth in production are projected for the next decade than those achieved in the last one. Table 4 gives trends in the commodity composition of agricultural output in different regions and shows the preponderence of food and feed over other agricultural commodities.

Although demand projections in Table 5 indicate that as measured by per caput demand at constant prices the food situation would improve moderately in poor countries, the dietary improvements implied by the projections of demand must be checked against (a) standards of nutritional requirements in relation to food demand based on economic factors, (b) distribution of food supplies within a country in terms of income groups and overtime and space, and, (c) availability of supplies to meet projected levels of demand.

Table 1. Past and projected gross food and feed production.

	1980 index numbers (1970=100) of projected production		Annual compound rates of growth: Total production 1959 to 1969	Total production 1970 to 1980	Per caput production 1959 to 1969	Per caput production 1970+ to 1980
	Total	Per caput	Actual	Projected	Actual	Projected
WORLD[1/]	129	104	2.8	2.5	0.6	0.4
High-income countries	124	112	2.7	2.2	1.5	1.1
Developed market economies	124	111	2.5	2.1	1.4	1.1
U.S.S.R. and eastern Europe	124	113	3.1	2.2	2.0	1.2
Developing countries	139	106	3.1	3.3	0.5	0.6
Latin America[2/]	139	104	3.9	3.3	1.0	0.4
Africa	141	107	2.3	3.5	-0.2	0.7
Near East	142	107	2.7	3.6	-	0.6
Asia and Far East	139	107	2.9	3.3	0.3	0.6
Asian centrally planned economies	128	105	...	2.5	...	0.5

1/ Excluding Asian centrally planned economies.

2/ As noted in the text, food and feed production is projected to grow more slowly mainly because fishery catches are not expected to expand as in the 1960's.

Source: Agricultural Commodity Projections, 1970-1980, Vol. I, FAO, Rome, 1971.

Table 2. Cereals: area, yield and production, 1970+ and projections for 1980.

	1970+			1980			Rates of growth 1970+ to 1980			Contribution to production of:	
	Area	Yield	Production	Area	Yield	Production	Area	Yield	Production	Area	Yield
	Million ha	100 kg/ ha	Million tons	Million ha	100 kg/ ha	Million tons	Percent per year compound			Percent	
Wheat											
Africa	6.3	7.1	4.5	6.1	10.5	6.4	-0.4	3.9	3.5	-11	111
Latin America	7.0	14.3	10.1	9.6	17.0	16.3	3.2	1.8	5.0	65	35
Near East	18.9	10.1	19.0	20.5	12.9	26.4	0.9	2.5	3.4	25	75
Asia and Far East	23.4	12.0	28.2	29.5	15.0	44.4	2.3	2.3	4.6	51	49
Total developing countries	55.6	11.1	61.8	65.7	14.2	93.5	1.7	2.5	4.2	40	60
Total high-income countries	117.7	18.1	212.7	125.2	20.9	261.1	0.6	1.4	2.0	30	70
Rice (paddy)											
Africa	3.5	14.0	4.9	4.3	16.9	7.3	2.2	1.9	4.1	54	46
Latin America	6.3	16.8	10.7	8.3	17.5	14.4	2.7	0.4	3.1	87	13
Near East	1.3	35.8	4.7	1.7	39.7	6.6	2.4	1.1	3.5	70	30
Asia and Far East	83.3	18.1	150.7	94.1	21.6	202.8	1.2	1.8	3.0	41	59
Total developing countries	94.4	18.1	171.0	108.4	21.3	231.1	1.4	1.7	3.1	45	55
Total high-income countries	4.5	53.6	24.1	4.0	61.0	24.4	-1.2	1.3	0.1	-	-
Coarse grains											
Africa	42.2	8.5	35.7	46.7	10.4	48.5	1.0	2.1	3.1	34	66
Latin America	34.9	13.8	48.1	39.0	17.1	66.9	1.1	2.2	3.3	34	66
Near East	12.7	13.0	16.6	13.3	14.8	19.7	0.4	1.3	1.7	26	74
Asia and Far East	58.6	7.0	41.1	62.3	8.5	52.9	0.6	2.0	2.6	24	76
Total developing countries	148.4	9.5	141.5	161.3	11.7	188.0	0.8	2.0	3.0	29	71
Total high-income countries	146.5	24.7	362.6	153.5	32.2	494.2	0.4	2.7	3.1	15	85

Source: Agricultural Commodity Projections, 1970-1980, Vol. I, FAO, Rome, 1971.

Table 3. Projected production of food commodities, 1980[1].

	Index numbers				Rates of growth (1970 + 1980)			
	World[2]	High income countries	Developing countries	Asian Centrally planned economies	World[2]	High income countries	Developing countries	Asian Centrally planned economies
	1970 = 100				Percent per year, compound			
Wheat	129	123	151	134	2.6	2.1	4.2	3.0
Rice	128	99	135	127	2.5	-0.1	3.1	2.4
Coarse grains	135	136	133	128	3.1	3.1	2.9	2.5
Starchy roots	107	95	132	125	0.7	-0.6	2.8	2.3
Sugar (centrifugal)	128	122	135	146	2.5	2.1	3.1	3.9
Pulses and nuts	135	113	138	128	3.0	1.2	3.3	2.5
Vegetables	129	124	143	131	2.6	2.2	3.7	2.8
Fruit	140	134	147	139	3.4	3.0	4.0	3.4
Beef and veal	128	124	143	124	2.5	2.2	3.7	2.2
Mutton and lamb	129	123	140	129	2.6	2.1	3.5	2.6
Pigmeat	124	121	155	148	2.2	1.9	4.5	4.0
Poultry meat	149	147	166	146	4.1	3.9	5.2	3.8
Eggs	127	122	156	145	2.4	2.0	4.5	3.8
Fish	126	124	127	137	2.4	2.2	2.4	3.2
Whole milk	119	115	131	128	1.8	1.4	2.8	2.5
Vegetable oils	143	136	160	121	3.7	3.1	4.8	1.9
Total Food	129	124	139	128	2.5	2.2	3.3	2.5
Coffee	138	133	138	-	3.3	2.9	3.3	-
Tea	145	132	147	118	3.8	2.8	3.9	1.6
Wine	124	122	131	-	2.1	2.0	2.8	-
Tobacco	127	119	146	139	2.5	1.8	3.9	3.4
Beverages & tobacco	131	121	141	135	2.7	2.0	3.5	3.0

[1]Data for starchy roots, pulses, nuts, vegetables, eggs and some fruits are based on projections of demand.
[2]Excluding Asian centrally planned economies.
Source: Agricultural Commodity Projections, 1970-1980, Vol. I, FAO, Rome, 1971.

Table 4. Trends in the commodity composition of agricultural output.

	Food and Feed			Beverages and tobacco			Agricultural raw materials		
	1960	1970+	1980	1960	1970+	1980	1960	1970+	1980
	Percent of total agricultural output								
World[1]	90.8	91.8	92.0	3.4	3.0	3.1	5.8	5.2	4.9
High income countries	92.5	93.6	94.1	2.4	2.2	2.1	5.1	4.2	3.8
North America	92.0	94.2	95.3	2.8	2.4	2.1	5.2	3.4	2.6
Western Europe	95.5	96.2	96.3	3.5	3.0	3.0	1.0	0.8	0.7
Oceania	65.4	67.9	69.9	1.0	1.4	1.4	33.6	30.7	28.7
Other developed market economies	95.0	96.1	96.3	2.4	2.0	2.1	2.6	1.9	1.6
USSR and eastern Europe	93.8	93.9	94.6	1.2	1.4	1.5	5.0	4.7	3.9
Developing countries	86.5	87.5	87.8	6.0	5.0	5.0	7.5	7.5	7.2
Latin America	80.3	85.2	85.7	11.8	7.6	8.3	7.9	7.2	6.0
Africa	88.3	87.2	88.1	7.6	8.2	7.3	4.1	4.6	4.6
Near East	86.9	85.6	86.1	1.6	1.8	1.8	11.5	12.6	12.1
Far East	89.5	89.5	89.5	3.4	3.4	3.4	7.1	7.1	7.1

[1]Excluding Asian centrally planned economies.

Source: Agricultural Commodity Projection, 1970-1980, Vol. I, FAO, Rome, 1971.

Table 5. Per caput daily food requirements and levels of demand in 1980.

	Per caput requirements 1/		Percentages of requirements			
			1970 consumption		1980 demand	
	Cal.	Prot. 2/	Cal.	Prot.	Cal.	Prot.
	Numbers per caput	Grs. per day				
World	2385	38.7	101	173	105	178
High-income countries	2560	39.5	121	229	123	237
Developed market economics	2555	39.2	119	228	122	237
U.S.S.R. and Eastern Europe	2570	40.0	124	232	126	238
Developing countries	2284	38.4	96	147	101	155
Asia and Far East	2223	36.6	93	141	99	150
Africa	2335	41.5	93	141	98	149
Latin America	2383	37.7	106	172	110	179
Near East	2456	45.5	97	147	101	153
Asian centrally planned economies	2355	38.3	88	153	93	163

1/ Revised standards of average physiological requirements, as defined by the FAO/WHO Expert Committee (April 1971).

2/ Expressed in local proteins.

Source: Agricultural Commodity Projections, 1970-1980, Vol. I, FAO, Rome, 1971.

Table 6. Relative importance of various food groups in average world daily per caput intake (Food Balance Sheets 1964-66).

	Calories		Protein		Fats	
	Number	Percent	Grams	Percent	Grams	Percent
Cereals	1245	52.4	31.1	47.4	5.1	9.3
Wheat	441	18.6	13.3	20.3	1.5	2.7
Rice	459	19.3	8.5	13.0	1.0	1.8
Maize	147	6.2	3.6	5.5	1.0	1.8
Millet and sorghum	119	5.0	3.5	5.3	1.2	2.2
Others	76	3.2	2.1	3.2	0.4	0.7
Roots and tubers	184	7.8	2.8	4.3	0.4	0.7
Sugar and sugar products	210	8.8	0.1	0.2	-	-
Pulses, nuts and oilseeds	121	5.1	7.9	12.0	3.6	6.5
Vegetables	36	1.5	2.2	3.4	0.3	0.5
Fruits	47	2.0	0.6	0.9	0.3	0.5
Total animal products	322	13.6	20.7	31.5	22.4	40.8
Meat	168	7.1	9.2	14.0	14.3	26.0
Eggs	18	0.8	1.4	2.1	1.3	2.4
Fish	19	0.8	3.0	4.6	0.6	1.1
Milk	117	4.9	7.1	1[illegible]	6.2	11.3
Fats and oils	199	8.4	0.1	0.2	22.5	40.9
Vegetable oils	127	5.3	-	-	14.4	26.2
Animal fats	72	3.1	0.1	0.2	8.1	14.7
Total	2374	100.0	65.6	100.0	55.0	100.0
Animal origin	396	16.7	20.8	31.7	30.5	55.5

Source: Agricultural Commodity Projections, 1970-1980, Vol. I, FAO, Rome, 1971.

NUTRITIONAL RESEARCH ON WHEAT AT THE UNIVERSITY OF NEBRASKA

by

V. A. Johnson, P. J. Mattern, J. W. Schmidt, and J. E. Stroike

The research is cooperative between the Agricultural Research Service, U.S. Department of Agriculture, and the Nebraska Agricultural Experiment Station. It has been financed in part by funds from the Agency for International Develop ment, U.S. Department of State, since 1966. The International Winter Wheat Performance Nursery was organized in 1968 as a part of the research effort.

The thrust of the research to date has been to improve the nutritional value of wheat by increasing its protein content and improving the ratio of essential amino acids in the protein. Progress in increasing the genetic potential of wheat for higher grain protein content has been substantial. Genetic differences in amino acid composition have been detected. Although not of the magnitude of the opaque-2 gene effect in maize, we believe they are of sufficient magnitude to be useful in breeding programs.

Protein Content

Variation

The protein content of wheat in most production areas of the world ranges from 10 to 13 percent. The effect of environment on protein content is large. Twelve thousand common wheats from the World Wheat Collection, maintained by the U.S. Department of Agriculture, ranged in protein content of their grain from 7 to 22 percent. The mean was 12.9 percent. The genetic component of this total variation probably does not exceed 4 or 5 percentage points.

We have relied heavily on the soft red winter wheat variety "Atlas 66" thus far in our breeding program. The genes for high protein in Atlas 66 come from the South American variety Frondoso. Additional genetic sources of high grain protein have been identified (Table 1). Most promising among these are NB542437, SD69103, C.I. 7337, C.I. 6225, and P.I. 176217. The last-named variety is of particular interest because it is also the most promising genetic source of high lysine uncovered to date.

Breeding Advances

We have accomplished protein increases in the range of 2 to 3 percentage points using genes from the Atlas 66 variety. Selections from the first breeding cycle for protein content were 15 to 25 percent higher in protein than commercial wheat varieties with which they were compared but they were 10 to 15 percent lower yielding (Table 2).

Selections from the second breeding cycle tested in 1970 averaged from 20 to 24 percent higher in protein and some were as much as 15 percent more productive than our main commercial wheat varieties (Table 3).

Table 1. Useful germplasm for the nutritional improvement of wheat.

Variety	C.I. or Sel. number	Source	Growth habit[1]	Useful trait
Atlas 50	12534	Beltsville	I	High protein
Atlas 66	12561	"	I	" "
Atlas-derived lines	---	Nebraska	W	" "
Aniversario	12578	Argentina	S	" "
Aniversario-derived lines	---	Nebraska	W	" "
Male Fertility Restorer	NB542437	"	W	" "
Hume^2 x Nb^4 - Agrus-Tc^7	SD69103	So. Dakota	W	" "
Nap Hal	176217	India	S	High protein, high lysine
April Bearded	7337	England	S	" " " "
Hybrid English	6225	"	W	" " " "
Pearl	3285	Sweden	S	Probable high lysine
22A	5484	USSR	S	" " "
Fultz x Hungarian	11849	USA	W	" " "
Fultz-Hungarian x Minturki-Fultz	12756	"	W	" " "
Norin 10-Brevor Sel. 14-derived line	13447	Washington	W	" " "
" "	13449	"	W	" " "

[1] I = intermediate; W = winter; S = spring.

Table 2. Four-year mean yield and protein content of high protein selections from the first breeding cycle grown in Nebraska replicated yield trials, 1966 to 1969.

Variety	C.I. or Sel. no.	Mean grain yield q/ha	Mean grain yield % of Scout	Mean protein content %	Mean protein content % of Scout
Scout	13546	29.2	--	11.3	--
Atlas 66 x Comanche	65307	26.0	89	12.9	114
"	65317	25.2	87	12.7	112
"	63518	24.8	85	13.3	118
Atlas 66 x Wichita	65320	24.8	85	13.2	117

Table 3. Mean yield and protein content of high protein selections from the second cycle of breeding grown in replicated yield trials at three Nebraska sites in 1970.[1]

Variety	C.I. or Sel. no.	Mean grain yield q/ha	Mean grain yield % of Scout	Mean protein content %	Mean protein content % of Scout
Scout 66	13996	34.6	---	11.8	---
Atlas 66-Cmn x Lancer	701132	39.6	115	14.4	123
"	701134	36.8	107	14.3	122
"	701137	36.0	104	14.1	120
(Wrr-Atlas 66-Cmn) F_1 x Lancer	701154	35.6	103	14.5	124
Lancer x Atlas 66-Cmn	70654	33.8	98	14.4	123

[1]Taken from Johnson, Mattern and Schmidt: Seed proteins-synthesis properties, and processing. (In press)

Twenty-six high protein lines from the first breeding cycle were released as germplasm in 1970 by the Nebraska Agricultural Experiment Station and the Agricultural Research Service, U.S. Department of Agriculture (Table 4).

Twelve lines from the second breeding cycle were sent to Turkey, Iran, and Afghanistan in 1972 for local evaluation (Table 5). Some could have direct usefulness as varieties in these countries.

Physiologic Considerations

High protein varieties of winter wheat developed in Nebraska do not have higher concentrations of nitrogen in their foliage than ordinary varieties during the growing season. Experimental evidence for more efficient and complete translocation of nitrogen from the foliage to grain has been provided by Nebraska studies (Johnson, Mattern and Schmidt, 1967). A greater percentage of total plant nitrogen resided in the grain of a high-protein variety at maturity than in an ordinary variety (Johnson, Mattern, Whited and Schmidt, 1969). Artificial defoliation of leaf blades of a high-protein variety prior to anthesis reduced its grain protein content to the level of an ordinary variety. Close

Table 4. High protein wheat germplasm released in 1970 by the Nebraska Agricultural Experiment Station and Agricultural Research Service, USDA.

Pedigree	Nebr. Sel. No.	C.I. No.
Atlas 66/Comanche	65304	14014
"	65305	14015
"	65307	14016
"	65309	14017
"	65312	13989
"	65313	13990
"	65314	13991
"	65669	14057
"	65670	14058
"	65673	14059
"	67730	14060
"	67786	14061
Atlas 66/Comanche//Warrior	66548	14062
"	66551	14063
"	66553	14064
Atlas 66/Wichita	65321	14065
"	65322	14066
"	67764	14067
"	67765	14068
"	67767	14069
"	67768	14070
"	67769	14071
"	67770	14072
"	67776	14073
"	67785	14074

Taken from Johnson, Schmidt, and Mattern, Crop Sci. 11: 141-142. 1971.

Table 5. Nebraska high protein experimental lines being evaluated in Turkey, Iran, and Afghanistan in 1972.

(Wrr//Atl 66/Cmn) F_1/3/Cmn/Ott	NB68513
(Wrr//Atl 66/Cmn) F_1/Lancer	NB68510
Cmn/Ott/3/Atl 66/2/Cmn/4/Lancer	NB68570
SS/2/C.I.12500/4/Rch/Cnn/6/Wrr/5/Atl 66/3/Cmn/7/Lcr	NB69559
Atlas 66/Cmn//Lancer	NB701132
"	NB701134
"	NB701136
"	NB701137
"	NB701139
(Wrr//Atl 66/Cmn) F_1/3/Lancer	NB701152
"	NB701154
Lancer//Atl 66/Cmn	NB70654

linkage of leaf rust resistance with high grain protein content in Atlas 66-derived lines has been established.

Research in Illinois involving high protein wheats from Nebraska has implicated the nitrate reductase enzyme system. Protease may also be involved in the high grain protein trait according to recent Oklahoma State University research.

Phenotypic Expression

A high protein and ordinary variety were equally responsive to nitrogen fertilizer in Nebraska tests (Table 6).

Table 6. Effect of nitrogen fertilizer on the yield and protein content of a normal and high protein wheat variety at six test sites in Nebraska, 1969 to 1970.[1]

Nitrogen applied	Grain yield			Protein content		
	Lancer	C.I.14016	Difference	Lancer	C.I.14016	Difference
kg/ha	q/ha	q/ha	q/ha	%	%	%
0	25.6	25.6	0	10.8	12.5	+1.7
45	31.2	29.2	-2.0	11.8	14.0	+2.2
90	30.8	30.0	-0.8	13.2	15.4	+2.2
135	30.0	30.8	+0.8	14.0	16.3	+2.3

[1]Taken from Johnson, Dreier, and Grabouski, Agron. Jour. (in press)

The high protein variety C.I.14016 maintained 2 percentage points protein advantage over Lancer at all levels of nitrogen application from 0 to 135 kg/ha. The protein advantage of C.I.14016 persisted whether its grain yield was higher or lower than Lancer. In six dryland tests during 1969 and 1970, fertilization of C.I.14016 with 135 kg/ha of nitrogen produced a mean yield of 30.8 q/ha of grain with 16.3 percent protein content. Comparable fertilization of Lancer produced 30 q/ha of grain with 14.0 percent protein content.

There has been excellent phenotypic expression of the high protein trait in the 1st and 2nd International Winter Wheat Performance Nurseries. Atlas 66, NB67730 and Purdue 28-2-1, all possessing similar genes for high grain protein, were consistently and significantly higher in protein than other varieties at most nursery sites. Atlas 66 and NB67730 are compared with Bezostaia 1, Lancer and Gaines at 3 test sites in Table 7.

The protein advantage of the high protein varieties over other varieties in the nursery persisted at sites at which nursery mean protein and yield levels were high as well as where they were low.

Table 7. Phenotypic expression of the high protein trait at 3 sites of the International Winter Wheat Performance Nursery in 1970.

Variety	Grain protein content at: Stillwater, Oklahoma	Martonvasar, Hungary	Cambridge, England
	%	%	%
Nursery $\bar{x}$ protein	17.8	15.8	12.5
Bezostaia	16.5	14.3	12.3
Lancer	16.2	14.6	12.1
Gaines	16.5	14.1	10.6
Atlas 66	20.6	19.4	13.5
NB67730	20.9	18.4	14.2
Nursery $\bar{x}$ yield (q/ha)	25.4	32.7	31.7

Kernel Morphology and Protein

We have been unable to demonstrate an effect of kernel size on protein content (Table 8).

Table 8. Average effect of kernel size on the protein and lysine contents of the grain of four winter wheat varieties.

Kernel size	Protein content	Lysine per unit protein
	%	%
Large (on sieve #8)	12.7	3.1
Medium (on sieve #7)	12.2	3.2
Small (on sieve #6)	12.5	3.1

Small, medium, and large kernels from each of 4 winter wheat varieties had comparable levels of protein and lysine. In each size category, wrinkled kernels with open creases had substantially higher protein content than smooth kernels with closed creases (Table 9).

Table 9. Average effect of kernel size and configuration on the protein and lysine contents of the grain of four winter wheat varieties.

Kernel			Protein content	Lysine per unit protein
Size	Configuration	Crease	%	%
Large	Plump	Closed	12.0	3.15
"	"	Open	12.6	3.13
"	Wrinkled	--	14.3	3.02
Small	Plump	Closed	11.8	3.31
"	"	Open	12.9	3.24
"	Wrinkled	--	15.4	3.04

Yield versus Protein

We believe that, within reasonably wide limits, high yield and high grain protein content are compatible in wheat. There is some evidence from the IWWPN. Correlation coefficients were computed for yield and protein of 7 different varieties over 1969 and 1970 (Table 10).

Table 10. Correlation coefficients for yield, protein and lysine computed for seven varieties grown in the International Winter Wheat Performance Nursery in 1969 and 1970.

Variety	Yield vs protein	Protein vs lysine	Protein vs adj. lysine
Bezostaia	-0.11	-0.73	-0.23
Scout 66	0.02	-0.82	-0.29
Triumph 64	-0.01	-0.74	-0.04
Heine VII	-0.43	-0.12	0.02
Bankuti	-0.18	-0.74	0.11
Atlas 66	-0.20	-0.61	0.33
NB67730	0.05	-0.75	0.11

The size of the correlation coefficients ranged from -0.43 to 0.05. These data suggest that high yield is not necessarily associated with low protein content in wheat varieties. However, a more useful comparison would involve yield protein relationships at individual test sites. The yields of a group of 24 varieties from the 1st and 2nd IWWPN's, not known to be genetically different in grain protein potential, were correlated with protein at 13 individual nursery sites (Table 11).

Table 11. Yield and protein correlations for a group of 24 winter wheat varieties[1] at selected International Winter Wheat Performance Nursery sites in 1969 and 1970.

Site and year		Mean Yield	Mean Protein content	r	r^2
		q/ha	%		
Stillwater	1970	26.0	17.3	-0.61	0.37
Svalof	1969	56.7	16.1	-0.57	0.32
Kabul	1969	54.8	13.2	-0.56	0.32
Kabul	1970	62.8	16.6	-0.49	0.24
Wageningen	1969	42.3	13.1	-0.45	0.20
Novi Sad	1969	48.2	14.7	-0.42	0.18
Cambridge	1970	32.7	12.4	-0.35	0.12
Ankara	1970	35.7	13.8	-0.25	0.06
Svalof	1970	50.5	15.6	-0.24	0.06
Novi Sad	1970	42.3	15.9	ns[2]	--
Fundulea	1970	35.6	14.6	ns	--
Rieti	1969	48.3	12.4	+0.24	0.06
Eskisehir	1969	44.6	12.8	+0.65	0.42

[1]None of varieties known to possess genes for high protein. (Atlas 66, Purdue 28-2-1, NB67730, Cappelle Desprez, Lerma Rojo and INIA excluded from computation.)

[2]Non-significant at 5% level

Protein was negatively correlated with yield at 9 sites; the highest value was -0.61. Yield and protein showed no correlation at 2 sites and were positively correlated at 2 sites. The highest positive correlation was +0.65 at Eskisehir, Turkey, in 1969.

Amino Acid Composition

Lysine is the most deficient among the essential amino acids in wheat protein. Wheat progein contains only 50 percent of the amount of lysine necessary to meet the requirements of man (Figure 1). Isoleucine, methionine, and threonine, in that order, also are present in lower quantities than are necessary for nutritional balance. There is an excess of phenylalanine, leucine, and tyrosine among the essential amino acids.

Lysine expressed as percent of protein is negatively correlated with protein. The relationship is curvilinear. At low protein levels, lysine is strongly affected by protein changes but, at high protein levels, it is only slightly affected by protein changes. There is a strong positive correlation between protein and lysine expressed as percent of dry grain weight. Because of this, progress in increasing the lysine content of wheat would be expected from increasing its protein content.

Lysine variation among 12,000 World Collection wheats was from 2.3 to 4.2 percent of the protein. Our data suggest that 0.5 percentage point represents the genetic component of total lysine variation among these wheats. We believe this to be sufficiently large for utilization in breeding programs.

Effect of Protein Level on Amino Acid Composition

The amino acid composition of 4 varieties grown at 15 sites in the 1st IWWPN was compared. The varieties ranged in protein content from 16.0 to 13.2 percent (Table 12).

Table 12. Protein and essential amino acid data (except tryptophan) for 4 varieties grown in the International Winter Wheat Performance Nursery at 15 sites in 1969.

Measurement	NB67730	Triumph 64	Sturdy	Bezostaia
Protein 1/	16.0	14.7	14.0	13.2
Lysine 2/	2.7	2.7	2.8	2.8
Isoleucine	3.6	3.8	3.9	4.0
Methionine	1.4	1.5	1.4	1.4
Threonine	3.2	3.2	3.1	3.2
Valine	4.7	4.9	5.0	5.1
Tyrosine	2.7	2.6	2.0	2.4
Leucine	7.3	7.3	7.4	7.5
Phenylalanine	5.0	5.1	5.3	5.1

1/ Percent of dry grain weight
2/ Amino acid values expressed as percent of protein

The varieties were comparable in lysine and most other essential amino acids except isoleucine, valine, and tyrosine.

The correlation of individual amino acids with protein (total amino acids) was determined among 114 low protein-high lysine wheats from the World Collection.

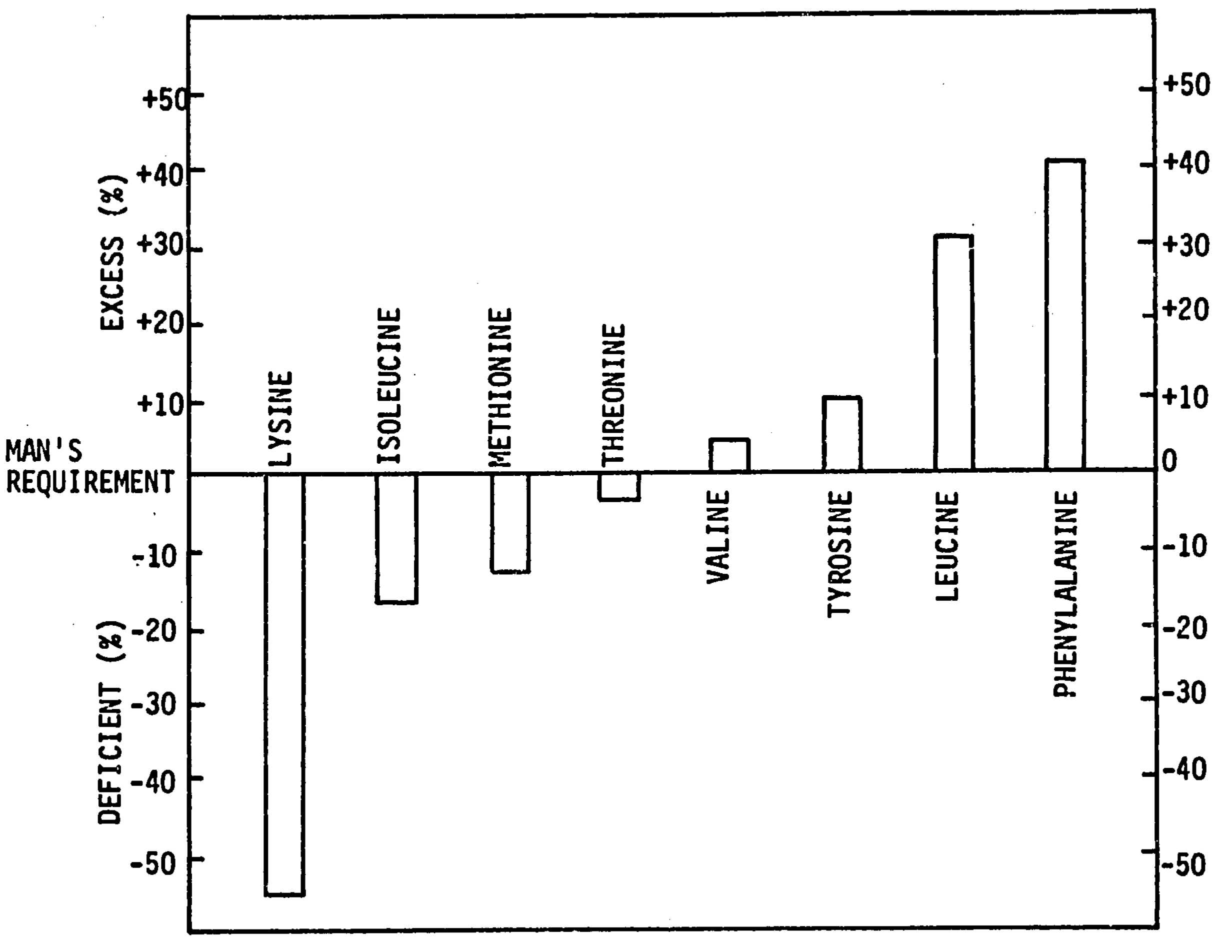

Figure 1.-- Deviation of essential amino acids in wheat protein from the requirements of man, FAO-1957 (value for tryptophan not included in the FAO report).

These are shown for the essential amino acids except tryptophan in Table 13. Lysine, threonine, leucine, and methionine were negatively correlated with protein. The other essential amino acids exhibited no correlation with protein.

Table 13. Protein-amino acid relationships among 114 low protein-high lysine wheats from the World Wheat Collection.

Measurement[1/]	Mean	Range	Correlation with total amino acids
	%	%	
Protein	9.5	6.9-13.8	---
Total amino acids	9.4	6.9-12.7	---
	Essential Amino Acids		
Lysine	3.4	3.0-4.0	-0.60
Isoleucine	3.7	3.3-4.0	ns[2/]
Methionine	1.6	1.1-1.9	-0.22
Threonine	3.4	3.0-3.6	-0.49
Valine	4.9	4.1-5.6	ns
Tyrosine	2.6	1.9-3.4	ns
Leucine	7.2	7.0-7.5	-0.37
Phenylalanine	4.6	4.1-4.9	ns

[1/]Reported on dry weight basis [2/]Nonsignificant at the 5% level

Protein-amino acid relationships were different among 50 high protein wheats from the World Collection (Table 14). Lysine was not correlated with protein in contrast to its negative correlation in the low protein group of wheats. Only threonine was negatively correlated, and isoleucine and methionine were positively correlated with protein. Tryptophan was not determined.

Table 14. Protein-amino acid relationships among 50 high protein wheats from the World Wheat Collection.

Measurement[1/]	Mean	Range	Correlation with total amino acids
	%	%	
Protein	18.8	17.6-22.0	---
Total amino acids	18.8	16.2-21.4	---
	Essential Amino Acids		
Lysine	2.8	2.3-3.2	ns[2/]
Isoleucine	3.6	3.4-3.9	+0.49
Methionine	1.3	0.9-1.6	+0.36
Threonine	3.0	2.8-3.2	-0.32
Valine	4.5	4.4-4.8	ns
Tyrosine	2.5	2.2-2.9	ns
Leucine	7.0	6.7-7.3	ns
Phenylalanine	4.9	4.6-5.2	ns

[1/]Reported on dry weight basis [2/]Nonsignificant at the 5% level

Wheats from the World Collection with the most promise as potential genetic sources of high lysine are listed in Table 1. Among these, Nap Hal (P.I.176217) may be the most useful in breeding programs.

Genetic Studies

We crossed Atlas 66 with Nap Hal to ascertain whether different genes condition the high protein trait in the two varieties and whether the above-normal lysine content of Nap Hal is heritable. Protein and lysine data were obtained from F_2 progeny bulk rows grown at Yuma, Arizona, in 1971. The frequency distribution for protein appears in Figure 2.

The parent varieties were similar in the protein content of their grain and substantially higher than Lerma Rojo and Triumph 64 grown in the same experimental area. There was pronounced transgressive segregation for both high and low protein among the F_2 progeny rows which we interpret as evidence for different protein genes in the parent varieties. These data also indicate the opportunity to increase the grain protein potential of wheat beyond the Atlas 66 level.

Nap Hal parent rows were significantly higher in lysine (adjusted to a common protein level) than the Atlas 66 parent rows and Lerma Rojo and Triumph 64 (Figure 3). There was evidence of segregation for lysine level in the F_2 progeny rows with apparent recovery of parent levels of lysine in some rows. The progeny rows will be re-analyzed from a 1972 planting.

Nap Hal also was crossed with the Nebraska winter wheat variety Lancer. Parent and F_2 progeny bulk rows also were grown in Arizona in 1971. Frequency distributions for protein and lysine are shown in Figures 4 and 5. The dye-binding method of protein analysis was utilized for this population instead of the normal Kjeldahl procedure. The pronounced cut-off at the 20 percent protein level evident in Figure 4 probably reflects the inability of the dye-binding method to differentiate protein differences above the 20-percent level. Otherwise, the observed distributions for both protein and lysine in which there was apparent recovery of parent levels but no transgressive segregation would be anticipated on the basis of genes for high protein and high lysine in Nap Hal only.

A small animal laboratory has been established in the Department of Foods and Nutrition at the University of Nebraska in which the mouse is utilized as the test animal. The results of mouse-feeding trials involving high protein wheat varieties as the protein source will be correlated with results from tests involving adult and young growing human subjects. Correlative studies of various in vitro laboratory tests with mouse-feeding results also are in progress.

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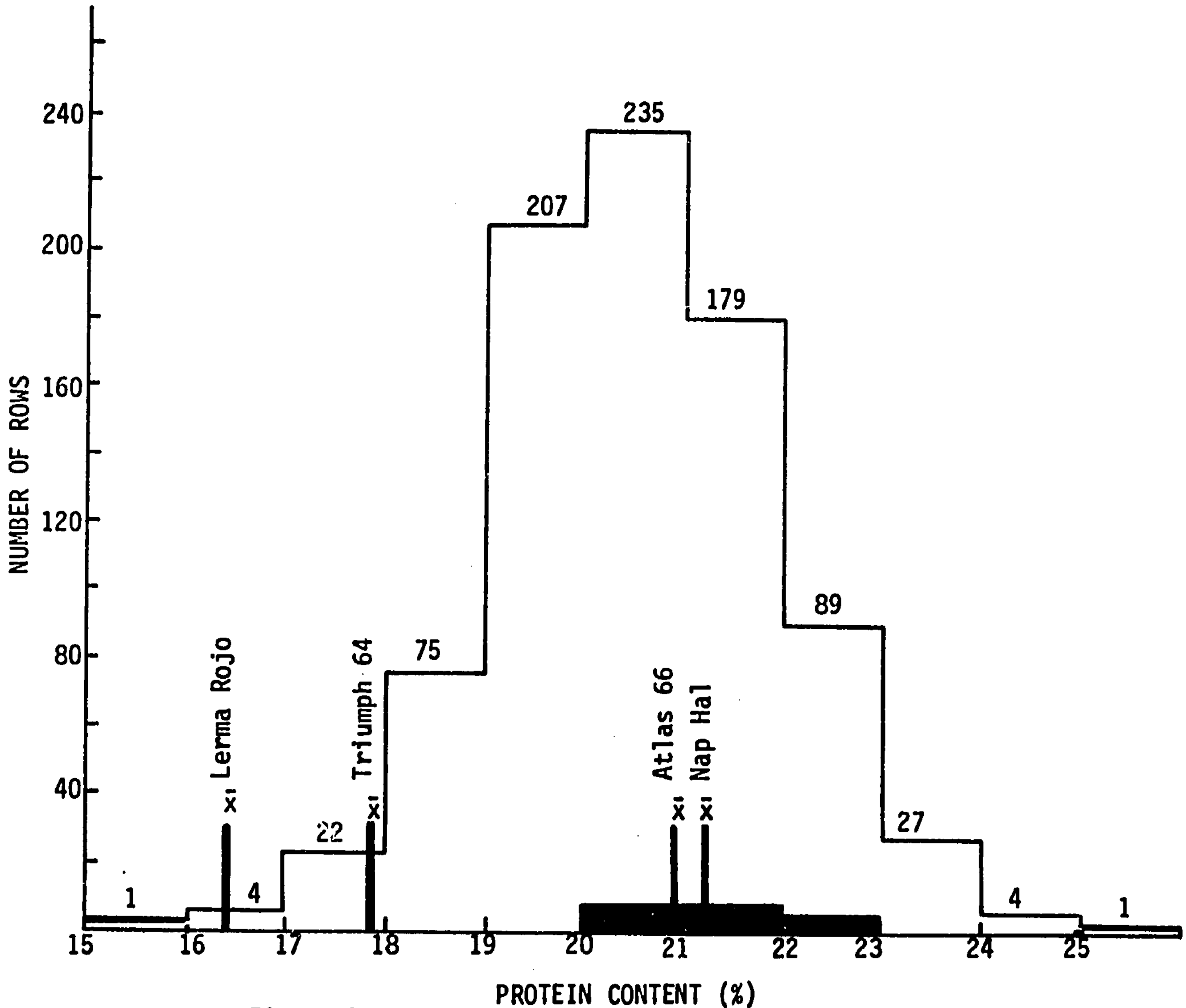

Figure 2.--
Protein frequency distribution for F_2 progeny bulk rows from a Nap Hal x Atlas 66 cross grown at Yuma, Arizona in 1971.

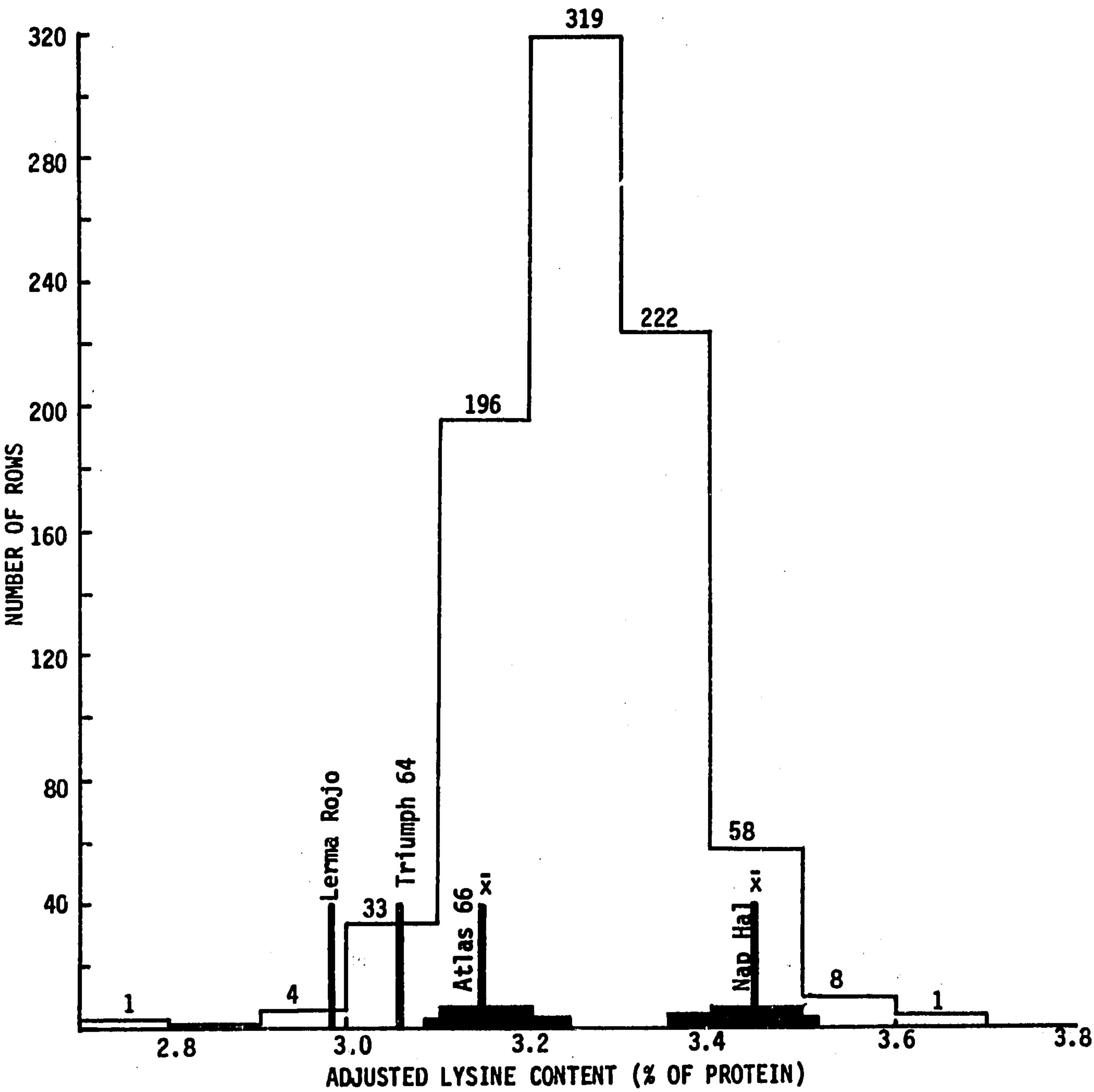

Figure 3.--
Frequency distribution for adjusted lysine among F_2 progeny bulk rows from a Nap Hal x Atlas 66 cross grown at Yuma, Arizona in 1971.

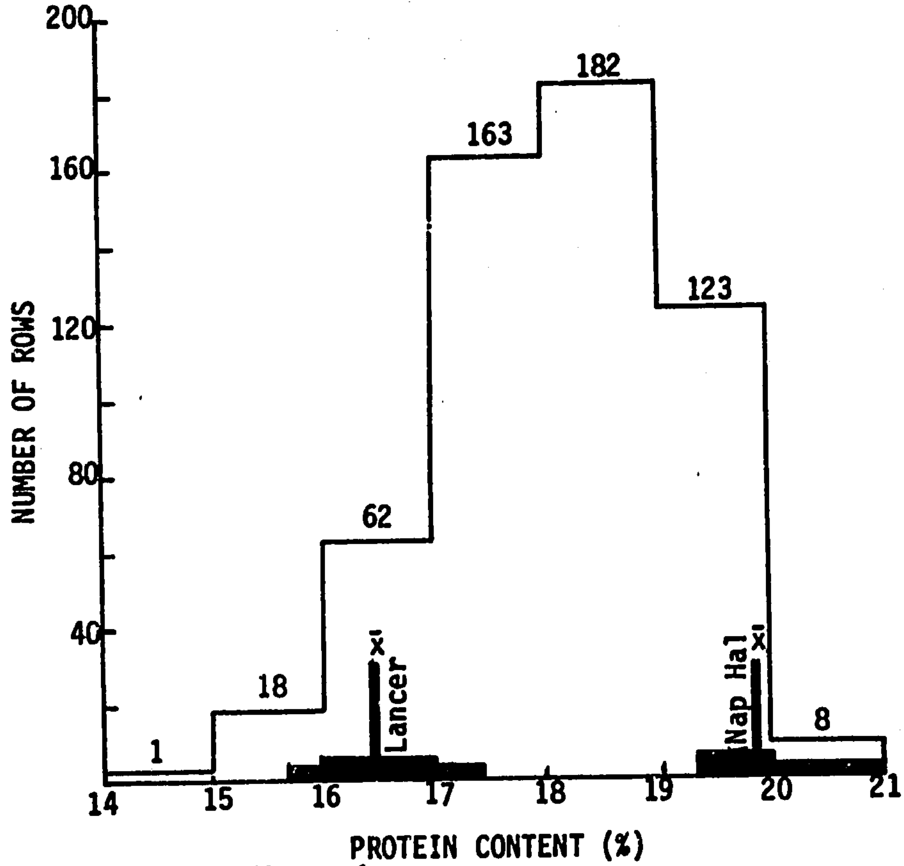

Figure 4.--
Protein frequency distribution for F_2 progeny bulk rows from a Nap Hal x Lancer cross grown at Yuma, Arizona in 1971.

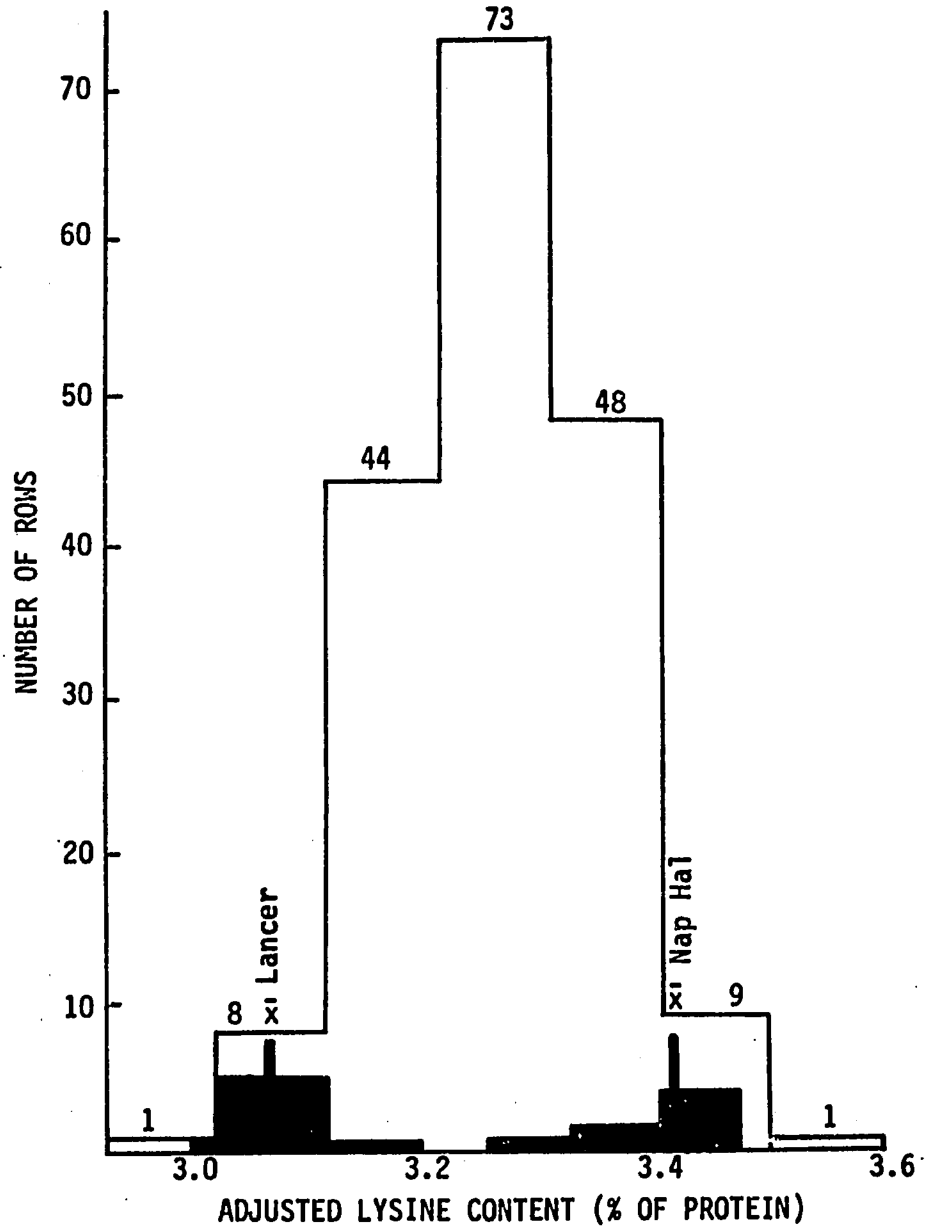

Figure 5.--
Frequency distribution for adjusted lysine among F_2 progeny bulk rows from a Nap Hal x Lancer cross grown at Yuma, Arizona in 1971.

ANALYTICAL PROCEDURES AND EQUIPMENT REQUIREMENTS

by

P. J. Mattern
United States

Analytical Procedures

Sampling

For large samples some method must be used to obtain representative portions for analysis. Various commercial sample splitters would be useful. Ten-gram samples from each replication from International Winter Wheat Performance Nurseries (IWWPN) are returned to Nebraska for analysis. Normally we process five grams for lysine and protein determinations.

Grinding Equipment

Several years ago there was a problem to find a grinder which would process 1-10 g. of wheat and not require clean out and also give good recovery of the original sample.

Several cereal laboratories have reported the use of a hand or power burr mill followed by sub-sampling and grinding on the Wig-L-Bug. However, the system is fairly time consuming and the samples are generally less than 1 g. It does offer potential with extremely small genetic samples in that kernels may be cut transversely, the germ ends saved for planting, and the remainder ground with the Wig-L-Bug.

Our first approach was to use the Udy Cyclone Sample Mill which was a modification of the Weber Bros. Laboratory Pulverizing Mill. This was a small hammer mill which was used with a 0.024" screen and a vacuum operated cyclone for sample pickup. An additional vacuum cleaner was required for a source of vacuum for the cyclone. We cleaned the grinder between samples, when processing 5-10 g. of wheat.

We are now using the newly designed Udy Cyclone Sample Mill. The grinding principle has been completely changed. Impact fins of a propellor force grain to an abrasive surface. The mill grinds wheat quickly without an additional vacuum source. In our experience, clean out between samples is not required for samples of 5 g. or larger.

Cereals containing higher levels of lipid often adhere to the sides of the cyclone. A removal plate over the cyclone permits one to clean the grinder easily. This mill is operated with the 0.020" (0.5 mm) screen when grinding wheat for use with normal dye binding methods (1).

Blending Ground Samples

Following grinding the samples are brushed through two sieves into a 2" x 2" storage box. If the container is approximately 1/2 full it can be further blended by tumbling. In our experience sampling was adequate following the brushing through the sieves.

Moisture Equilibration of Samples

Moisture contents of cereal samples are necessary to calculate analytical data to a constant moisture value. These determinations waste sample and are time consuming for a large laboratory screening effort.

In 1965 we started to equip and test an available baking fermentation cabinet (Fig. 1) from the National Manufacturing Company, 1218 North 22nd, Lincoln, Nebraska 68503, as a moisture equilibrating cabinet.[1] Since we had adequate control of room temperature we did not use the temperature controls provided in the cabinet. Air circulation was provided with a built in squirrel cage fan. Humidity control was our main concern. To provide maximum space for storage the humidifier unit (Walton Montclair Model WF-225, Walton Laboratories, Inc., 1835 Burnett Avenue, Union, New Jersey 07083 which is supplied by the National Manufacturing Co.) was placed below the cabinet. The output of the humidifier was transported with the use of a rubber stopper reducing unit and 1/4" I.D. pressure rubber tubing through the bottom of the cabinet. This small opening was extremely important to prevent drastic over-shooting of humidity in the cabinet during cycling of the humidity controller unit.

Since the fermentation cabinet was already provided with a satisfactory air circulating system the main problem was to provide humidity controls, racks and shelving for sample containers.

The following items for humidity control are available from Hygrodynamics, Inc., 949 Selim Road, Silver Springs, Maryland 20910:

1. Electronic hygrometer controller, Model 15-3216
2. Wall mounting unit no. 15-6100 (for sensor)
3. Humidity sensor no. 4-4819 (color code green)
4. Sensor cable no. 88-301-37 from the wall mounting unit to the hygrometer controller box (6 feet normally would be sufficient)

At a setting on the hygrometer controller to maintain a relative humidity (R.H.) of 46% in the cabinet one can maintain ground wheat at a moisture content of 11.7-11.9 at approximately 21-22°C.

Depending on the moisture content of the cereals when placed in the cabinet, constant moistures are obtained in 3-5 days for ground material and 21 days for whole kernels of wheat.

Various cereals come to their own specific moisture levels at the constant condition in the equilibrating cabinet. Differing protein levels and previous drying treatments may influence final moisture slightly.

The moisture equilibrating cabinet is supplied with 12 small doors. Normally we place 9 or 10 shelves in the unit. Each shelf contains 9 drawers, each drawer holds 45 polystyrene sample boxes or 405 samples per door or approximately 4000 samples per cabinet. Individual trays being used are placed alone in a door section to permit easy access to samples.

[1]Mention of firm names or trade products does not imply that they are recommended by the U. S. Department of Agriculture, U. S. Agency for International Development over other firms or similar products not mentioned.

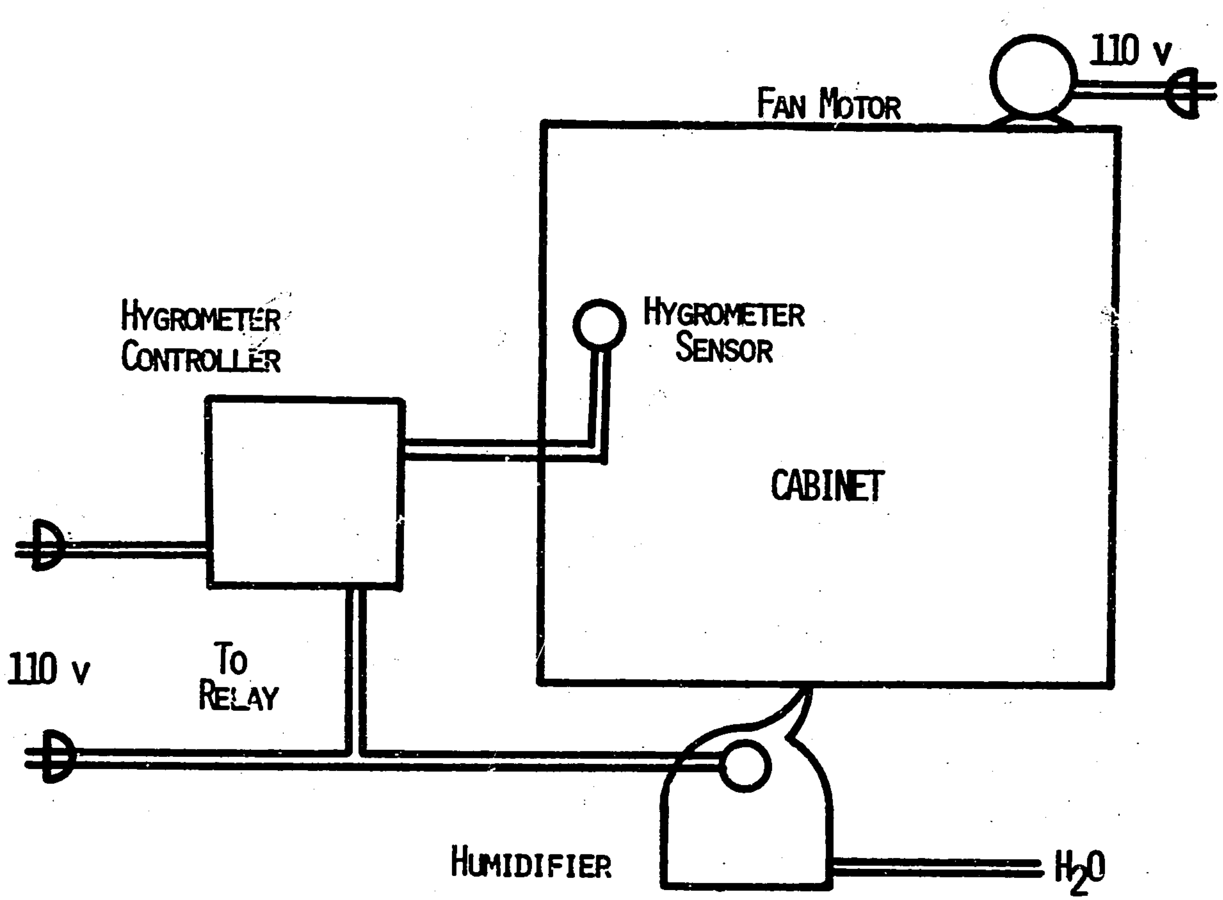

Figure 1.-- MOISTURE EQUILIBRATING CABINET

We routinely place self adhesive teflon on the runner edges of the shelf in order to minimize friction and keep powdered metal from falling into the samples.

Several control samples are weighed each morning for moisture. Since sample moistures are known the technicians can weigh samples to a constant moisture content. Tables for sample weights have been prepared for 0% (dry weight) and 14% moisture levels. Using this technique it is not necessary to make conversions on analytical data after an analysis has been completed.

In summary, the main advantages of using a moisture equilibrating cabinet are:
1. Moisture determinations are limited to two per day per cabinet.
2. No moisture conversion required for data obtained on "pre-adjusted" weights.
3. Samples can be held and rechecks made if necessary with a minimum of effort.

Protein Analyses

In order to select wheat varieties with improved protein potential we have primarily concerned ourselves with screening methods for total protein and lysine. To gain information on varietal differences and environmental effects we have also analyzed selected samples for their complete amino acid content.

Protein by Kjeldahl

The macro Kjeldahl continues to be our method of choice providing sample size is adequate. It requires a special laboratory installation and competent technicians. The Kjeldahl is not necessarily easy just because it has been run routinely for more than 80 years. We obtain Kjeldahl values on samples to be analyzed for complete amino acid content.

If samples are small we often run micro Kjeldahls. Digestions for the micro Kjeldahl have been simplified by the use of a 40 unit digestor produced by Tector ab, Kronborgsgatan 6, Helsingborg, Sweden. Samples are digested in 25 x 250 mm tubes. Sulfuric acid will accumulate in a regular laboratory hood. Therefore, one needs a special exhaust system. The manufacturer does supply such an item but it must be used in conjunction with a water aspirator.

Following digestion any number of automatic detection systems can be used. We employ an alkaline-phenol color development recommended by the Technicon Corporation for use with their auto analyzer.

Protein by Dye-Binding

Over the past 25 years dye-binding methods have been developed to estimate crude protein in a variety of materials (2,3). We use an azo sulfonic dye, acid orange 12 (C.I.15970). The acid buffered dye solution is mixed with a ground cereal sample and the single anionic dye bonds with the basic imidazol, quanidine and amino groups of the protein. These groups originate from the basic amino acids histidine, arginine and lysine, or from the free amino groups at the end of the protein chains (4).

We use a modification of the Udy Method (1). One-half gram ground samples are weighed into 50 ml polycarbonate centrifuge tubes. Twenty-five ml of dye are added with a mechanically driven syringe (Brewer Automatic Pipetting Machine).

Tubes are capped and given a hand shaking to wet contents and placed in special racks each holding 24 samples. Racks are placed on the tray of an Eberbach reciprocating shaker. Tubes are agitated in a horizontal position for one hour at 146 excursions per minute.

Tubes are centrifuged for 15 minutes at 5000 rpm in a Model GLC-1 Sorvall Clinical Centrifuge. The supernatant dye solution is evaluated in a Udy colorimeter. The percent transmission is converted to percent protein with appropriate standardized conversion charts.

If sampling is adequate and sample size small one can obtain a dye-binding value with a 0.2 g. sample and 10 ml of dye solution.

Amino Acid Determination

Ion Exchange Chromatography

Ion exchange chromatography (5,6) is still considered the most reliable method for the determination of amino acids. Completely automatic amino acid analyzers are expensive. A laboratory with minimal financial support and technical personnel can employ other methods for screening lysine.

The original lysine screening of the World Wheat Collection and samples from the IWWPN were analyzed with an automatic amino acid analyzer modified with four short columns (7). Samples must be acid hydrolyzed prior to analysis by ion exchange chromatography. The procedure was programmed so that only the lysine peak was recorded and integrated. One operator can analyze 50 samples per day.

Dye-Binding

With samples of barley, wheat, oats, rye, triticale, and corn Mossberg (8) showed that dye-binding capacity (DBC) was more highly correlated with the basic amino acid content, r = 0.940, than with nitrogen and crude protein content, r = 0.767. Lysine was highly correlated with the DBC. The correlation coefficient was 0.819. Munck, et al. (9) incorporated the concept of obtaining DBC with a constant amount of protein.

At the University of Nebraska we are using modifications of the procedures in (8,9) for screening lysine in wheat. First, a crude protein content is determined by Kjeldahl. A ground wheat sample containing 65 mg of protein is shaken for one hour with 25 ml of a dye solution containing 1.3 mg/ml (commercial Udy Analyzer Company dye) in a 50 ml polycarbonate centrifuge tube. The mixture is centrifuged as noted above for the normal Udy method. Apparent "lysine" is determined from a standard curve prepared from lysine data determined by ion exchange chromatography. Our DBC data correlated well with standard lysine values (r = 0.78).

Complete Amino Acid Determinations

We do not see an immediate need for wheat breeding programs in all countries to equip laboratories with amino acid analyzers to evaluate samples for complete amino acid profiles.

We have completed specialized studies on environmental and varietal differences for four selected samples grown at 15 locations in the First IWWPN.

The four varieties were:

- NB67730 -- a Nebraska high protein selection
- Triumph 64 -- CI13679, an early-maturing, fairly widely-adapted productive U.S. variety
- Bezostaia -- PI304092, a universally-adapted, productive USSR wheat which is used as a check in the IWWPN
- Sturdy -- CI13684, a Texas semi-dwarf wheat.

The mean differences in the four varieties were quite small, but a large range in values for protein and lysine indicates a sizeable influence of the environment on the amino acid composition of the protein.

Tryptophan

Since tryptophan is destroyed during the normal 6N HCl acid hydrolysis procedure for the complete amino acid profile,it is evaluated on a separate basic hydrolyzate by an ion exchange method (10) which was modified. An 8 cm column of PA 35 resin is equilibrated with a 3.28 pH sodium citrate buffer and developed with a 5.28 pH sodium citrate buffer.

Nutritional Studies

In Vitro Nutritional Assays

We have used an in vitro assay for wheat protein to calculate a Pepsin Pancreatin Digest Index which uses hog pepsin and pancreatin (11). The method as given made use of the amino acid analyzer to determine the essential amino acids released by the proteolytic enzyme system. The calculation makes use of acid hydrolysis data for whole egg and the unknown wheat sample and essential amino acid data from proteolytic enzyme treated whole egg and the wheat sample. From these four sets of data the PPDR index is calculated by the use of a computer program. Whole egg is the reference at 100.

One improvement is the use of DEAE-Sephadex to recover the essential amino acids following the pepsin pancreatin digest (12).

Quite often lysine is difficult to determine on the amino acid analyzer because of formation of ornithine during the assay. To separate lysine from ornithine a 20 cm column of PA 35 resin was used. The resin was first equilibrated with 3.28 pH sodium citrate buffer and then the sample was eluted with 5.28 pH sodium citrate buffer.

Data from the in vitro test is being compared with mouse feeding values. At present we have a backlog of in vitro data awaiting comparison with feeding experiments. The indices on wheat range from 46 to 57. We will soon know how these data compare with PER's from our mouse feeding laboratory.

This particular in vitro test requires a sophisticated laboratory. The calculations are very tedious and the use of a computer would be recommended.

For the best results with a dye-binding procedure one should:

1. Grind all samples on the same mill with as uniform conditions as possible.
2. Evaluate a known standard wheat sample daily in order to check accuracy of weighing, solutions, etc.
3. Check calibration of the colorimeter with known dye solutions if the standard wheat sample is in error.
4. Use a centrifuge to remove sample from the dye solution to avoid problems associated with filtering systems.

At present a genetic source for higher lysine in wheat appears to be a reality. If this proves to be true we recommend the dye-binding procedure for lysine screening of nursery materials. This must be used in conjunction with the Kjeldahl procedure as pointed out under the specific procedure.

There are a number of other satisfactory procedures available for lysine. It is not the intent of this report to summarize them. However, if it becomes necessary to set up methods for lysine we could make recommendations at that time for specific laboratories, taking into consideration the number of samples to be analyzed, funding, available laboratory facilities, and equipment, etc.

As higher protein and lysine samples become available, there will be an additional need for complete amino acid determinations, and small animal feeding trials. These tests should perhaps be conducted at larger laboratory centers in order to keep costs reasonable and utilize equipment and personnel efficiently.

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NUTRITIONAL EVALUATION

by

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Cereal and plant products are the chief source of dietary protein for the majority of people in the world today. In general, plant proteins are considered to be of lower nutritional value than those of animal origins. However, increasing populations will probably increase rather than decrease human dependence on these resources.

Various approaches may be used in the improvement of protein value of basic foods such as wheat grain materials. Whether these changes are based on genetic, production, or processing alterations, there is a need to assay supposed improvements.

At the University of Nebraska, the Department of Agronomy and the Department of Food and Nutrition recently entered into an agreement to cooperatively investigate the protein value of various wheat materials. Although both departments have other independent projects concerned with nutritional evaluation of cereal materials, the objectives of this project are as follows.

1) To set up a mass testing operation for biological evaluation of various wheat materials as sources of protein.
2) To attempt to isolate and define causes of variability among different wheat samples in relation to protein value.
3) To lay a foundation for establishment of general guidelines for predicting the value of wheat materials as sources of protein.

This paper will attempt to do two things:

1) Review our philosophy for what we are doing and why we have selected the procedures we have.
2) Review our progress. This project really is only fairly beyond the initiation stage.

One of the first problems to be faced in the evaluation of cereal products such as those based on wheat is that of goals. Suitable assay procedures should be carefully matched with ultimate goals. Unlike many cereals, wheat is primarily consumed directly by humans. Hence, goals for improvement in wheat protein should be matched by goals for human nutrition. Expectations for human nutrition in the large sense, have not been fully defined. Most practical assay tools for judging adequacy of protein were originally derived for use in animal nutrition where greatest growth for least feed expenditure was the goal. Is to have bigger humans the goal of human nutrition? Is it more truly to have longer life span or to improve "quality" of life? If these correlate well with growth, no problem exists; but this has not been shown to be the case. Practical evaluation tools are difficult to develop with well-defined goals for human nutrition as a whole. Even so, efforts must be made for carrying out evaluation procedures even while recognizing their limitations.

Various interacting factors are involved in determining the protein value of wheats as sources of protein. Some of the defined direct determinants are thought to be as follows:
1) Amino acid proportionality patterns. Lysine content has received much stress in the case of wheat but other interrelationships may well be involved.
2) Total protein content.
3) Protein digestibility and amino acid availability.
4) Total nutritional environment.

Indirect determinants of value of wheat materials as sources of protein may involve the following:
1) Palatability and acceptability. Regardless of the nutritional merits of a product if people won't eat it or if dietary habits limit its inclusion in the diet to very small amounts, its value is nil.
2) Availability.
3) Cost.
4) Other constituents of the wheat materials. These may enhance or detract from value as protein resources.
5) Other constituents of the diet. For example, if the diet contains legumes, usually fairly good sources of lysine, the relatively low lysine content of many wheat lines may be unimportant.

Obviously, no single assay procedure could possibly take all of these factors into account. An idealized approach to evaluating the value of a supplementary protein would involve a sequential progression from chemical evaluations, to biological evaluations with animals, to biological evaluation with humans, to controlled field and uncontrolled field trials. For routine evaluation of large numbers of test materials such a procedure is prohibitive in terms of time, money and limitations of test materials. In the Nebraska project, the first stage involving chemical evaluation of amino acid proportionality patterns (particularly lysine) and total protein content of the wheat materials is being carried out in the laboratory of Professor Paul Mattern, Department of Agronomy. The second stage evaluation involving small animal biological evaluation is being completed in our laboratories. The mouse was selected tentatively as the animal model for biological assay in our laboratory for the following reasons:
1) Low ration requirements of this animal makes practical the biological evaluation of materials which, in some cases, are available only in small amounts.
2) Relatively large amount of information available on nutritional requirements of the animal making data derived of more valid use in terms of transfer of conclusions to other species including man.
3) Uniformity of animals due to long inbreeding reducing number of test animals needed per group feeding evaluation.
4) Availability of weanling mice from commercial colonies eliminating the need for establishing (at this time) of an independent breeding colony which greatly simplifies the entire undertaking.
5) Acceptability by the scientific community of this animal as a suitable bioassay tool.

Throughout our studies weanling mice (18 g weight at start of test runs) of the Swiss Webster strain have been used.

Several methods of biological assay are available. The commonly used PER method (protein efficiency ratio method) was considered. This method involves feeding rations containing equal levels of protein (traditionally 10%) to growing animals for test period of usually 28 days. PER is equal to the weight gain of the animal per unit protein consumed. This method is of value for answering questions concerning protein quality. Results obtained reflect adequacy of amino acid proportionality patterns and protein digestibility primarily.

Humans eat in terms of portions or measures of food rather then in terms of portions or measures of nutrients. For example, people select slices of bread; they do not make selections on the basis of grams of wheat protein. Thus, among wheat-eating peoples if other variables remain unchanged, an increase in protein content of wheat will result in an increase in total dietary protein proportional to the amount of wheat in the diet. People will not reduce the amount of wheat consumed on purpose to maintain a steady-state protein intake. This being the case, we decided to do the mouse biological assays of the wheat samples using rations formulated to contain equal rcentages of wheat grain or wheat products rather than equal percentages of wheat protein. Thus, the rations vary in protein content proportional to the protein content of the test product. Ration consumed per unit of weight gain is measured. This method is referred to as FER (feed efficiency ratio). An increase in FER number value is indicative of a decrease in the value of the wheat as a source of protein. Results of this method are dependent upon protein quality (amino acid proportionality pattern), protein quantity, and digestibility/availability.

The initial studies were devoted to an attempt to determine a desirable ration formula. For testing purposes an ideal formula should not give maximal growth of animals but should allow for separation among animals fed different rations. Thus, the range in likely protein contents as incorporated into the ration must be high enough to allow some growth but not so large as to allow maximal growth for most samples tested. Neither no growth or maximal growth allows for separation among samples, the objective of the project. The ration formula which works for us in bringing samples into testing range is as follows:

Wheat	75%
Sucrose	9.8%
Corn oil	10%
Mineral mix	5%
Vitamin mix	0.2%

A total of 600 g of grain or less is needed for each 5 mouse, 28 day, assay.

Biological assay evaluation demands the use of control materials against which all samples are measured in terms of animal performance. Casein has been most commonly used for this purpose. For sake of tradition, we, too, use casein control data but to increase the relevancy of the data, standard wheat materials are also used as controls. After all, wheat is more likely to replace wheat rather than wheat replacing casein in practice. We have been able to get good reproducibility in FER values for control materials on various runs.

Reports of value of various lines of wheat grown at various locations as sources of protein are somewhat tedious in a report such as this. Thus far we have collected insufficient data for general conclusions to be made. However I thought that you might be interested in spread of data and trends.

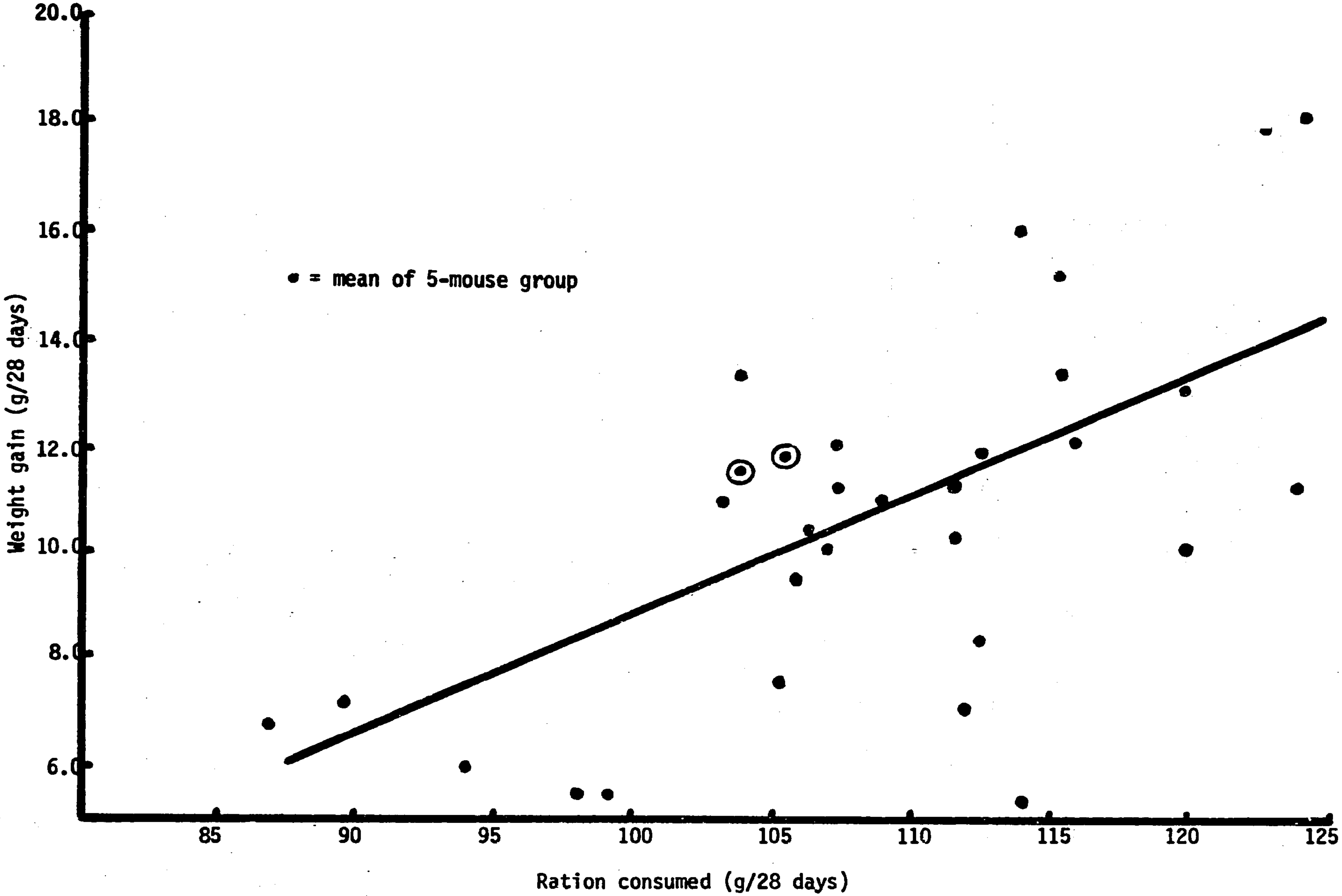
On Figure 1, mean growth of mice fed 30 wheat materials is plotted against amount of ration consumed. Each dot represents the mean of 5 animals fed each wheat material for 28 days. The encircled dots are casein control values. Growth is plotted on the vertical axis and ration consumed on the horizontal axis. Mean growth of animals fed the various materials ranged from 5.3 g to 17.6 g over the 28 day period. Mean ration consumed ranged from 87 to 124.5 g. As one might expect there is seemingly a tendency for greater growth with increased feed consumption. However, this relationship is not as clear-cut as one might expect. Biological evaluation would be much easier if one simply used growth as an evaluation. The work of measuring feed consumption is time-consuming. However the variation in ration consumption illustrated here suggests the necessity of taking this measurement into account. FER value obtained by dividing weight gain by ration consumed in part eliminates this factor. However, this is not completely the case because efficiency of ration for promoting growth is not the same at all points on the growth scale.

Figure 2 compares FER values and crude protein levels in the test materials. FER values are charted on the vertical axis and protein content on the horizontal axis. Each dot represents the mean value of 5 mice fed each wheat material. FER values ranged from 6.3 to 21.5 while protein content of the test materials ranged from 10.75 to 17.88%. An increase in FER value denotes a decrease in nutritive value of the ration. Seemingly the value of the wheat material as a source of protein tends to be related to the protein content of the grain. This is particularly true at the extremes of protein content. However, in the middle range, great variability exists. This may be related to variations in digestibility or lysine content. These factors are under investigation. Other factors may also be involved.

An important spin-off project from this testing program, my co-researcher Dr. Hazel Fox and I believe, is a study attempting to determine how will the results of biological evaluation of wheat materials using mice as bio-assay tools correlate with biological evaluation with humans. After all, this type of project is worthless if the results do not closely approximate results in the specie for which the materials are actually intended.

Three test wheat materials were selected: Scout 66, Scoutland, and Gage. Skim milk and casein were selected for positive controls. Mouse bioassays were more extensive than usual because of relatively unlimited amounts of available material. These evaluations included rations formulated at equal quantities of grain (75% grain) fed at two levels of vitamin supplementation and rations formulated at equal levels of grain protein (7% and 10%).

Human bioassays included tests with adults and growing adolescent boys. In laboratory controlled study with humans procedures are somewhat different than with animals. Instead of formulating rations according to formula and allowing free consumption, in human studies it is pre-decided how much of the test material each subject will consume each day. Instead of feeding uncooked ground flour, it is necessary to incorporate the test materials into at least a semi-palatability product. In this study baked, yeast risen rolls were used. Evaluations were carried out at equal intakes of protein (4 g N per day) at two levels of vitamin intake and at equal intakes of grain (150 g per subject per day). The study with adolescent boys involved comparisons at equal levels of



20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
Weight gain (g/28 days)
• = mean of 5-mouse group
85
90
95
100
105
110
115
120
125
Ration consumed (g/28 days)

Figure 1.

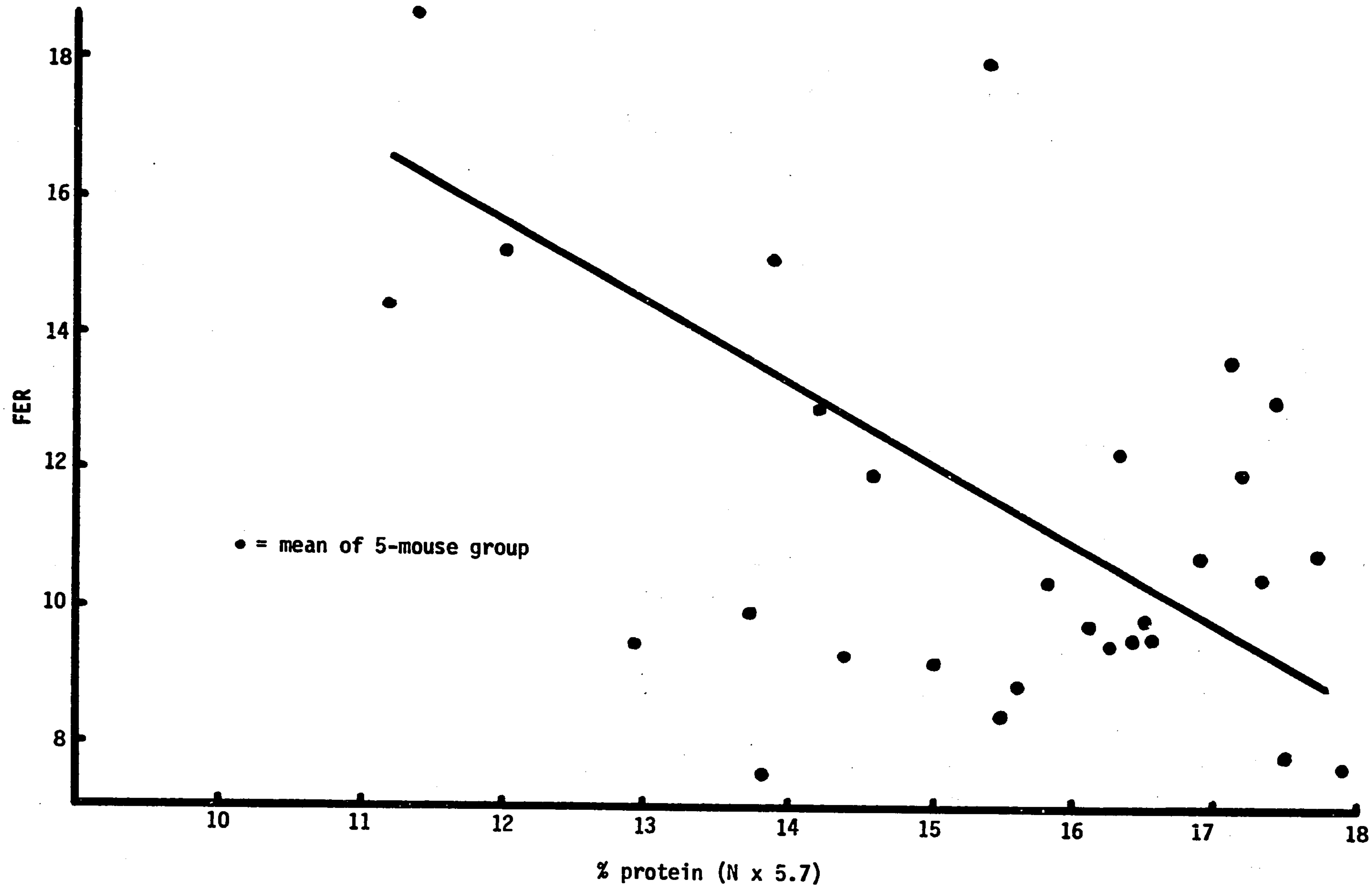

FER
18
16
14
12
10
8
10
11
12
13
14
15
16
17
18
• = mean of 5-mouse group
% protein (N x 5.7)

Figure 2.

protein intake (4 g N per day). In human studies, the nitrogen balance technique is used as the chief means of protein evaluation. The feeding phases of these studies have been completed, however, evaluation of data is still in process. By cooperation with other laboratories we hope to see the expansion of this comparative data to other animal species.

Solution of world nutrition problems requires many approaches by many disciplines. I am delighted to be involved with the area of agronomy in their approach to improvement of human nutrition through improvement in wheat quality. I believe that only through cross-disciplinary cooperation can solutions to the multi-causal problems with which we are faced be solved.

OPPORTUNITIES FOR COOPERATION IN THE NUTRITIONAL AND AGRONOMIC IMPROVEMENT OF WHEAT

by

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Cooperation in research is widely recognized as a requirement for sustained progress and effective use of resources in modern agricultural development. A hundred years ago agriculture placed a relatively low demand on science for new technology. This was due in part to the much lower total requirements for food, and in part to the lack of relevant research results that could make agriculture that much more efficient and profitable.

Now the situation is vastly different. A mushrooming world population has placed alarming strains on agriculture to meet basic food requirements. These strains differ greatly from one area to the other, but present a problem of worldwide concern. Science and technology have been harnessed to modernize agriculture and results have been dramatic but disparate in terms of individual country needs. And, with a rather general insufficiency of resources, efforts have been intensified to find ways to find ways to use them more effectively in the generation of the technology required to increase agricultural production. This, naturally, has resulted in a greater degree of and effectiveness in cooperative research -- an attempt to get more out of each dollar, or lira, or rupee invested.

The significance of cooperation in research to increase the production and quality of wheat can be appreciated by considering a couple of examples. Current world production of wheat (excluding Mainland China) is around 300 million tons (FAO, 1971). Development and utilization of production technology that would increase yield only 10% would add 30 million tons extra of wheat. This is about two-thirds of the total wheat production of North America; almost three times that of South America; more than that of India. Increase of the average protein content of the wheat grain by 20% (this seems to be feasible) would increase total world protein production by about 7.5 million of tons. This would provide the basic daily requirement of protein (75 g) for around 275 millions of adults for about a year. And wheat protein is of relatively high quality.

The full account of cooperative wheat improvement research would be very interesting. We are reasonably well-informed about the present status, but when and how did this cooperation start? And, more importantly, what are the opportunities to further strengthen it?

Progress in Cooperative Wheat Improvement Research

Exchange of improved seed serves to illustrate progress in wheat research. We can use our imagination to guess how the first progressive wheat farmer, probably somewhere in this part of the world, made selections in his crops and saved seed of the "best" material. This test may have been because of special characters for yield or it may have been that it was earlier in maturity, possibly escaping prevalent insects or diseases, or it may have just looked better. The selection was multiplied and in due course he cooperated with his neighbor by making some of the seed available. This probably was one of the first technical assistance activities in wheat improvement! The immediate impact was rather limited, although very significant in the long run.

Then, many centuries later (in 1963 to be exact) wheat researchers in Mexico (building on results of the first improvement in seed exchange) made seed of the semi-dwarf, fertilizer-responsive, disease resistant, high-yielding varieties and selections available to India. The effect was revolutionary: for example, from about 1965, when India started using the new varieties commercially, until 1971, total national wheat production increased from around 11.5 million tons to more than 23 million -- a doubling of production of the second most important cereal crop in the country. The specific result of sharing the fruits of agricultural research from one country to another perhaps has not been equalled considering the need filled and the time span involved. It is certain that each of you could relate similar results of such cooperation that has been particularly meaningful to your project.

An International Wheat Research Network

The sharing and exchange of improved seed and of other research results on related cultural practices progressed from stage to stage -- through successively more involved relationships -- to what amounts at present to an international wheat research network. An examination of this network should be useful in getting a better impression of how far we have progressed, and in seeking ways to strengthen the network through more effective linkages.

A Generalized Model

Figure I presents a simplified schematic international wheat research network. The capital letters in the corner boxes refer to individual country wheat research projects, or even individual wheat research centers in the countries. A regional center or project is shown linking "A" and "B". Corresponding links could be shown between any of the other country programs/stations. An international center is shown in the figure as the focal point, although it is recognized that for particular links in the network this will not be the situation.

The International Center serves to link wheat research in the various cooperating centers or countries. It carries out research, training, and works through outreach activities in developing nations, making sure that these are coordinated with and serve to strengthen the overall network. In one way, the international center serves to couple the resources and capabilities of countries having relatively high levels to those with relatively low levels, thus attempting to bring them all to the highest level possible.

Correspondingly, the Regional Center serves to link countries in a particular geographic area having similar needs for, or capability in, wheat research. In the schematic network, the regional center is also linked to the international center.

A Real Spring Wheat Research Network

Figure 2 shows, in simplified manner, an important portion of an existing larger overall international wheat research network. This particular network is concerned primarily with spring wheat (non-winter hardy). Instead of letters in the corners and sides, specific countries are now substituted. Of course, space considerations make it impractical to list individually all of the countries and agencies involved in spring wheat network. Thus a compromise has been made by

GENERALIZED WHEAT NETWORK

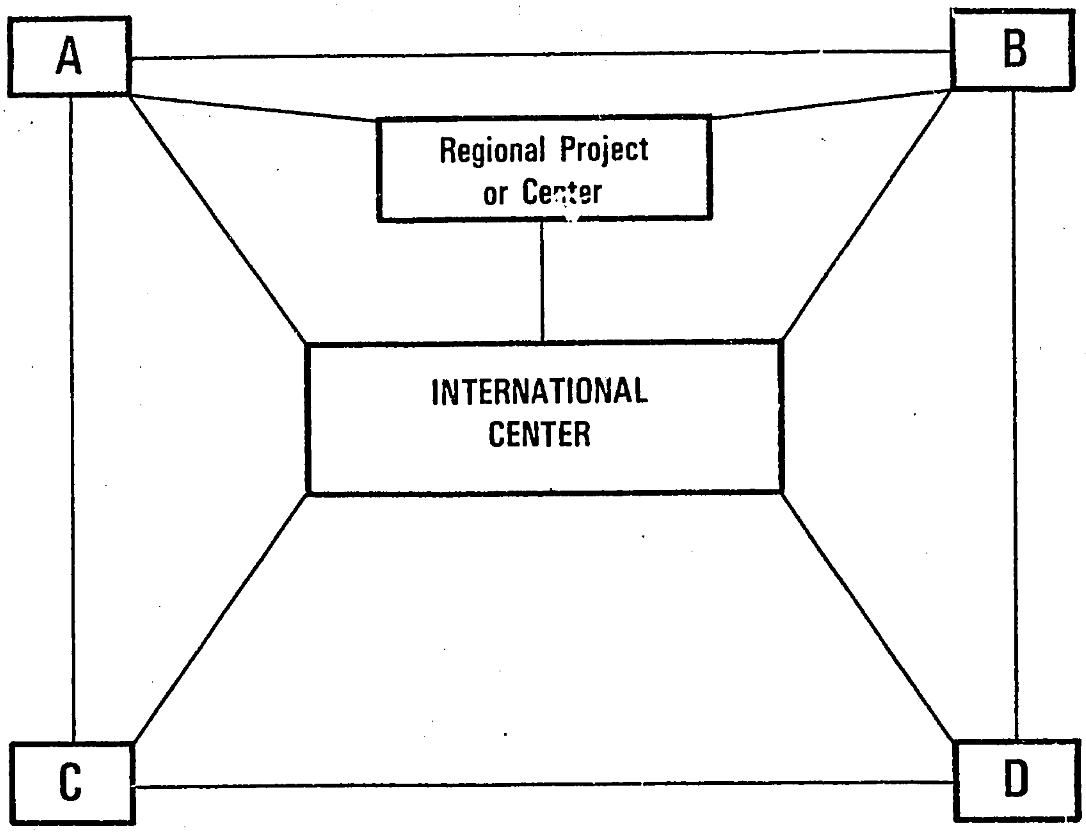

Fig. 1. *A generalized international wheat research network. Letters refer to individual country programs, or to specific research stations or cooperating agencies.*

SPRING WHEAT NETWORK

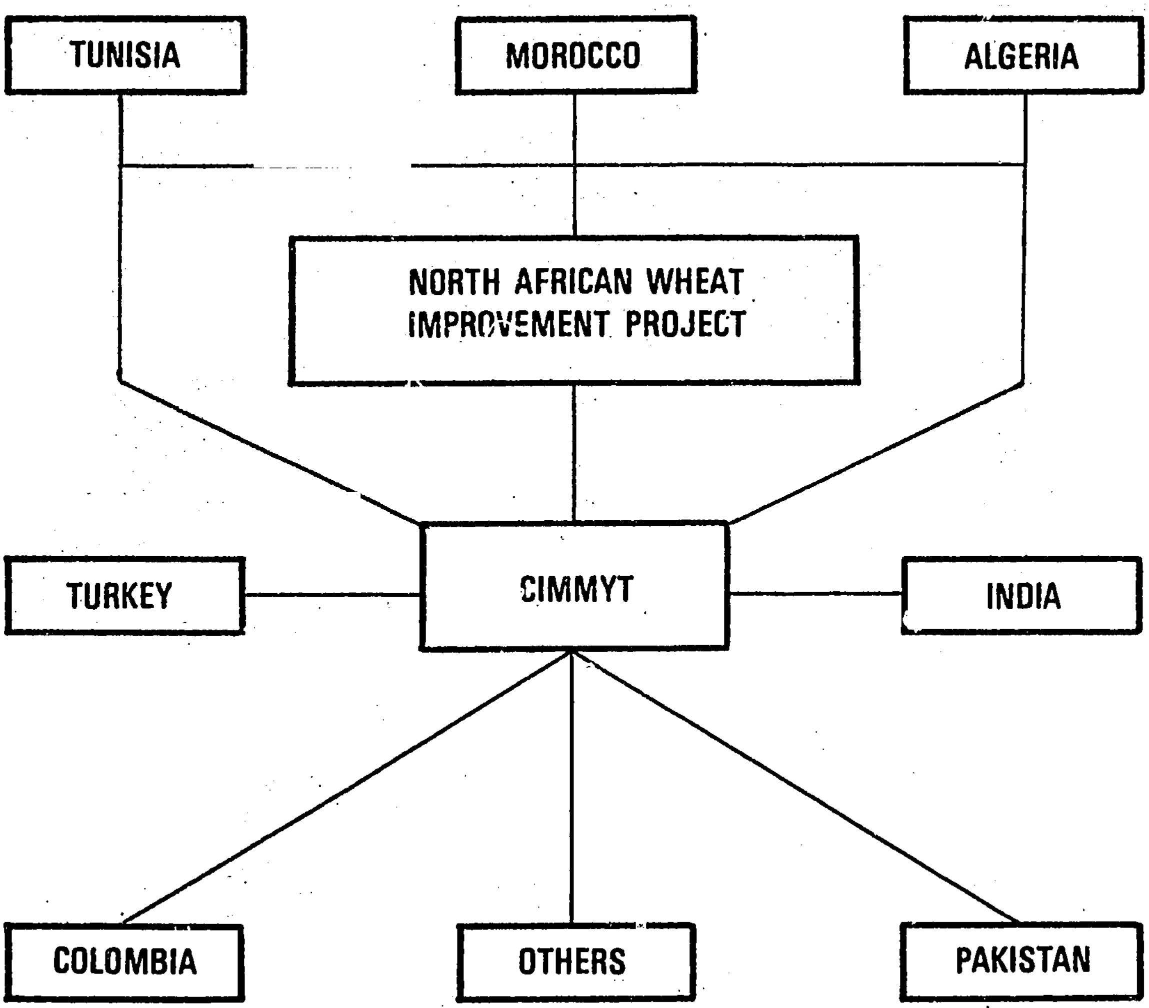

Fig. 2. *A spring wheat research network "OTHERS" refers to the many other country programs, agencies, or projects involved. Many international agencies and foundations make important inputs to this network.*

listing some and then making a box for all "others". Further, for a regional center, the North African Wheat Improvement Project has been listed as an example. And, instead of a hypothetical international center, we have CIMMYT (International Center for the Improvement of Maize and Wheat established in Mexico by the Rockefeller and Ford Foundations and now also supported by the Agency for International Development and other donors).

In the spring wheat network CIMMYT is the primary focal point, or coordinating center. In its spring wheat program CIMMYT's worldwide network is linked to most spring wheat producing countries of the world, as well as other interested agencies such as the FAO, UNDP, the Foundations, World Bank, etc. It has its own research and training program. Research is directed toward development of higher yielding varieties with broad general solid and climatic adaptation, disease resistance and improved grain quality. It cooperates with all interested countries as schematically shown in Figure 2 as well as with many "Others" (Table 1). These cooperating countries receive breeding or advanced materials from CIMMYT and use them in their own programs. Results on the performance of the materials provided as well as the results from uniform cooperative tests are internationally made available through CIMMYT. Also, CIMMYT depends on certain individual institutions for doing important research for which it is not specially equipped.

Table 1. United States and international developmental agencies supporting high protein crops production.

Private organizations and foundations	Agri-business	International organizations
Foundations	Ford	United Nations Development Program(UNDP)
Ford(CIMMYT,NTA,CIAT,IRRI)	Purina Mills	Food and Agriculture Organization(FAO)
Kellogg(CIAT)	John Deere	Int. Bank for Rural Development(IBRD)
Near East	Massey-Ferguson	World Health Organization(WHO)
Asia	Int. Harvester	UN Educational, Scientific and Cultural Org.(UNESCO)
Rockefeller (CIMMYT,NTA,CIAT,IRRI)	E. L. DuPont	Asian Dev. Bank(ADB)
Fulbright(training)	Quaker Oats	Inter-American Bank
Societies	Dow Chemical Etc.	Org. of American States(OAS)
Agronomy	Pioneer Seeds	Southeast Asian Development Agricultural Group(SEADAG)
Phytopathology	DeKalb Seeds	
Asia	Northrup-King Seeds	
International Voluntary Services(IVS)	Asgrow Seeds	
National Academy of Sciences	Fastgrow Seeds	
Assn. of Landgrant Colleges and Universities	United Seeds	
Agric. Dev. Council(ADC)	Agroceres	
African-American Inst.	Uniroyal	
Pan-Amer. Dev. Foundation	United Fruit	

Table 1. (continued)

Government Agencies		Individual contributing nations
Federal	State	
Dept. of State	Univ. and Expt. Sta.	Australia
Agency for Int. Dev.(AID)	Nebraska(Lincoln)	Belgium
Tech. Assist. Bureau	Wheat Protein(AID-1208)	Canada
Agric. and Fisheries	Sorghum Phys.(Rockefeller)	Denmark
Nutrition	Sorghum Production	France
Health	(USAID/Vietnam)	Germany
Education-Human Res.	Purdue(Lafayette)	Italy
Population	Corn Protein(AID-2809)	Japan
Dev. Adm.	Sorghum Protein(AID-1175)	Netherlands
Sc. and Tech.	Sorghum Production	Russia
Regional Bureaus and Country	(USAID/Brazil)	Sweden
Desks	Illinois(Urbana)	Taiwan
VN(Vietnam)	Soybean Production	USA
LA(Brazil,Nic.,etc.)	(USAID/India)	United Kingdom
AFR(Nigeria,Tunisia,etc.)	Soybean Food Utilization	Romania
NESA(Turkey,India,etc.)	Kentucky	
EA(Indonesia,Philippines,	Thailand	
etc.)	Oregon(Corvallis)	
Country Missions(38)	Wheat Production	
VN(1)	(USAID/Turkey)	
LA(15)	North Carolina	
NESA(6)	Potatoes(USAID/Peru)	
EA(5)	Wyoming	
AFR(11)	Afghanistan	
Peace Corp	Tennessee	
Information Agency(USIA)	Fertilizers(TVA)	
Department of Agriculture	Kansas State	
(USDA)	Nigeria	
Regional Pulse Improvement	India	
(PASA RA(AJ)3-00	Hawaii	
Plant and Seed Materials	Philippines	
(PASA(AJ)2-00	Thailand	
East Africa Major Cereals	Laos	
PASA	East-West Center	
West Africa Major Cereals	Georgia	
PASA	Cassava(Monograph)	
Department of Interior	Florida	
Bureau of Reclamation	Fibers(Monograph)	
	Puerto Rico	
	Plant and Seed Materials	
	Sorghum, Food Legumes,	
	Root Crops	

The improved protein and related nutritional work at Nebraska University, the uniform testing of varieties for disease performance through the University of Minnesota, and the spring winter wheat crossing program at Oregon State are such examples.

The Regional North African Wheat Improvement Project, to which AID, the Ford Foundation and the Near East Foundation contribute financially or materially, coordinates research and production efforts of the three North African countries, Tunisia, Morocco, and Algeria, whose wheat production areas are very similar. Libya, a fourth North African country with similar soils, climate and production programs is also considering joining the other three nations to take advantage of CIMMYT's outreach program.

It also serves as a regional outreach effort helping other nearby countries with similar soil and climatic environments put into practice what it proposes: developing production packages for the efficient wheat varieties they develop -- relatively short and stiff-strawed, photoperiod insensitive, pest resistant and responsive to favorable soil and moisture conditions.

Those of us concerned specifically with country programs involving spring wheat can see the present and potential links in the research network. For example, Turkey cooperates with CIMMYT using materials from the latter to strengthen its own breeding program. Work in Turkey on such things as disease control (rust and Septoria) is not only valuable to Turkey, but also serves all countries where these diseases are problems. With strong outreach programs such as in North Africa, special breeding programs are being supported through CIMMYT to develop varieties resistant to the diseases which have become limiting in that environment, namely Septoria. Until certain of the Mexican varieties were introduced and extensively grown in these areas, Septoria was considered a minor disease. Similarly in the coastal areas of Turkey, and the Mediterranean in general, this disease has become a major problem with the new introductions. More recent breeding efforts in Tunisia and Morocco have now resolved this problem and new Septoria-resistant, high yielding varieties are rapidly replacing the first released Mexican developments.

A Wheat Protein Quality Network

It is not necessary or possible for CIMMYT to serve as the coordinating center, or focal point, in a wheat research network as in the case of spring wheat. In figure 3 a network is shown which is concerned with the improvement of the content and nutritional quality of protein in winter wheat. In this case, the main project is centered at the University of Nebraska where the program is being supported jointly with the USDA. Again, only some of the cooperators are listed. If your country or center is not listed, it occurs in the block "Others".

In the network Nebraska is both a donor and a receiver. As a donor under a contract with A.I.D., the University research team of breeders, biochemists, and animal nutritionists have undertaken the responsibility of improving the protein content and quality in the winter wheat crop. As promising lines with higher and/or improved protein are discovered or developed they are made available to all cooperators. This may be directly or it may be indirectly through the uniform varietal testing program which is conducted on a worldwide basis with cooperating countries. Breeding and nutritional evaluations by means of chemical and animal feeding tests are regularly conducted at Nebraska. Nebraska depends on its outreach cooperators to measure performance of these promising materials under the wide range of agro-climatic conditions involved, and for their incorporation into the country breeding and crop improvement programs. The Nebraska project also depends on the USDA and Colorado and other sources for new diverse germplasm to be tested for additional factors for improved quality characteristics and use in breeding programs.

WINTER WHEAT NETWORK

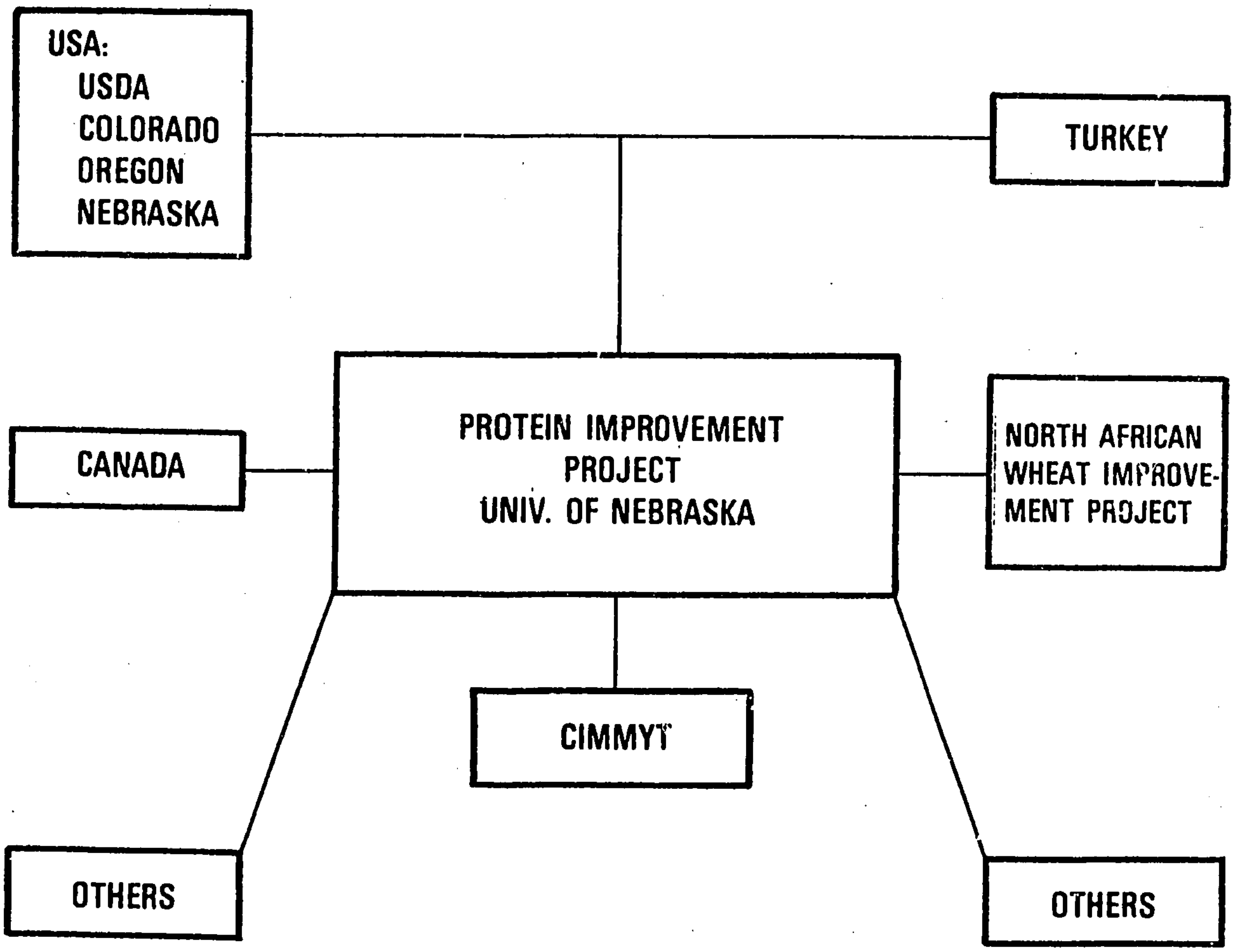

Fig. 3. A winter wheat quality research network "OTHERS" refers to other country programs, projects or agencies and foundations make important inputs to this network.

Through CIMMYT Nebraska is directly assisting spring wheat improvement collaborators by its cooperative work with Oregon State University where crosses between spring and high protein winter wheat varieties are being effected.

As the USDA, FAO, the several Foundations, A.I.D. and the individual cooperating countries are successful in further sampling older more or less natural, unselected and wild ancestral populations, important additions will be made to germplasm pools for subsequent use. Many may be potential contributors for varietal improvement.

Again, it is apparent how each country program currently fits into this international network; it also becomes apparent as to ways in which cooperation can be extended and made more effective. As individual country programs expand and are able to accept greater responsibilities in the worldwide research network, the responsibilities and performance of the central research and training institutes will also change, always in keeping with national program needs -- be it related to developing superior strains for yield, nutritional quality, disease and insect resistance, or supporting cultural practices.

Opportunities to Improve the International Network

It is evident that commendable progress has been made in coordinating wheat research efforts on a worldwide basis. This International Conference on Winter Wheat Improvement is a concrete manifestation of an important part of the network. This is only a good beginning toward development of an international wheat research network that represents the full potential. In order to move ahead, it is important to be in accord on what constitutes "the ideal" international network. In our view the following conditions must prevail:

1) Each country program and its constituent research stations (units) must be so oriented that they can readily provide needed wheat production technology to the producers for which they are responsible.

2) Each unit in the network must be able to readily and routinely avail itself of relevant research results generated by any other unit.

3) Each unit must readily and routinely make available research results to any other cooperating unit desiring them, or which might benefit from them.

4) Each unit must be prepared to cooperate in research and training activities which may not be designed to meet the exclusive needs of its own area, but which specifically contribute to the strengthening of the research network itself.

Each of these conditions are examined more in detail below as are some of the requirements for their realization.

Competence of Research Units

The capability of an individual country wheat program, or of anyone of its constituent stations, depends on a number of factors, among the important of which are four. These are: 1) financial support provided by the country (importance accorded by the country to wheat improvement); 2) qualification of the wheat researchers; 3) effectiveness in cooperating (working as a team) within the stations and country, and internationally; and 4) ready access to the world's wheat germplasm.

In looking at each of these factors, it is apparent that some needed inputs are commonly not always available from within, and outside assistance is required for an individual program. It may be technical, material or financial support that is required. Most of the economically less developed countries, where wheat production is important, rightly add to their own support by making use of such assistance that may be available to them from outside countries or organizations. In Turkey for example, such collaboration is provided by the United States Agency for International Development -- both directly and through a contract with Oregon State University. The Rockefeller Foundation, cooperating with CIMMYT, likewise provides assistance. As in the case of Turkey, other countries utilize similar external sources of support to strengthen national wheat programs. The important consideration is that the external and national assistance be molded into a single coordinated national program.

The qualification of the wheat researchers is also usually a function of national and external efforts. The initial academic and professional training experience is commonly obtained by the researchers in their own country. But large numbers broaden their experience and enhance their capability by additional training outside. Advanced degrees obtained in the U.S.A., and training at CIMMYT are illustrations of measures taken to improve the competence of research units through improvement in the qualifications of the research personnel. Another and perhaps more obvious example of improvement of competence of personnel is this Conference itself. The gathering here is to share information and learn more about winter wheat improvement. Participants should leave the conference better qualified for work in their own programs!

Of course to have an impact, training in wheat improvement must be put to effective use. Statistics in Table 2 raise serious questions as to the priority accorded wheat improvement in the international training of technical personnel from winter wheat producing countries. The data are incomplete, but serve to show the very low number of trained participants that are currently involved in wheat breeding. During the period of 1952-72 there was a total of 5370 AID trained participants from nine countries cooperating with the Winter Wheat Nursery Program. Of this total, only 23 persons are known to be working in plant breeding. Still fewer of these are actually working on wheat.

The importance of cooperating within disciplines (e.g., cooperating with other breeders), between disciplines (e.g., breeders cooperating with pathologists, entomologists, and agronomists and biochemists), between stations within a country, and internationally is obvious to all. This Conference clearly highlights the importance of these kinds of collaboration. The continuing development of winter wheat varieties that are higher yielding, more resistant to prevalent diseases and insects, and of superior nutritional value involves the efforts of the breeders, pathologists, entomologists, agronomists, biochemists and nutritionists working cooperatively at all levels.

Ready access to the world's wheat germplasm is certainly a prerequisite to any effective country wheat improvement program. The use of the IWWPN to quickly evaluate varieties on a world-wide basis is an excellent example of an effective mechanism for systematically making accessible to cooperating improvement specialists potentially useful improved varieties or breeding material on a worldwide basis. It was through the IWWPN that the broad adaptation of Bezostaia, a new improved Russian variety, was realized at a very early stage. Accordingly, it has spread rapidly to other winter wheat areas providing increased yields per hectare and total production.

Table 2. USAID trained participants in countries cooperating in winter wheat nursery program in selected countries.

Country	No. trained in agriculture	Percent using trng.	No. in seed* improvement	No. in plant** breeding
Afghanistan	173	93	6	3
Algeria	NA	NA	NA	NA
Iran	302	80	9	0
Iraq	134	82	3	7
India	1670	NA	10	3
Turkey	1644	84	18	7
South Korea	528	82	4	3
Argentina	473	95	NA	NA
Chile	446	100	NA	NA
TOTAL	5370	85	55	23

* Training period of 12 months or longer.
** Training not necessarily in wheat breeding but applicable to this crop.

Source: Training Office Summaries for period of 1952-1972.

Access to Outside Research Results

Country programs have increasingly greater opportunities to obtain results of research done elsewhere. One of the functions of CIMMYT is to facilitate this access by acting as an intermediary between country programs. Regional projects can play the same role for a group of countries with similar research and production problems.

But the individual country needing access to outside research results must not be content to be passive -- to wait until the results are presented. Active efforts are required to assure availability of possible useful results if they are not normally made available to the people concerned. The presence here of selected specialists is evidence of specific interest of the participants in obtaining information that might be useful in satisfying the needs of their respective winter wheat programs.

Sharing Your Research Results

Cooperation, the essence of an international wheat research network, is a two-way street. If you wish to have access to results of other workers on a continuing basis, you must be willing to reciprocate.

Consider the case of the IWWPN, as has been the case, each cooperator must cooperate by conscientiously growing this nursery and making complete and reliable data available to all other cooperators. Each cooperator must willingly make available his best variety as an entry in the nursery. The breeders must readily share material from their program with other country programs -- directly or through intermediaries such as CIMMYT.

It is not enough to try to rationalize cooperation by being satisfied that in due course of time others will benefit from ones work by reading the resulting publications in scientific journals. Today when everything is being accelerated it is too slow, too impersonal, and very inadequate. One must not only be eager to receive, but also eager to share what one has. Based on reports received, cooperation in this area has been excellent -- essentially 100%. No other international program can boast a record equal to the IWWPN one in terms of cooperative performance.

Responsibility for an Equal Broader Role

An increasing number of country wheat improvement projects have capabilities in research or training that not only respond to their own national needs, but can materially assist in meeting certain needs of country programs which are in a less advanced stage of development.

The All-India Coordinated Wheat Improvement Project is a good example insofar as spring wheat is concerned. Personnel and facilities in this project are adequate for broad-based research and training in the major disciplines. Work on breeding, agronomy, pathology, and nutrition not only has made an impact in that country, but in others as well. Facilities are available for training -- in-service or practical training in the project, or academic support leading to advanced degrees. This kind of capability, perhaps with some additional external financing, can be very important in assisting cooperating countries which are not so fortunate.

Turkey is another example of a country program that has the potential for a regional leadership role in an area such as moisture conservation for winter wheat production.

The University of Nebraska, as mentioned earlier, is the focal point in a network concerned with improving the protein level and quality in winter wheat. Research and training facilities of international importance are involved.

A constant lookout must be in effect for specific country programs or centers that are particularly qualified by capability, or by geographic location to do particular work needed by other country programs. For example, what can be done toward establishment of a regional project to control such once-minor diseases as Septoria and mildew, or occasionally serious insects as the wheat stem maggot, saw fly, Hessian fly and cereal leaf beetle which currently involve the Mediterranean countries? Those problems are common to the countries of this area. Is there a location that could serve as a focal point or a coordinating center? What would the nature of such a center or the related network be? How would it relate to the overall international wheat research network?

Looking Ahead

The broad framework has been established for a truly all-inclusive international wheat research network. Although the results to date have been exceedingly rewarding, the demands of wheat production for the future will require much greater efforts in cooperative research and production. Part of this will be to maintain gains made to date against man's enemies, who also compete for existence, while at the same time making additional advancements in developing winter wheat varieties which yield more nutrients per hectare. This is essential if man expects to stay abreast of an ever increasing population.

We as individuals, collectively as members of specific disciplines, as interdisciplinary teams at station and country projects, and as members of regional and international networks have the responsibility to meet the challenge. We have responsibilities and opportunities in each of these roles to increase our effectiveness. May this Conference serve as an important step to move us closer to our ultimate goal.

THE ROLE OF INTERNATIONAL RESEARCH INSTITUTES IN NUTRITIONAL AND AGRONOMIC EVALUATION OF WINTER WHEAT

Panel Discussion

Contribution from the Joint FAO/IAEA Division of Atomic Energy in Food and Agriculture, Vienna, Austria

by

A. Micke
Austria

The Joint FAO/IAEA Division of Atomic Energy in Food and Agriculture is carrying out various programmes on crop improvement by employing nuclear techniques (induction of mutations, utilization of isotopes for tracer studies). These programmes are carried out through research contracts, technical assistance projects, training courses, etc.

IAEA has its own laboratory at Seibersdorf near Vienna which has an agricultural section whose programme supplements Headquarters' technical assistance and research contract programmes. The Plant Breeding Group deals with training of fellows, service treatment of plant material with mutagens, methodological studies for improving such treatments and model studies on mutation breeding and mutant screening.

In connection with the FAO/IAEA Co-ordinated Research Programme on Seed Protein Improvement through Nuclear Techniques, in which 24 scientific institutions in 19 countries are now cooperating, the laboratory has now gained facilities for analyzing grain samples for protein quantity and quality. The Co-ordinated Research Programme is supported for a 5-year period by the Federal Republic of Germany with about US $900,000.00 out of which approximately US $50,000.00 annually is used to strengthen the work at the Laboratory.

The work at the Laboratory is concerned with 3 aspects of the protein improvement programme.
(a) Plant breeding research directed to plant protein improvement.
(b) Developmental work on improved analytical screening techniques.
(c) Analysis of grain samples supplied by plant breeders from developing countries who cooperate in the programme.

This work is conducted in close cooperation and coordination with the participating institutes in developing and developed countries, in particular with institutes in the Federal Republic of Germany. Such coordination is achieved by progress reports sent by cooperators twice a year, by frequent correspondence, and by annual research coordination meetings where all cooperating institutes are represented and have the opportunity to exchange data and experiences as well as breeding stocks.

The present capacity of the service laboratory is in the range of 100 analyses for protein quality (Udy DBC method) per day. However, the capacity will be tripled this year and might reach a maximum of 800 samples/day by 1973. Fifty total nitrogen assays can be made per day by an automated Dumas combustion apparatus built in the laboratory. Total amino acid composition can be determined by a Beckman model 121 amino acid analyzer. As the shipping of large numbers of seed samples from tropical countries to Seibersdorf is difficult, IAEA has provided several Udy analyzers to cooperating institutions in developing countries to enable them to do their own initial screening. The Laboratory's role will be to standardize analytical procedures and to carry out upon request more careful analysis of advanced breeding material with regard to protein content and amino acid composition.

As grain quality is a character affected by many environmental factors we do not consider worthwhile the attempt to have the material grown under "uniform conditions" of only one location prior to chemical analysis. We are convinced that the best procedure is to have the breeding lines cultivated under optimal local conditions, under the breeders' control, in order to assess the full yield and quality potential for the country. The most useful role of an international institute appears to be the standardization of experimental procedures, by advising on planting, fertilization, harvest and sampling, by instructing on appropriate preparation of seed samples before analysis and by checking reliability and reproducibility of local chemical analysis.

The Seibersdorf laboratory restrains from agronomic evaluation of breeders' lines and cultivars at its own premises, but encourages cooperating plant breeders to establish cooperative multi-location trials. In such cases assistance is often given by providing standardized field books, and computerized analysis of experimental data.

This may be considered as an example for

- a particular type of international cooperation for increasing efficiency of research on a specific subject;
- a way of tapping research capacities and expertise existing in developed countries in order to attack urgent problems of agricultural production in developing countries;
- a truly international laboratory servicing scientists and research institutes with inadequately equipped laboratories;
- a way of financing with an international project.

Contribution from the Food and Agriculture Organization of the United Nations, Rome, Italy

by

A. Hafiz
Egypt

After the Second World War and the formation of the United Nations and with greater developments in air travel, the idea of cooperation and coordination on regional and world-wide basis has gained fast momentum in several fields including wheat improvement. The various national, regional and international organizations joined hands for working together toward the same end. FAO of the United Nations has helped in bringing different agencies and national governments together to achieve the speedy solutions of common problems.

Some success has already been achieved in the development of disease-resistant varieties of quality bread wheat in many parts of the world. This varietal testing on an international basis was started between Canada, U.S.A., Mexico, Colombia, Brazil, Uruguay, Chile, Peru, and Ecuador, by maintaining rust nurseries for testing and screening. Similar tests were carried out by FAO with the help of the USDA and later with the cooperation of the European Cereal Rusts Association in 22 countries of the Near East and North African Regions.

From 1961 onwards, the Near East Region developed close cooperation with CIMMYT for the testing of Mexican varieties and the training of young research workers. This paid rich dividends. It was possible for many countries to identify in a short period of 3-4 years some high-yielding varieties (HYV) which were disease-resistant and fertilizer-responsive and possessing a wide range of adaptability. These HYV occupied about 12 million ha. in this Region (from Morocco to India) during 1971-72 giving an additional production of about 12 million tons worth US $840 million. This cooperation also helped promote breeding programmes within the Region and certain countries have now developed even better varieties than the original ones.

Another outstanding example of unusual success is the outcome of our cooperation with the University of Nebraska in the yield-testing of winter wheats. As a result, a Russian variety - Bezostaya - was identified which now occupies a substantial hectarage in Turkey, Iran and Afghanistan.

The FAO Cereal Improvement and Production Project has also developed excellent close cooperation with EUCARPIA, IRRI, and other international organizations (IITA, CIAT, etc.) to the mutual benefit.

We find that the following points are very important in achieving useful results from the cooperation:

a) The traffic should always be in two directions to the mutual benefit of both recipient and donor.
b) All the work should be considered on the basis of a team approach giving full credit to every participating member (with special reference to the persons from developing countries). This will give them encouragement and impetus for furthering their active participation.
c) The cooperation will flourish more if it is based on personal relations rather than on official ones. No rules and regulations can bring about the real cooperation.
d) To have better and quicker results one should refrain from saying that "I have done it" but should rather say "we all have done it" or even better to say "you have done it".
e) The good research workers should always be praised before their administrators in order to give them incentive and encourage others to improve their work.
f) The results of the material received from any source must always be made available with thanks and appreciation.
g) Agricultural research is a missionary work and should always be carried out in that spirit. This will help to increase food production in the world and bring about peace and prosperity which are badly needed.
h) One should always try to avoid jealousies which will not only kill cooperation but will also retard progress.

Contribution of the Mid-East Wheat Project

(A Cooperative Project between The Turkish Government and The Rockefeller Foundation)

by

B. C. Wright
Turkey

On April 28, 1969, an agreement between the Turkish Government and the Rockefeller Foundation was signed in Ankara. This agreement was intended to serve as a basis of understanding for the establishment of a cooperative wheat research and training center and it outlined in general terms the aims and objectives of the cooperative project as well as the obligations of each party. The project was established to increase wheat yields (per hectare) and the profitability of production of winter and spring type bread wheats, and of durums, wherever the crop is or could be important in Turkey and other countries of the region. In order to accomplish this goal, it was agreed with the Turkish Government:

1. To organize a smoothly functioning, efficient National Coordinated Wheat Improvement Program. This is to be a functional, inter-disciplinary team unified under Turkish leadership. Such a research project could serve as a model for other research projects in Turkey and other countries of the region.

2. To develop new varieties and cultural practices for the future, including both bread wheat and durums, which will permit maximum yields yet result in grain qualities preferred in the trade for bread-making and macaroni products. Quantity of production is to be the first object and quality a secondary objective.

3. To develop a capability of surveillance and control of diseases and insect pests, for the purpose of minimizing losses, and particularly for the purpose of minimizing epiphytotics of the type that have plagued other wheat growing nations.

4. To develop the scientific basis and techniques for a program of soil and moisture conservation and crop management leading to maximum economic return of usable food products, on a sustained basis, in each ecological area of Turkey.

5. To provide for a continuing study of the economics of wheat production in relation to alternative farming enterprises and for appraisal of the economic feasibility of new or modified production practices.

6. To organize an in-service training program designed to improve the scientific capability of staff engaged in wheat improvement and production program in Turkey and in other countries.

7. To provide for advanced training designed to improve the technical and leadership capabilities of scientific workers for the wheat program.

8. To provide a group of scientists who will be able to consult with and assist in the development of wheat improvement programs in other countries of the region.

This agreement specifically mentions that the Rockefeller Foundation will expect to work in the closest possible coordination with CIMMYT, and other international organizations, and that CIMMYT staff may be assigned to the programs. The Foundation also has granted funds to Oregon State University to permit this institution to participate in the wheat project in several ways, including:

1. Assignment of a full-time staff member to the project in Turkey.

2. Provision of OSU staff members, mutually agreed upon by OSU and the Rockefeller Foundation project leader, as short-term consultants.

3. Acceptance of an increased number of graduate students from the Mid-East Region.

The Middle East Wheat Improvement Project in Turkey has great importance for the following reasons:

1. Wheat production in Turkey comprises almost half of the total production of the Middle East Region.

2. Turkey is a country in which winter, winter-hardy spring, and spring wheats are grown. Very little research has been done by CIMMYT with winter wheats. Turkey provides an ideal ecology in which materials being developed by Dr. J. A. Rupert can be tested.

3. Turkey represents a transition climate in which unusual climatic conditions have resulted in the evolution of valuable germ plasm which is now being systematically collected and utilized.

Present Status

Staffing
In July, 1970, the first Foundation staff member, Bill C. Wright, was assigned to the project as leader. In October, 1970, Dr. Floyd E. Bolton of Oregon State University was assigned by OSU to the project as a production agronomist. On 1 August, 1971, Dr. J. M. Prescott joined the project from India as a plant pathologist, and on 15 October, 1971, Dr. A. R. Klatt, a wheat breeder, arrived from Mexico. These four foreign staff members represent all the resident staff which is anticipated in the immediate future. There may be temporary staff added from time to time for specialized assignments.

Training
At the present time four Turkish scientists have returned to the project after having obtained the M.S. degree abroad. Three of these obtained degrees in plant breeding and one in cereal technology. Four other scholars are presently

studying toward the M.S. degree in the United States; two in plant breeding, one in plant pathology, and one in agronomy. Four additional potential scholarship candidates have been identified.

Three Turkish scientists are presently attending training programs at CIMMYT. When these three return, a total of 18 trainees will have attended CIMMYT training courses since 1961 with funds provided by FAO and the Rockefeller Foundation. Furthermore, almost all of the students working for the M.S. degree in the U. S. will spend several weeks at CIMMYT during the crossing and selecting period.

Organization of the Project

The formal project was drawn up by a panel of wheat scientists and administrators and has been approved by the Ministry of Agriculture, the Ministry of Finance, and the State Planning Organization. This project provides for 10 research stations in the major wheat growing areas of Turkey. There are three principal breeding stations, at Ankara and Eskişehir for winter wheat and at Izmir for spring wheat. The seven remaining stations are largely selecting and testing sites. In addition there are off-station tests on farmers' fields and an off-season breeding nursery for spring wheat.

In September 1971, the second research conference under the auspices of the new project was held. All wheat workers attended, past research was reviewed, and plans for the 1971-72 research work were made. These included the exchange of breeding material among stations, the establishment of uniform yield trials, disease surveys and nurseries, and better communication among stations.

Immediate Problems of Research

In Turkey there are two distinct wheat growing areas: the dry, cold winter wheat area of Central Plateau and South-East Turkey, and the warmer, wetter spring wheat areas of the coasts. In these two regions, the immediate problems are entirely different.

In the winter wheat area there are a number of improved varieties which are yielding less than their potential mainly because of lack of moisture. Moisture is limiting because of the scantness of the rainfall and because of the poor management applied to the fallow period. Weeds are permitted to grow, the soil is plowed and left in a rough condition, the wrong implements are used, and tillage operations are performed at the wrong time. The most pressing problem in the winter wheat area is to develop a set of tillage practices which will permit the early establishment of the wheat seedlings (preferably germinating from residual moisture) and the greatest conservation of rain falling on the fallow land.

In the spring wheat areas the most pressing problem is the identification of varieties which have good resistance to stripe rust, septoria and which are long enough in duration to permit sowing in early October yet which will not flower until April. In 1967 a large quantity of Mexican wheat seed of several varieties was imported into Turkey. Because of susceptibility to stripe rust and Septoria and because many of these varieties were too short-seasoned, all have been discarded except Penjamo 62; and Penjamo 62 does not have outstanding resistance to either stripe rust or Septoria.

Breeding
In 1970-71 a system of uniform yield tests and the exchange of breeding materials was initiated. This effort was expanded in 1971-72. In the winter wheat program Dr. J. A. Rupert and Dr. W. E. Kronstad have supplied a large number of spring-winter crosses. At the present time the breeders are making a determined effort to incorporate as much diversity into the breeding material as is possible by acquiring exotic germplasm from around the world and carrying on a large crossing program.

In the spring wheat breeding program centered at Izmir a very large number of lines from many different parts of the world have been screened for resistance to Septoria and stripe rust as well as high-yielding ability. Regrettably only a few of the high-yielding advanced lines and varieties from Mexico possess resistance to both Septoria and stripe rust; therefore, an intensive crossing program was launched in 1970-71 to create varieties with these characteristics.

Agronomy
Before being assigned to the Wheat Research Project, Dr. Bolton was a member of the OSU-AID-supported team studying summer fallow. He now has a series of tillage experiments consisting of six experiments at three locations. Plans have been made to expand this work to more locations and to begin a comprehensive series of experiments studying other aspects of wheat management. The tillage research is a joint effort by the OSU-AID team, Topraksu, and the Wheat Research Project.

Plant Pathology
During the 1970-71 wheat season a mobile disease survey and a series of disease trap nurseries was established with the help of Dr. J. M. Prescott and Dr. E. E. Saari, both then stationed at India. In 1971-72 the disease survey was expanded greatly with the full cooperation and assistance of the Plant Protection General Directorate. The trap nursery program was also expanded and a regional cooperative trap nursery was established. The pathologists have been very successful in creating disease epidemics in the breeding nurseries to aid the breeders in selecting for disease resistance. Additional greenhouse facilities are under construction and an adequate pathology laboratory is being equipped.

Cereal Quality
Just recently Mr. Ergin Ünver returned to the project after having completed the M.S. degree in cereal technology at North Dakota State University. He also spent about one month working with the personnel of wheat quality laboratory at CIMMYT. He will now begin to set up the quality laboratory in Ankara which will provide service for the entire wheat project. Hopefully, the first quality tests will be made on the 1971-72 harvest beginning this fall.

GERM PLASM AND FUTURE WHEAT IMPROVEMENT

by

J. C. Craddock
United States

The introduction of plant materials into a country for testing as new varieties of cultivated crops, as new crops, or for use as parental material is as old as man's migrations on the earth. The U. S. Department of Agriculture in 1897 provided for systematic introduction of plant materials into the United States by establishing the Office for Seed and Plant Introduction. Under the Research and Marketing Act of 1946 funds were allocated for the specific purpose of maintaining a collection of small grain cereal germ plasm. Since 1946, using these and other funds, the USDA has built and maintained a germ plasm collection of *Aegilops*, *Avena*, *Hordeum*, *Secale*, and *Triticum*. This collection was assembled by combining seed stocks obtained through the Plant Introduction Program, and the seed samples of domestic varieties and selections maintained as separate collections by the Wheat, Oats, and Barley Investigations of the Cereal Crops Research Branch. Through regular funds a rice collection was maintained and it has now reached a number in excess of 10,000 items. All accessions in the collection are open stock and are available upon request to any research worker - public, private, domestic and foreign. Restricting the distribution of seed defeats the purpose of a germ plasm collection.

Large collections are expensive to maintain. There is little justification for establishing a working germ plasm collection unless provision is made for long term funding. The true value of a germ plasm collection is measured by how well it serves the plant breeders in providing the viable plant materials they need. Dead seed is of no value to the plant breeder.

The number of entries in the Small Grains Collection has increased nearly four-fold since 1946. There are now more than 57,000 accessions in the collection: 51 percent *Triticum*, 26 percent *Hordeum*, 21 percent *Avena*, one percent *Secale*, and less than one percent *Aegilops*. Although this is a large collection composed of germ plasm from most parts of the world it represents only a small random sampling of the distinct and potentially useful genotypes that remain to be collected. We must be aware that future needs will demand a much larger collection. The primary purposes of germ plasm collections are (1) to conserve as wide a range of genetic diversity as possible from throughout the world, (2) maintain and distribute living plants, seeds in the case of cereals, to plantsmen, and (3) document the phenotypic, genotypic and economic characters of the accessions.

A germ plasm collection should contain indigenous plant types, native cultivars, and synthetic cultivars from all regions where a genus is indigenous or is cultivated. Collecting and maintaining seed of all genotypes of the small grain cereals is not feasible and probably is not necessary. The genetic diversity needed for developing varieties for a wide range of environments and with resistance to a wide range of insect and disease pests cannot be predicted. So we must err on the side of collecting too much rather than too little from disappearing germ plasm sources. No longer can we depend upon wilderness areas and regions where primitive types of agriculture are practiced to be natural storage reservoirs of germ plasm. In the past we went repeatedly to such areas for the genetic variability needed to solve specific problems faced by our plant breeders. The world wide trend in agriculture is to replace the multitude of heterogeneous native varieties with a few highly uniform modern varieties. This practice is not only rapidly narrowing the genetic base of cultivated crops but is also eroding the source of new genetic variability.

What we must resolve is how to preserve the maximum amount of genetic variability with the minimum number of accessions. Duplicate samples are sure to be collected and many probably will not be detected. There are several methods for handling suspected duplicates: (1) add them to the collection as new entries, (2) bulk with existing samples, and (3) discard. In most cases the duplicate is added to the Small Grains Collection as it is very difficult to identify them. If the decision is to bulk, it is so noted in the records. Some duplicates are discarded but these are generally named varieties that can be positively identified. Regardless of the disposition of a suspected duplicate, a seed sample and the original seed packet is saved for reference. Our policy is to be very conservative when discarding. Once a sample has been assigned an accession number the seed stocks are never willfully discarded. There is a positive value in preserving duplicate samples as the probability of losing both entries is greatly reduced.

Rather than maintaining a collection of individual entries should we consider a collection composed of populations? Entries could be bulked according to their phenotypic similarities. Such a scheme would permit the preservation of an unlimited amount of genetic variability. The number of entries in the collection could be varied from one large composite sample to an infinite number of smaller composites or accessions. Bulks can be created manually by mixing seed from each accession or genetically by using male sterile plants. Such bulks are already being maintained for the barley collection. Another example is the 'World Gene Bank' for wheat, oats, and barley. These gene banks were created by bulking according to growth habit seeds from F_1 and F_2 plants.

In view of the rapid disappearance of gene reservoirs in nature, it is prudent to collect as much material as possible and for the immediate hold it under good storage conditions. These samples could be accessioned and added to the working collections as resources permit.

Now is the time to initiate a systematic approach to the collecting of germ plasm instead of the random sampling of the past. Any systematic approach should be designed to minimize the number of duplicates and assure a better sampling of the variability of plant types in an area. I am not sure how this can be accomplished but am optimistic that a workable procedure can be devised. I want to emphasize the need to coordinate the planning of such organizations as FAO, CIMMYT, Lenningrad, Izmir, USDA and its PL480 projects, and etc., for collecting germ plasm. It is a waste for more than one organization to collect the same kind of materials in the same geographic regions at the same time. Much duplication of effort and germ plasm could be eliminated with proper organization. However, this will only be profitable if each organization will exchange material freely with all others.

It must be understood that for the foreseeable future the USDA Small Grains Collection will be composed of accessions intended for use as parental materials and will usually lack the documentation of genetic constitution that our so-called genetic stocks have. The only requirement placed upon accessioning entries into the collection is that they be open stock and not require reselecting each generation to maintain their identity. Collecting and documentation are both important but time-wise their priorities are very different. Living materials must be collected when available. Documentation may be delayed until resources are available. The history of an accession rarely reveals the value of its germ plasm at the time of introduction. Varieties of the future may require many characters that are not considered important today. For the present, documentation of the USDA Collection is being limited to cataloging and describing characters most frequently requested by plant breeders. How to minimize documentation and still provide the plant breeder with a meaningful description of the entry is a real problem. The objective of our system is to describe each character with the least number of classes or use the actual data whenever possible. This system is not intended to provide the detailed taxonomic information needed for botanical and varietal classification. It should be clearly understood that as soon as a world-wide system for documentation is implemented the Small Grains Collection will adopt the coding of those portions of the system that are pertinent to the objectives of the Collection.

There is considerably more to the maintenance of a germ plasm collection than the periodic renewal of seed stocks. Cataloging an entry begins with assigning a permanent number to the entry. This number is used to identify the entry in the seed storage and in the automated data processing system. There are two series of numbers: the Plant Introduction (P.I.) numbers assigned by the New Crops Research Branch to materials received from foreign sources and the Cereal Investigation (C.I.) numbers assigned to materials of domestic origin. A master record is prepared on each accession. This record includes the identification number (C.I. or P.I.), varietal designation, seed source and origin, genus, species, and any additional information that accompanies the original sample. This record serves two functions: an intro-office file cross-indexed by varietal designation and identification number, and provides the information to be fed into the data processing system.

The original seed packet and a seed sample of each new entry are preserved for reference. The remainder of the sample is identified by number, then processed for seed increase. The size of the sample determines whether it is sown in the greenhouse or field. All new introductions are grown in detention or partial quarantine where the plants are checked for mixtures and diseases. Diseased plants are rogued and destroyed. Field notes are taken describing the entry for chaff color; length, type and color of awns; straw color, type of spike, pubescence, plant height, and any obvious unique character. Herbarium specimens (spikes or panicles) are taken from each accession. If the population is uniform the samples are taken at random; if mixed, a sample of each component is taken. Out of the first seed increase of a new accession reserve samples are taken. Two samples of 5-10 grams each are sent to the National Seed Storage Laboratory, Fort Collins, Colorado, for long-term storage as a precautionary measure; another 25-30 gram sample is taken to be used only for seed inventory renewal. The change of gene frequencies in a population may be very rapid when plants are grown in a new environment. In a germ plasm collection some changes in gene frequencies are unavoidable but acceptable provided the unique genes are not eliminated from the population. The sample taken for seed inventory renewal is the precaution used to minimize the effect of selection pressures on entries in the Small Grains Collection. This system minimizes genetic change and the accumulation of mechanical mixtures that may occur during seed increase.

The automated data system used in the Small Grains Collection was designed by the Data Application Service of the U. S. Department of Agriculture. This system utilizes the standard 80 column punch card and a form based on the mark sensing principle. The use of the form permits on-sight documentation without the aid of a key punch machine. The completed forms are forwarded directly to the computer laboratory for processing.

Many of the countries represented here now are maintaining collections of various sizes. If we can all work together at least when collecting and distributing seed stocks each will profit. If all collections are completely open stock and shared by everyone, it will not be necessary for each country to maintain a collection that more or less duplicates a collection of the wheats maintained by another country. Each country could maintain as large a collection as its resources permit, yet still have access to the germ plasm in all other collections. Such a system requires the complete cooperation of everyone. Each breeder has to know he can get seed from any collection when it is needed.

The seed stocks that you willingly contributed have made the USDA Small Grains Collection what it is today. None of the basic germ plasm is indigenous to the western hemisphere, it all originally came from your countries.

Will all the people now and in the future be fed as we contemplate? Will the next disease crisis be met? Only if we have the germ plasm readily available to meet the need.

THE INTERNATIONAL WINTER WHEAT PERFORMANCE NURSERY ESTABLISHMENT AND EXPECTATIONS

by

V. A. Johnson
United States

Research on wheat protein improvement has been conducted at the University of Nebraska since 1954. The research is cooperative between the Agricultural Research Service, U. S. Department of Agriculture, and the Agronomy Department, University of Nebraska. Contract funds from the Agency for International Development, U. S. Department of State, have partially supported the research since 1966. The International Winter Wheat Performance Nursery (IWWPN) was developed as a part of the AID-funded Nebraska protein research effort.

An objective of the contract research is to identify and transfer to agronomically-acceptable varieties in developing countries, genes for high protein and high lysine. Genes that promote high grain protein have been identified and transferred to productive winter wheat experimental lines adapted to Nebraska. The usefulness of such varieties in developing countries would be questionable. Productive winter varieties best suited to conditions in developing countries, to serve as recipient genotypes for protein and lysine genes were largely unknown. An important objective of the IWWPN, therefore, is the early identification of productive varieties with broad adaptation. We believe these varieties would have the greatest potential value in developing countries as recipient genotypes for protein and lysine genes. Results from the 1st and 2nd IWWPN's identify Bezostaia 1 as such a variety.

Local experimentation in Nebraska indicated that the high protein trait derived from Atlas 66 was relatively stable in the various production environments of Nebraska. Nothing was known of its stability in an international array of winter wheat production environments. Therefore, a second important objective of the IWWPN has been to assess the stability of the high protein trait in the widely different environments sampled by the nursery. Early results indicate that the phenotypic expression of the Atlas high protein genes is excellent and that these genes can be effectively utilized to increase the protein content of winter wheat in developing countries.

The effect of environment on the lysine content of wheat protein is not known. Seed samples from harvested plots at each nursery site which are returned to our laboratory by cooperators have permitted measurements of the direct effect of environment on lysine as well as the indirect effect via its effect on level of protein.

The IWWPN was organized by the ARS-Nebraska team in 1968. The first nursery was grown in 1969 at 23 sites in 16 countries. The number of tests has increased to 44 in 27 countries in 1972 (fig. 1). Additional sites are anticipated in 1973. Aside from its importance to the objectives of the AID-supported Nebraska-ARS protein research program, the nursery provides a useful vehicle for early evaluation of diverse new varieties in developed and developing countries. The performance data generated by the nursery should permit sound judgements to be made on the recommendation and registration of useful new varieties in the developing countries

4TH INTERNATIONAL WINTER WHEAT PERFORMANCE NURSERY
44 SITES; 27 COUNTRIES

Figure 1.

INTERNATIONAL WINTER WHEAT PERFORMANCE NURSERY (IWWPN)

NURSERY MANAGEMENT

by

J. E. Stroike
United States

Seed increase and distribution for the IWWPN is an increasingly time-consuming task. The International Winter Wheat Performance Nursery, grown at 23 sites in 16 countries in 1969, has increased in size to 44 sites in 27 countries in 1972.

In 1969, the nursery was comprised of 30 varieties grown in a randomized complete block design with four replications. The seeding rate was 80 kg/ha at all sites. Uniform packaging of seed was possible with the same amount of seed in all seed packets. The 23 sites required 16,560 packets of seed. Seed was packaged for individual rows. In 1970, nursery seed was provided to cooperators in the approximate quantity requested by them. This allowed each cooperator to plant according to his basic plot size at seeding rates comparable to his own nurseries. For the 44 sites, 18,870 packets of seed were packaged and distributed. The number of packages did not increase greatly over 1969 because some sites requested seed by replications or by entries. The increase in number of different sizes of packets and amounts of seed per packet were the cause of problems in seed distribution. The large amount of seed requested by many sites also caused difficulty due to air-mail weight limitations that required packaging of seed in more than one carton.

The need for more uniformity in seed packaging and distribution among nursery sites is important. Increasing efficiency during this operation is essential and the reduction in packaging and shipping errors is very important. Can we make nurseries more uniform and still conduct meaningful experiments at all sites? This will be pursued at this conference.

Communications must be maintained between the Lincoln staff and nursery cooperators during shipment of planting seed. Each cooperator will be informed of a shipment to them, and we ask that acknowledgement of its arrival be sent to us. This will eliminate many questions and problems.

Candidate varieties and experimental lines are available for inclusion in the nursery. An arbitrary limit of 30 varieties in the nursery has been made. Our plan for replacing varieties is as follows:

Nursery	Total no. of varieties	Check [1/] varieties	No. varieties retained	No. varieties replaced
1969	30	4	--	--
1970	30	4	26	--
1971	30	4	13	13
1972	30	4	13	13
1973	30	4	26	0

[1/] Bezostaia 1, Blueboy, Atlas 66, Lerma Rojo 64

A variety may be grown for 3 years in the nursery. Candidate varieties will be grown in a preliminary nursery for general observation and seed increase before being admitted to the IWWPN. The preliminary nursery will be discussed in another paper during the conference.

Instructions for nursery management and data records are provided to nursery cooperators. These are intended to standardize the nursery as much as possible. Deviations from our instructions are expected, but we ask that you explain how you have made them. Indicate the unit of measurement used for data records and relate them to the requested measurements, if they differ.

The first page of each field book is for notes of general nursery management. Record this information as completely and concisely as possible. This is necessary for accurate data interpretation. This type of information many times is not subject to interpretation and must be published as we receive it. We have attempted to report fertilizer information as amount of elements applied. Therefore, if ammonium phosphate is used, record the percentage of each element in such a compound. If irrigation is used, record the amount of water applied and the dates of applications. These are only a few examples of how information of this type can be very helpful in the interpretation of the data received.

One of the most important notes to be recorded is the harvested area for yield. Record this in square meters or in units readily converted to square meters.

To date we have requested test weight of seed. We are now considering the use of 1000 kernel weight instead. The value of test weight is questionable in a nursery of this type. Thousand kernel weights are more closely related to seed size than test weights. Therefore, I wish to propose this change at this time and ask for discussion from you during this conference.

Seed samples from harvested plots are shipped from each nursery site to Lincoln for protein and other laboratory analyses. Prompt shipment is requested. Much time is required for these analyses and the earlier we receive the samples, the sooner we can issue a report. If insect control is necessary, fumigation is desirable. Dusts or slurries should not be used because these cause problems in laboratory analyses. Whatever control is applied, please inform us of it. Prompt shipment of seed immediately after harvest will also reduce the chances of insect infestation.

We accept an important responsibility of keeping nursery cooperators informed of the results from all nursery sites as early as possible. We have attempted to distribute a preliminary report for each year at the earliest possible date, and a more complete summary of data on an annual basis. The main reports will be published as Nebraska Research Bulletins. Further analyses must be and will be done as time allows for more precise evaluation and interpretation. These will also be published as Nebraska Research Bulletins.

CANDIDATE VARIETIES FOR THE IWWPN

by

J. W. Schmidt, V. A. Johnson, and J. E. Stroike
United States

The purposes of the International Winter Wheat Performance Nursery, as stated in the first report, are to:

1. Test the adaptation of winter wheat varieties under a range of latitudes, daylengths, fertility conditions, water management, and disease complexes.

2. Identify superior winter varieties to serve as recipient genotypes for high protein and high lysine genes.

3. Test the degree of expression and stability of the high protein and high lysine traits in an array of environments.

These purposes are achieved best by continued testing with new products from the various winter wheat projects of the world. Therefore, candidate varieties are and will be solicited for future testing.

In accordance with the stated purposes of this nursery, three types of candidate varieties are especially desired. These are:

1. New commercial or promising experimental varieties with desirable combinations of high yield potential, acceptable winterhardiness, straw strength, disease and insect resistance, and protein quality and quantity.

2. Lines with improved nutritional value from higher protein quantity and/or quality even though deficient in some of the traits listed above.

3. Germplasm lines with especially valuable traits useful in breeding programs.

One kilogram of clean seed of candidate varieties is needed for seed increase. The variety name and pedigree should be furnished along with a description, including special merits, of the variety.

All candidate varieties will be seeded for increase at Yuma, Arizona, U.S.A. If a considerable number of candidate varieties is received, these varieties will be planted from the Arizona-grown seed in a preliminary screening nursery at a number of locations. In 1972, such a nursery is being grown at Ankara, Turkey; Fundulea, Romania; Cambridge, England; Lincoln, Nebraska, U.S.A.; and Yuma, Arizona, U.S.A. From this nursery, varieties will be selected for inclusion in the IWWPN as they can be accommodated.

INTERNATIONAL WINTER WHEAT PERFORMANCE NURSERY DATA INTERPRETATION

by

J. E. Stroike and V. A. Johnson
United States

The International Winter Wheat Performance Nursery (IWWPN) is designed to study the performance of winter wheat cultivars and experimental lines from major winter wheat producing areas of the world and to identify superior genotypes for use in breeding wheats with improved nutritional quality. The nursery will also provide valuable information on the adaptation characteristics of winter wheat.

Reports published for the first and second IWWPNs provide means and tests for significant varietal differences of various agronomic and grain quality traits (5,6). Variety comparisons can be made within each location or across many locations in 1969 and 1970. Stability of variety performance or adaptation may be observed from such data, but statistical techniques are now available to achieve more precise measurements.

Yates and Cochran (7) proposed that the regression of variety mean yield on the mean yield of all varieties in an environment would provide a parameter for characterization of the stability of hybrids. Finlay and Wilkinson (2) utilized this technique to compare the performance of a set of varieties grown at many sites for several seasons. The mean yield of all varieties at each site and for each season provided a numerical grading of environment over sites and season.

Eberhart and Russell (1) proposed that the regression of each variety on an environmental index and a function of the squared deviations from this regression would provide useful estimates of cultivar stability parameters. The index is primarily a coded deviation of each environment from the grand mean over all environments. This forces the regression of the mean of cultivars on the environmental index to have unit slope ($\beta_1 = 1.0$). They defined a desirable cultivar as one with a high mean yield, unit regression coefficient, and deviation from regression as small as possible. A similar technique was utilized to help interpret data received from the first and second IWWPN's grown in 1969 and 1970.

The IWWPN provides a unique opportunity to study agronomic and grain quality performance of varieties grown over an international array of environments. Major wheat-producing areas of the world, except Australia, Canada, China, and the U.S.S.R., were represented in the 1969 and 1970 nurseries.

Three stability parameters were calculated for each variety grown in each year and for varietal data combined over the years. Each parameter provided measurement of a different aspect of variety performance. All three are needed to fully describe a variety's performance potential.

Regression analyses provide two parameters, the regression coefficient and deviation mean square, which are useful as predicative measurements of variety.

performance. The regression coefficient measures the sensitivity of a variety to changing environments. The deviation mean square provides evidence of the consistency or repeatability of performance. The third parameter, the mean, is indicative of the average performance level a variety can be expected to maintain if grown again in a similar range of environments. This level of performance is important for interpretation of the other two parameters. Many different combinations of the three stability parameters are possible and each requires somewhat different interpretation.

A variety may exhibit high mean performance and a high regression coefficient with a low deviation mean square. Such a variety could be described as productive, strongly responsive to changes in environment, and with highly predictable performance in specified environments. A variety with low average performance, low regression coefficient, and high deviation mean square could be described as non-productive, with a weak response to changes in environment, and non-predictable in performance if grown in similar environments again. It would exhibit random performance variations unassociated with either of the other two parameters. Scout 66 and Benhur grown in 1970 are examples of these two classifications (Figure 1).

Stability parameters for most traits measured in this study indicated wide varietal differences. Wide ranges in cultivar means for yield, test weight, plant height, lodging, and grain protein content were detected. Parameters from regression analyses for these traits also differentiated variety performance potential. The mean yield of a Russian variety, Bezostaia, was consistently the highest among the 28 varieties studied. Bezostaia also responded strongly and predictably in yield to changes in environment. Moderately short, lodging resistant straw contributed to its superior performance. Stability parameters for yield of 12 of the 28 winter wheat varieties grown in the IWWPN in 1969 and 1970 are presented in Table 1.

Three varieties with widely different 2-year mean yield stability parameters are illustrated in Figure 2. Bezostaia, with a high mean yield and high regression coefficient, is compared with Odin and Triumph 64. The low regression coefficient of Triumph 64 contrasts with the higher values for Bezostaia and Odin. Further contrast is the large deviation mean square for Odin compared to relatively low values for Bezostaia and Triumph 64.

Plant height and lodging were closely associated. Short varieties lodged less than tall varieties on the average and responded less strongly to changes in environment. Highly consistent mean differences in maturity and in maturity responses to changes in environment were exhibited.

Phenotypic expression of the protein genes possessed by three varieties in this nursery was excellent. The mean protein contents of these varieties were the highest in the nursery and the stability parameters indicate their superiority, also (Table 2).

The influence of grain yield on grain protein content has been reported in the literature (3). High-yielding varieties frequently produce less protein than lower-yielding varieties grown in the same environment. The influence of differential yield on protein content can be minimized by restricting comparisons to groups of varieties with comparable yields as shown in Table 3.

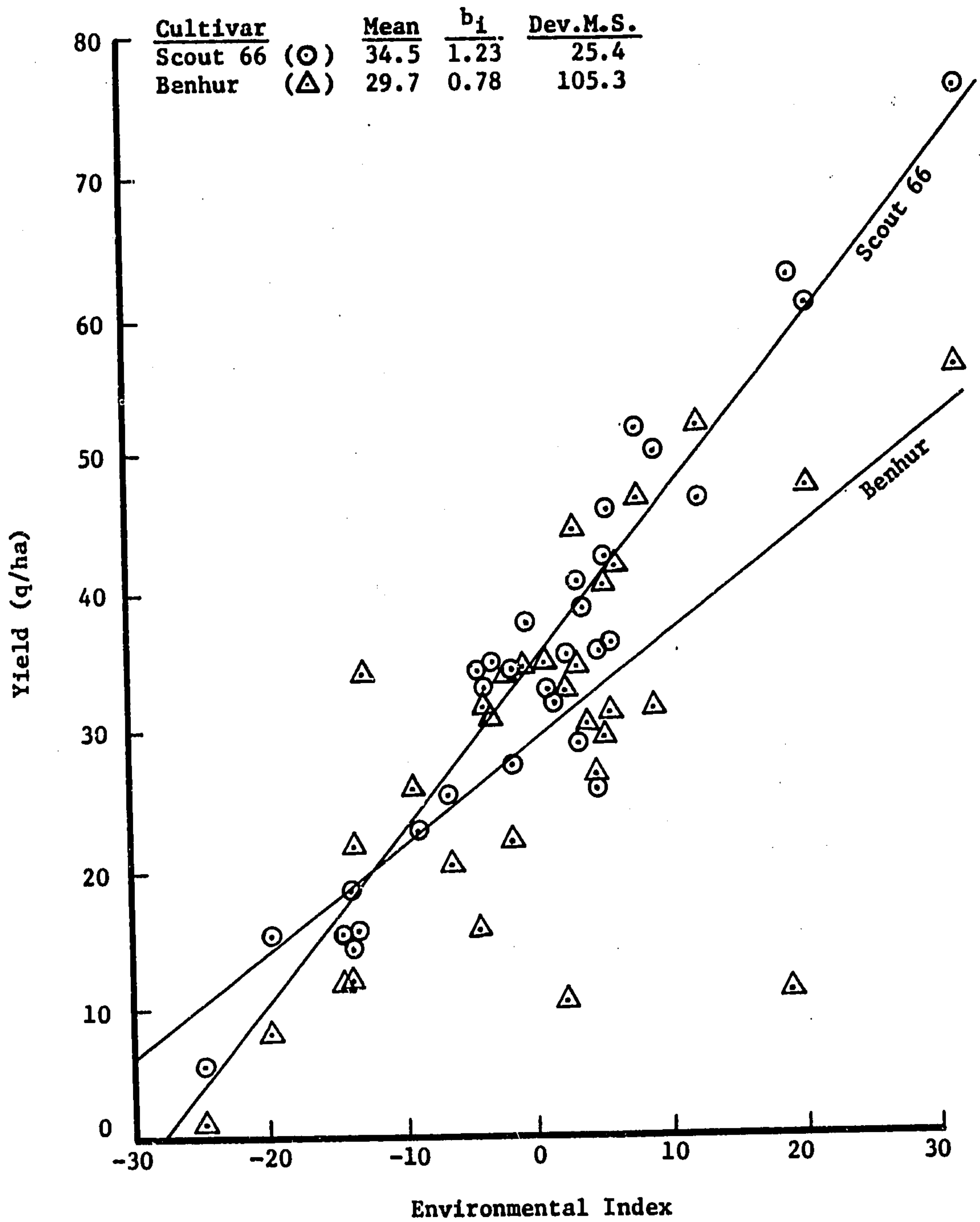

Figure 1. Regression of yield of Scout 66 and Benhur on environmental indices of the International Winter Wheat Performance Nursery grown at 31 sites in 1970.

1/ Table 1. Stability parameters for yield of 12 winter wheat cultivars grown in the International Winter Wheat Performance Nursery in 1969 and 1970.

Cultivar	Mean (q/ha)			Regression coefficient			Deviation mean square		
	1969	1970	1969-1970	1969	1970	1969-1970	1969	1970	1969-1970
No. of sites	16	31	15	16	31	15	16	31	15
Bezostaia	45.1	39.5	43.7	1.21	1.03	1.21	37.5	57.6	33.7
Timwin	39.9	35.4	39.2	1.05	1.15	1.16	24.0	67.9	14.1
Arthur	38.0	33.7	38.6	0.83	1.25	0.96	58.2	64.8	43.3
Sturdy	40.5	32.2	38.5	1.04	1.01	0.92	19.6	46.2	17.3
Parker	39.7	32.7	38.3	0.99	1.11	0.98	15.4	51.8	14.0
Scout 66	38.3	34.5	38.1	0.82	1.23	1.00	49.8	25.4	12.2
San Pastore	41.0	26.7	35.9	0.98	0.99	0.75	28.3	123.8	39.2
Triumph 64	35.5	29.8	34.6	0.64	0.81	0.67	44.6	51.9	25.7
NB67730	34.8	28.1	33.3	0.92	1.02	0.90	22.7	27.7	18.6
Atlas 66	33.4	28.8	32.2	0.89	1.01	0.98	40.4	53.2	27.0
Cappelle Desprez	32.5	25.8	29.1	1.18	0.88	1.05	48.9	67.6	39.2
Odin	26.7	21.5	24.3	1.18	0.84	1.23	153.2	136.8	122.7

1/ From Nebraska Agr. Exp. Sta. Bull. 251, 1972 (8)

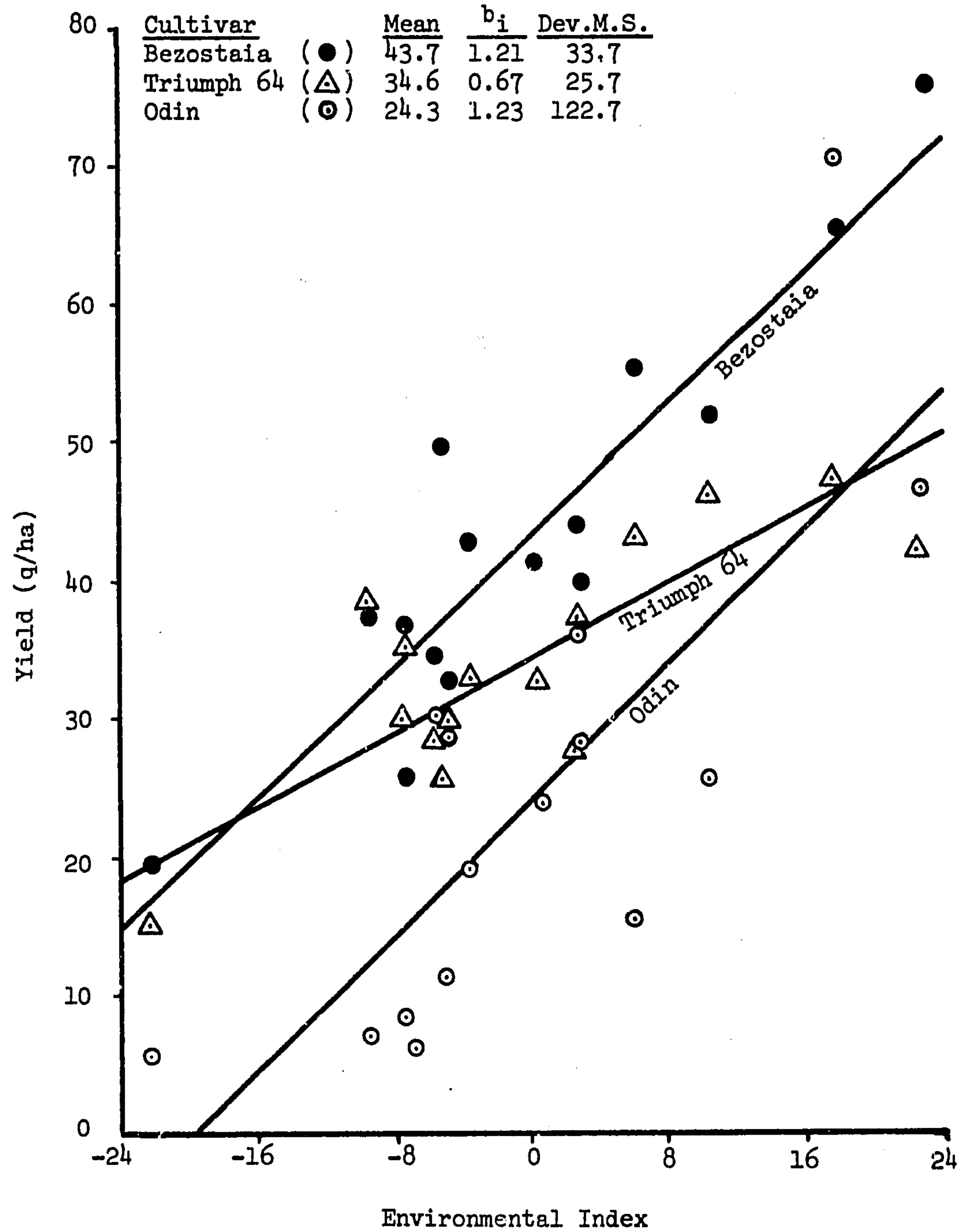

Figure 2. Regression of 2-year mean yields of three cultivars on environmental indices of the International Winter Wheat Performance Nursery grown in 1969 and 1970 (from Nebr. Agr. Expt. Sta. Res. Bul. 251, 1972 (8)).

1/ Table 2. Stability parameters for grain protein content of 12 winter wheat cultivars grown in the International Winter Wheat Performance Nursery in 1969 and 1970.

Cultivar	Mean (%)			Regression coefficient			Deviation mean square		
	1969	1970	1969-1970	1969	1970	1969-1970	1969	1970	1969-1970
No. of sites	11	23	10	11	23	10	11	23	10
Atlas 66	17.0	18.3	17.7	1.12	0.90	0.61	0.57	1.15	0.78
Purdue 28-2-1 2/	16.3	18.4	17.3	1.07	1.22	1.21	0.70	2.90	1.19
NB67730	16.1	17.3	16.6	1.20	1.11	0.98	1.18	1.08	0.67
Cappelle Desprez	15.2	15.9	15.9	1.02	1.01	0.87	2.21	2.07	1.87
Triumph 64	14.8	15.7	15.5	0.61	0.82	0.65	1.34	1.14	0.62
Bankuti 1201	14.9	15.8	15.4	0.89	0.90	0.89	0.43	0.58	0.37
Sturdy	14.1	15.2	14.8	1.18	0.73	0.51	0.58	0.70	0.44
Parker	14.1	15.1	14.6	1.04	1.00	0.95	0.17	0.90	0.39
San Pastore	13.1	14.5	13.9	0.70	1.21	0.85	1.64	1.20	1.15
Bezostaia	13.2	14.2	13.8	0.55	0.88	0.77	0.32	0.45	0.22
Gaines	12.3	13.7	13.2	1.05	1.08	1.38	0.43	1.80	0.68
Yorkstar	11.8	13.1	12.6	1.17	0.98	1.47	0.88	1.48	0.80

1/ From Nebraska Agr. Exp. Sta. Res. Bull. 251, 1972 (8)

2/ Purdue 4930A6-28-2-1

1/ Table 3. Comparison of grain protein of 12 cultivars with comparable yield levels grown in the International Winter Wheat Performance Nursery in 1969 and 1970.

Cultivar	Grain yield (q/ha)	Grain protein (%)
No. of sites	15	10
Bezostaia	43.7	13.8
Timwin	39.2	14.3
Arthur	38.6	14.6
Sturdy	38.5	14.8
Parker	38.3	14.6
Scout 66	38.1	14.7
Heine VII	34.2	14.6
NB67730	33.3	16.6
Bankuti 1201	33.2	15.4
Atlas 66	32.2	17.7
Purdue 4930A6-28-2-1	31.8	17.3
Cappelle Desprez	29.1	15.9

1/ From Nebraska Agr. Exp. Sta. Res. Bull. 251, 1972 (8)

The inverse relationship between protein and lysine content expressed as a percent of protein first reported by McElroy (4) also existed in the IWWPN varieties grown. Yorkstar, Gaines, and Stadler, with the lowest grain protein, were the highest in lysine content. Conversely, the high protein varieties, Atlas 66, Purdue 4930A6-28-2-1, and NB67730, produced protein with the lowest lysine content (Table 4).

Table 4. Comparison of grain protein with lysine content in six cultivars grown in the International Winter Wheat Performance Nursery in 1969 and 1970.[1/]

Cultivar	Protein	Lysine
	(%)	(% of protein)
Yorkstar	12.6	3.12
Gaines	13.2	3.07
San Pastore	13.9	2.92
Bezostaia	13.8	2.87
Cappelle Desprez	15.9	2.78
Atlas 66	17.7	2.69

[1/] From Nebraska Agr. Exp. Sta. Res. Bull. 251, 1972 (8)

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SOIL ANALYSES--ARE THEY NEEDED FOR NURSERY DATA INTERPRETATION?

by

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United States

Introduction

Demonstrations and trials of fertilizer use on farmers' fields can be quite sufficient to give a general picture of nutrient needs in an area new to fertilizer use, especially in the less exotic soil regions of the world where N, P, and/or K is/are the likely deficient nutrient(s). With refinements in production capabilities, however, including the introduction of modern, high-yielding varieties in place of traditional varieties, and especially as differential management results in nutrient buildup in some soils and not in others, soil analyses become increasingly essential. Not only are they useful for predicting nutrient deficiency and the most economic rates of fertilizer application for profit, but they can forecast the imminence of excessive buildup of a certain element that may be capable of inducing the deficiency of a competitive nutrient if not of generating a toxic condition. Eventually, with widespread and intensive fertilizer use, they become indispensable for assuring that applied nutrients do not become environmental pollutants.

With the advent of inexpensive inorganic fertilizers since 1945, it has become very apparent that plant breeding efforts must be directed toward optimum fertility conditions. The great success of the CIMMYT and IRRI programs has come about through recognition of the need for integrating the additional factors of effective water management, pest control, and appropriate fertility treatment for validating the 'miracle' varieties (1).

Nutrient Role in Wheat Production

Yield Effects. Availability of plant nutrients plays a determinate role on the yield and quality of wheat wherever produced. A recent world-wide trend of increasing average annual yield is apparent as agricultural statistics are studied, a growth heavily hinged to increasing fertilizer consumption (2). It is not the fundamental purpose of this paper to focus on response of wheat to fertilizers *per se*, since this has been the topic of previous presentations (5, 11). Certainly, we cannot overstress the need for adequately supplying the thirteen known essential nutrients normally absorbed through the root system by the crop. Limitation of any one of these will be yield inhibitive until correction of that deficiency has been accomplished. Thereafter, with adequate genetic and climatic potential, the next most limiting nutrient will represent the yield barrier, as was detailed by Liebig in his Law of the Minimum.

Although N, P, and K are the nutrients most extensively deficient for optimum production, certain soils in most of the countries here represented are deficient in Ca, Mg or S. Note in Table 1 that a maximum expression of yield and protein content of wheat with a nominal rate of N application was obtained only as the

Sharpsburg soil with plentiful available P and pH 5.6 had been limed in this 3-year study. The Ca and Mg base limitation with possible Al and Mn toxicity will become more and more evident in noncalcareous soils with increasing use of fertilizer N as time passes. Sulfur limitation becomes increasingly probable the more humid the climatic environment and may exist in subhumid regions with soils of low clay and organic matter contents.

There is increasing recent evidence as well of local deficiencies in one or more of the elements Fe, Zn, Mn, Cu, B and Mo. These shortages have been accentuated by the introduction of improved varieties with greater yield potentials and by the decreasing dependence on animal manures as the sole fertilizer treatment by substitution of high analysis inorganic fertilizers.

Accepted that adequate nutrients are essential to efficient wheat production, it is almost equally mandatory that there be no appreciable excess in nutrient availability. Care must be exercised in the use of most of the trace elements as fertilizer by reason of toxicity potentials. Perhaps most problems in respect of excess, however, have been experienced with N. An overabundance of N will commonly cause excessive vegetative growth in most conventional wheat varieties of the drier regions with resulting tall, weak-stemmed plants that readily lodge. Excepted are some of the recently developed varieties with especially short and stiff straw. Too much N will also delay flowering, particularly where P availability is borderline or deficient, which can be deleterious to yield with a short growing season or if severe moisture stress develops.

Real differences are known to exist in the nutrient requirements of different wheat varieties because of varied yield potential and composition. It has also been demonstrated that differential Al toxicity effects exist with different wheat varieties grown on acid soils where the residual acidity is primarily a reflection of exchangeable Al (4). Differences in both respects are great enough that wheat breeders have been encouraged to develop varieties not only responsive to high nutrient availability but also resistant to toxicities that exist in specified soil regions, correction of the latter of which could well be more difficult and expensive than developing a tolerant variety.

Table 1. Yields of wheat and N uptake as influenced by liming and rate of fertilizer N applied on Sharpsburg si.c.l. (pH 5.6), Mead Field Laboratory, Nebraska, 1965-67.

N applied[1]	Grain yield		Protein content		Straw yield		Total N uptake	
	No lime	Lime[2]	No lime	Lime	No lime	Lime	No lime	Lime
kg/ha	kg/ha	kg/ha	%	%	kg/ha	kg/ha	kg/ha	kg/ha
0	2228	2363	11.6	12.6	3319	3341	51	57
Topdressed N after seeding								
28	2633	2835	11.9	12.5	3938	4050	66	73
56	2970	2970	12.8	13.1	4478	4388	81	84
N drilled 2.5 cm to side of seed row								
28	2700	2903	11.8	12.4	4219	4343	65	74
56	2970	3105	12.3	12.9	4680	4725	80	87

1Yield and uptake data are averages obtained with four NP carriers with P levels equalized by CSP.

2Limed plots received 25 tons lime/ha, bringing pH up to 7.5.

Protein Effects. A relatively high protein content has distinguished wheat as one of the higher quality foods traditionally consumed by man. It is a trait that is appreciably influenced by crop yield obtained and by the amount of N available to the crop. With a given variety and location and N limiting, yield and protein content are inversely related due to dilution, as evidenced in Fig. 1. Yields for each of the N treatment levels increased with increasing moisture availability in this experiment (0, 7, 15 and 21 cm irrigation water applied before planting in each of three years) at the expense of protein content of the grain. It is also apparent in Fig. 1 that both grain yield and protein percentage benefited from increased rate of N application.

Not only are protein effects from applied N very much dependent on water available to the crop, but residual N in the soil has a pronounced influence. Nebraska studies during the period 1965-1967 indicated that with high residual NO_3-N sites, non-responsive in respect of yield, the primary effect of applied N was to increase protein content (Fig. 2). With low residual NO_3-N in the 180-cm profile, however, the major effect of applied N was to increase yield with minimal effects on protein within the range of N rates employed. Correspondingly, yield increases from other nutrients usually caused decreases in protein from the dilution of a given quantity of N in the crop imposed by the higher yield.

Earlier papers in this conference have dwelt on the substantial differences in protein that may exist among varieties at a given location. It should be noted additionally that varied levels of applied N as well as other environmental factors can have greater impact on protein content than varietal effects among varieties yielding at a common level. Whereas the difference in average protein content among 19 varieties in 7 field tests of 1971 in Nebraska was only 1.6 percent, averages for all varieties among locations varied from 9.1 to 13.4 percent. Wheat protein thus varied more from location effects than from varietal effects in that year, as has been observed in previous years (9).

Much of the location variability can be explained in terms of moisture availability and fertility. An additional factor, however, is that of air temperature in the period shortly before maturity, with increasing temperature causing a shriveling of grain and consequent increased protein percentage. Where the four factors of NO_3-N in the soil profile to 1.5 m, precipitation during a 15-day period 40-55 days before maturity, available water to 1.5 m at seeding, and maximum air temperature for a 5-day period 15-20 days before maturity were combined in multiple correlation with protein content in a Nebraska-Colorado study, 96 percent of the variability in protein could be accounted for (8).

Response to Residual Fertility. Of utmost significance is the fact that the wheat crop responds to residual fertility as well as currently applied fertilizer nutrients. Recognition of this fact is essential for deriving efficient response to applied nutrient and for controlling potential pollution from fertilizer.

Figure 3 demonstrates the need for evaluating residual mineral N in soil for commercial wheat production as well as nursery plot evaluation of breeding stock. The wheat in this figure produced on continuously cropped land with mean annual rainfall ranging between 58-64 cm, evidenced little or no response to applied N when residual NO_3-N exceeded 90 kg/ha in the 180-cm soil profile. The growth response curve was still decidedly on the upgrade with 67 kg fertilizer N/ha applied for those experiments where residual NO_3-N was less than 45 kg/ha.

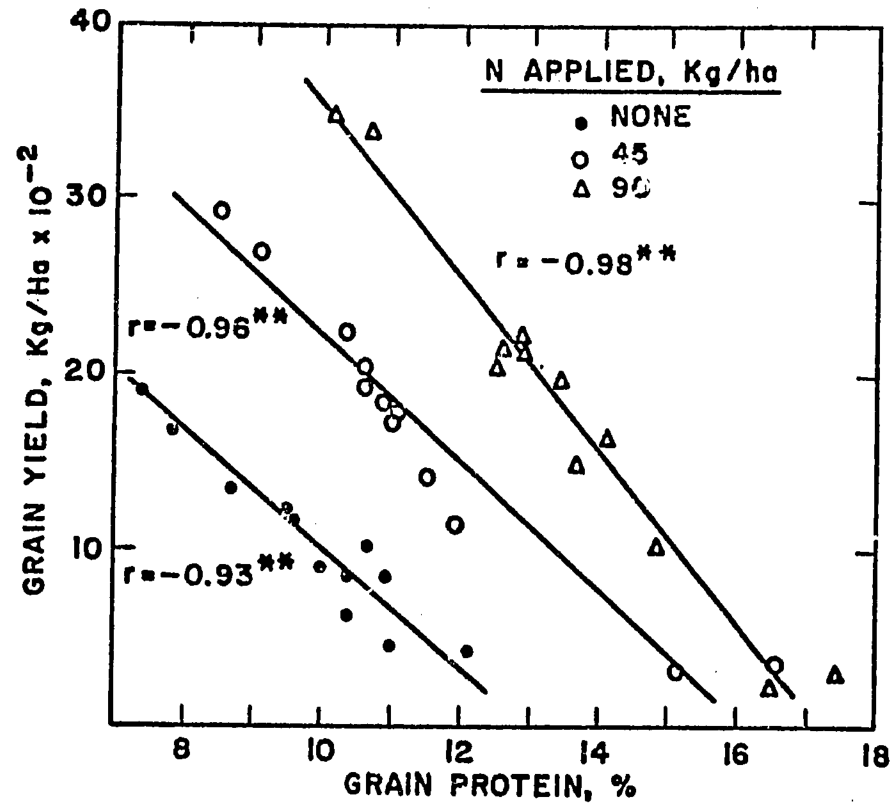

Fig. 1. Relation between grain yield and protein content of Cheyenne hard red winter wheat at North Platte, Nebraska, 1954-56 (9).

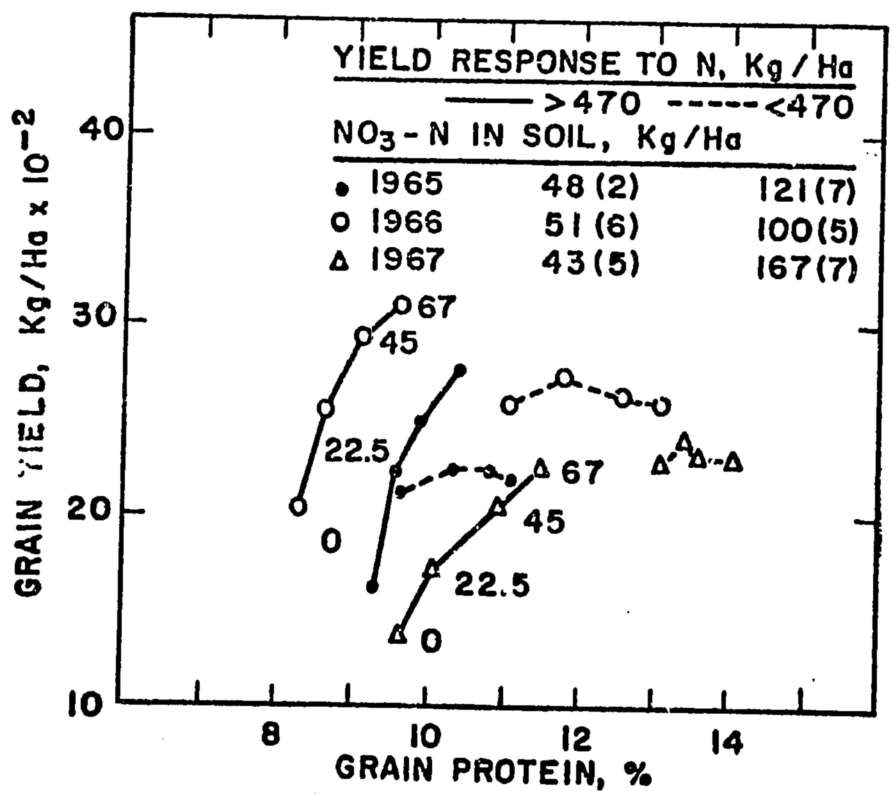

Fig. 2. Relation between grain yield and protein content of winter wheat as influenced by residual NO3-N in the soil and applied N (0, 22.5, 45 and 67 represent rate of applied N) 32 experiments in Nebraska, 1965-67.

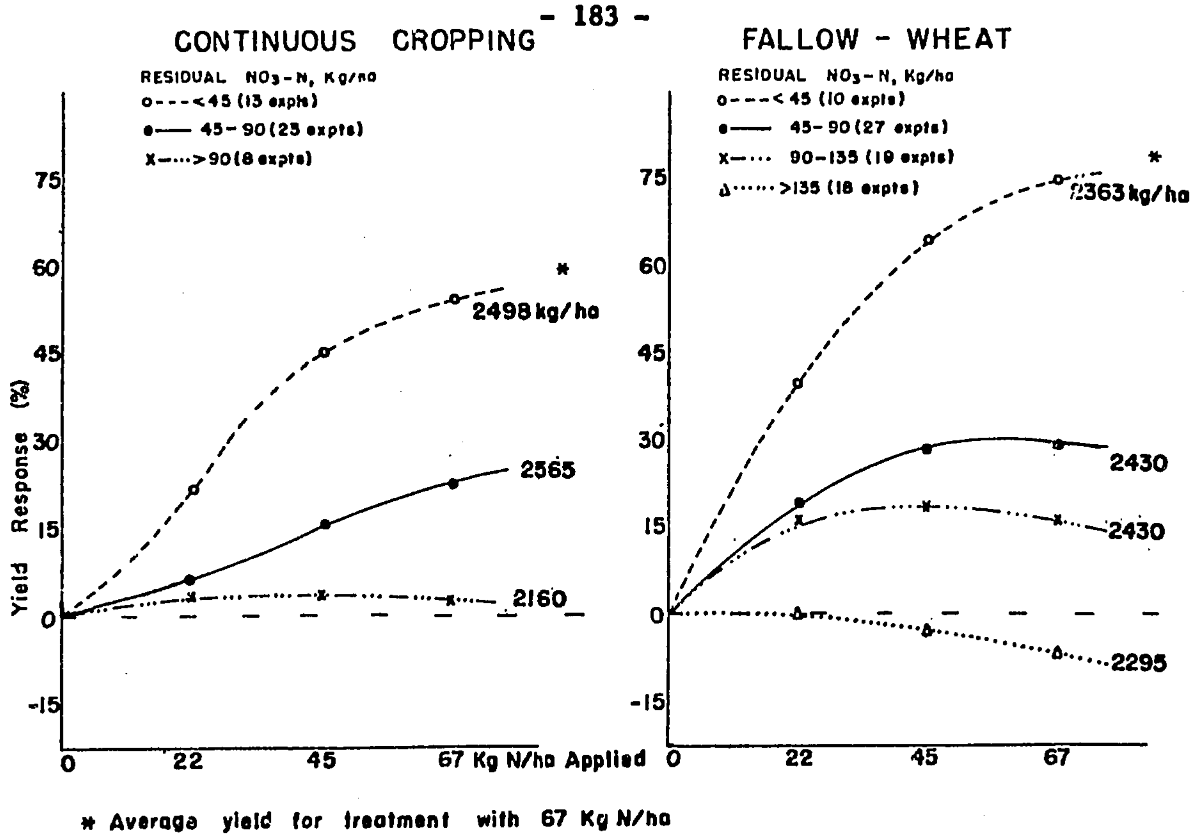

Fig. 3. Yield response of hard red winter wheat to increasing rate of applied N as influenced by residual mineral N in the 180 cm soil profile at planting time in 118 Nebraska field experiments of 1962-68.

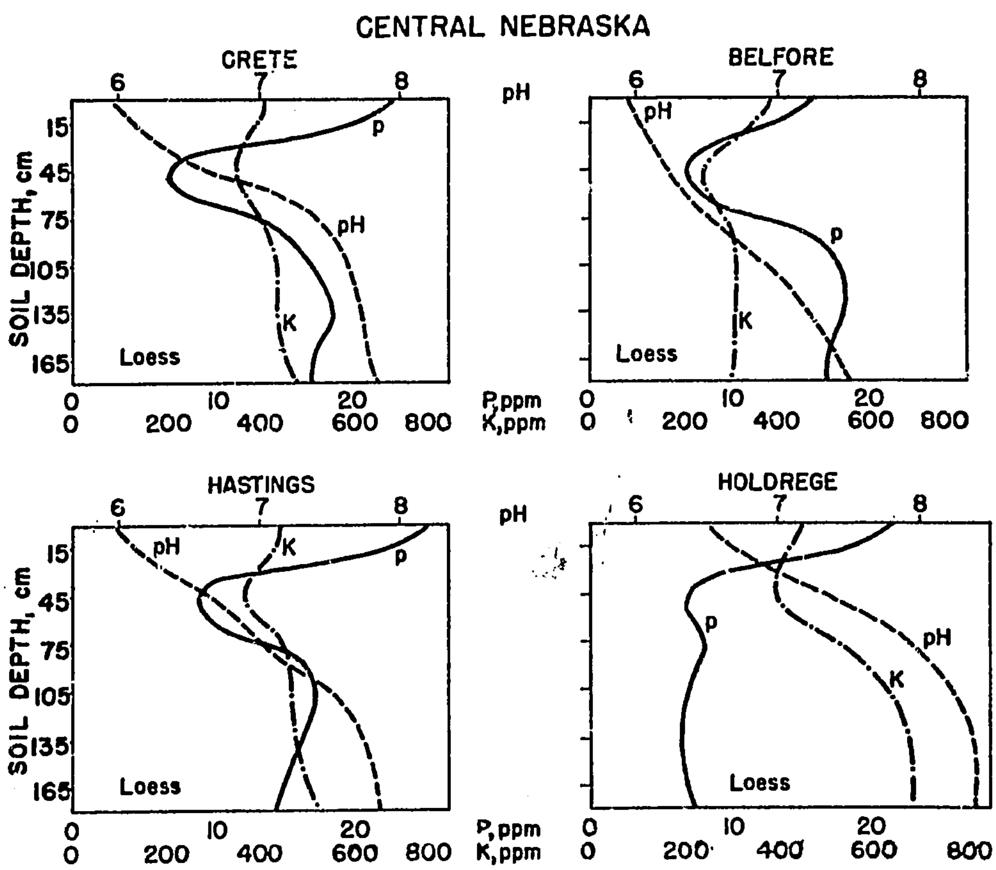

Fig. 4. Soil P (Bray & Kurtz #1), exchangeable K and pH levels of the 180 cm profile of major soils in central Nebraska; mean values determined from several locations of each soil series.

In the case of the fallow-wheat cropping experiments in a region with 40-58 cm annual rainfall, yield response was negative at 45 and 67 kg N/ha application rates when residual NO_3-N exceeded 135 kg/ha. No response occurred above 22 kg N/ha when the residual was between 90-135 kg/ha, whereas the response curve leveled out with the intermediate applied rate when the residual ranged between 45-90 kg/ha. With less than 45 kg N/ha residual, the response curve was still rising steeply at the 67-kg application level. Clearly, it should be a matter of real concern in wheat nurseries to know whether additional N as fertilizer would be required for top performance of the genetic material under evaluation, and alternatively, if added increments were likely to have depressional effects.

Not only do the locations with low residual mineral soil N show maximum response to applied N and conversely, but lower protein levels result across the range of treatments on deficient soil. Nor was the protein level made equivalent with even the highest N treatment of the soil employed in these experiments, suggesting that some modest level of soil residual N must be present for maximum combined yield and protein expression (Table 2). Probable explanation is that declining root activity from the surface downward through the season as moisture is progressively depleted prevents full utilization of even heavy fertilizer treatment from the upper soil horizon in the year of application.

Table 2. Protein content of wheat in response to applied N for experiments of Figure 3.

Soil residual NO_3-N	N applied, kg/ha			
	0	22	45	67
kg/ha	percent			
	Continuous Cropping			
<45	10.6	11.0	11.3	11.8
45-90	11.3	11.7	12.5	12.9
>90	12.0	12.4	12.9	13.2
	Fallow Wheat			
<45	9.0	9.4	10.0	10.8
45-90	9.3	10.1	10.8	11.7
90-135	10.6	11.2	11.8	12.5
>135	11.2	11.8	12.3	12.8

Reliability of Soil Tests

Soil testing methods have been refined to the extent that reliable prediction can be made of nutrient needs for crops grown on most soils. Reliability depends first on the collection of representative samples, thereafter on proper handling, authentic testing methods, and valid interpretation based on a sound correlation and calibration background.

Among the primary elements of plant nutrition, measurement of the plant availability of only soil N has remained largely enigmatic. The data of Table 3 acquired from 119 field experiments during the 1950's indicate that the nitrate production test quite effectively delineated between response and non-response situations. It is an adequate test for situations where the wheat crop is largely dependent on N mineralized from the surface soil's organic matter supply. By 1960, however, it became evident that another nutrient N source would have to be considered in Nebraska, viz., that mineral N remaining as residual in the soil profile from previous years' fertilizer N application.

Earlier correlation work on soil testing at Nebraska had indicated the efficacy of an organic matter determination to reflect N status on a single soil type in a given climatic region. The measurement lost significance, however, when carried out on soils widely divergent in morphological properties, such as pH, texture, base saturation, clay type, etc. Readily decomposable portions of the total organic matter fraction have similarly failed of credibility as a N measure when investigated across a broad gamut of soils. Mineral N accumulations in the lower portion of the rooting profile no doubt contributed to the limited usefulness of organic matter values for assessing soil N status.

Most of the soil testing calibration work reported in the literature has been accomplished with surface soil samples only. It has become increasingly evident that additional nutrient information from the rooting profile of soil is needed, especially for the more mobile nutrients like N and S. Calibrations must be developed for each crop species in any soil region and will likely require modifications with the introduction of new genotypes of greater yield potentials.

Table 3. Calibration of soil nitrate production test with supplemental N needs for winter wheat in Nebraska field experiments, 1952-1959 (6).

Nitrate production (NR) range and interpretation 1/	Locations with Increase to N	Locations with No effect of N	Locations with Decrease to N	Fertilizer recommendation
ppm NO_3-N	percent	percent	percent	kg N/ha
Response assured				
C 0-15	97	3	0	45-67
F 0-10	100		0	33-45
Response likely				
C 15-20	75	25	0	33-45
F 10-14	50	22	28	22-33
Response possible				
C 20-25	50	50	0	22-33
F 14-18	42	19	39	22
Response unlikely				
C >25	0	100	0	None
F >18	0	27	73	None

Correlations 2/

Continuous Cropping	Y=52.1 - 1.85 X	r = -.630**	(n=59)
Fallow Wheat	Y=17.9 - 1.04 X	r = -.463**	(n=60)

1/C = continuous cropping; F = after fallow

2/Y = yield response in % of max. yield; X = NR in 10^d

Table 4 presents recent correlation information for the winter wheat crop in respect of the elements N and P. These are the elements most extensively required for wheat production in Nebraska. It is apparent that neither of the N testing procedures investigated on surface samples alone is useful for predictive purposes, with less than 25 percent of the variation explained by the regression equation. The 180-cm profile value for residual NO_3-N, however, does rather effectively indicate probability of response to applied N. By further integrating the surface soil's nitrification capacity in multiple correlation, 41 percent of the variation in yield is explained.

Table 4. Regression analyses relating soil testing values for N and P with yield response of winter wheat to applied fertilizer (115 field experiments in Nebraska, 1960-68).

Variable (x) related to % yield response	Regression equation[1]	Correlation coefficient[2] r
	NITROGEN	
Surface soil NO_3-N	$Y = 66.5 - 1.14799X$	0.481**
Surface soil NR	$Y = 49.72 - 1.08136X$	.241*
Profile NO_3-N	$Y = 103.87 - .01279X + .0041432X^2 - .0000034X^3$	.624**
Profile NO_3-N + NR	$Y = 119.61 - 1.33750X + .0040270X^2 - .0000032X^3$	.643**
	PHOSPHORUS	
Surface soil P	$Y = 36.91 - 1.69102X + .0187306X^2$	.492**

Calibration for profile NO_3-N

NO_3-N, kg/ha	Calibration range
0 - 45	Response assured
45 - 90	Response likely
90 -135	Response possible
>135	Response unlikely

Calibration for surface soil P

Bray P, ppm	Calibration range
0 - 15	Response assured
15 - 23	Response likely
23 - 30	Response possible
>30	Response unlikely

[1] X = soil test value in ppm; Y = yield response from applied nutrient in percent; NR = soil nitrate production in 10 days

[2] * = significant at 5% level; ** = significant at 1% level

The P correlation data for field experiments with wheat in Nebraska from 1960 to 1968 fortify interpretations made from field studies prior to 1963. There is no cause for altering the conclusions made at that time, nor is there need for adjusting calibrations made then. In this case, no benefit is derived from integrating deeper profile information on P. The relationships expressed for N and P testing become the more meaningful as recognition is given to varied climatic conditions over the 9 years of study, different varieties employed, differential farming practices, and the wide range of morphological soil units involved across the state of Nebraska.

Meaningful correlation data from soil testing necessitate a reasonable level of moisture availability and certainly more efficient utilization of water can be expected as nutrient deficiency is corrected (10). A crop suffering severe drouth stress will produce a maximum yield with substantially lower levels of most available nutrients than are required for top yields when moisture is adequate. On the other hand, hard red winter wheat varieties presently grown on the Great Plains of the U.S. do not afford the best yield response to fertilizers in years of above-normal rainfall, especially if excess moisture comes during the head-forming and grain-filling stages. For these reasons, poor correlations are found as yields and moisture availability are related over several years (7), and there is little reason to expect improved correlation of soil testing results with yield response by integrating the additional moisture factor unless it is never excessive.

While on the subject of soil testing, reference should perhaps be made to the use of plant analysis for evaluating crop nutrient needs. Plant analysis has proved to be a useful research tool, helping to explain why a crop is doing well or poorly, but the information acquired is post mortem insofar as the current crop is concerned. Where used, the most meaningful information is obtained from the upper leaves of wheat collected just before heading.

Nutrient Variability in Field Soils

Figure 4 depicts differences in nutrient levels that are found in Nebraska soils classified on a soil series basis that are the consequence of pedogenic processes in soil formation. Although all four soil series represented are fairly similar in surface soil pH and all become alkaline from calcareousness with depth, there is appreciable difference in the depth at which the free lime is expressed. All of these soils are high in exchangeable potassium throughout the profile with Holdrege being especially high in this component. Surface adsorbed phosphorus levels are more variable, Holdrege containing much less in its lower profile than the others. None of these apparent differences could be adjusted to uniformity by feasible means and they do have nutritional implications. A winter wheat nursery made up of half Hastings and half Holdrege soil could be expected to express varied growth characteristics of the wheat crop on opposite sides of the dividing line which were nutritionally related.

The wheat nursery represented in Figure 5 on the Mead Field Laboratory of the University of Nebraska is of very uniform surface topography, and morphological characteristics of the soil profile visible to the naked eye other than thickness of A horizon do not vary throughout the area. Nonetheless, significant variations do exist in surface soil pH as well as mean pH of the 180-cm profile. It is quite likely that the half unit of pH from the areas of lowest mean profile value to the highest levels would have nutritional significance.

Variations in available soil P levels are even more striking for this 'uniform' nursery (Figure 6). A fairly consistent gradient exists from southwest to northeast for the surface soil, from a medium calibration range to a very high level. Profile mean values depicted in the lower half of the figure, however, vary even more and not exactly in conformity with the surface soil values. The differences expressed, especially throughout the profile, are more than enough to account for appreciable variability in crop growth under moisture stress conditions. The surface soil differences could be equalized quite readily by fertilizer treatment, but the profile discrepancies could not be corrected by practical means in any reasonable time interval. There is good reason to believe that erratic yield data acquired in years of excessive or deficient moisture are related to the high or low availability of P throughout the profile.

Soil mineral N (NH_4^+ plus NO_3^-), expressed in Figure 7, also evidences more than a two-times range within the nursery plot area despite uniform fertilizer N treatment during the last six years. As with P, the surface soil and the 180-cm profile do not tell a common story. The delineations made on the chart for profile N are all gradations of 'high' calibration, and it seems quite probable that excessive N could be a yield-limiting factor for some varieties over a considerable portion of the nursery, judging by the criteria of Figure 4. An overabundance of available N, together with the nutrient P situation depicted above, may largely explain the plant breeders' general dissatisfaction with the site.

No simple way exists for explaining the variability in the soil pH and nutrient status expressed in Figures 5-8. Natural effects from pedogenesis may be partially involved although no differences are apparent in visual properties of the soil profile involved. The site being an ancient terrace with a loess cap on a hummocky sand surface, it is possible that the capillary discontinuity of the underlying sand at varied depth influenced root movement and magnitude, ultimately nutrient accumulation in the profile during genesis.

Long-forgotten field boundaries with differential management of the soil on opposite sides could explain some of the differences observed at the present time. Especially would an area exposed to a high livestock density for a period of time in the past be likely to show appreciable P accumulation in the upper profile and N throughout. Even a human living site with associated small animal life will evidence high P concentration of the soil for as long as centuries after the habitat has been leveled and forgotten (3). Such possibilities need investigation by thorough profile sampling and soil analyses prior to the establishment of long-term wheat nurseries.

Summary

Soil fertility exerts a major role on the yield and quality of winter wheat wherever produced. Although deficiencies of N, P and K are most likely to limit production in wheat-producing regions of the world, shortages of other elements are being increasingly recognized with introduction of varieties of higher yield potential and with application of improved overall soil-crop management systems. With the exception of a few elements like Fe and Mn, authenticated methods have been developed for soil nutrient evaluation by soil testing which should prove invaluable to the researcher responsible for varietal evaluation in wheat nurseries. Not only is knowledge of nutrient level needed for preventing deficiency, but this information is essential for preventing excesses that may be responsible for yield reduction due to toxicity or unfavorable interaction with

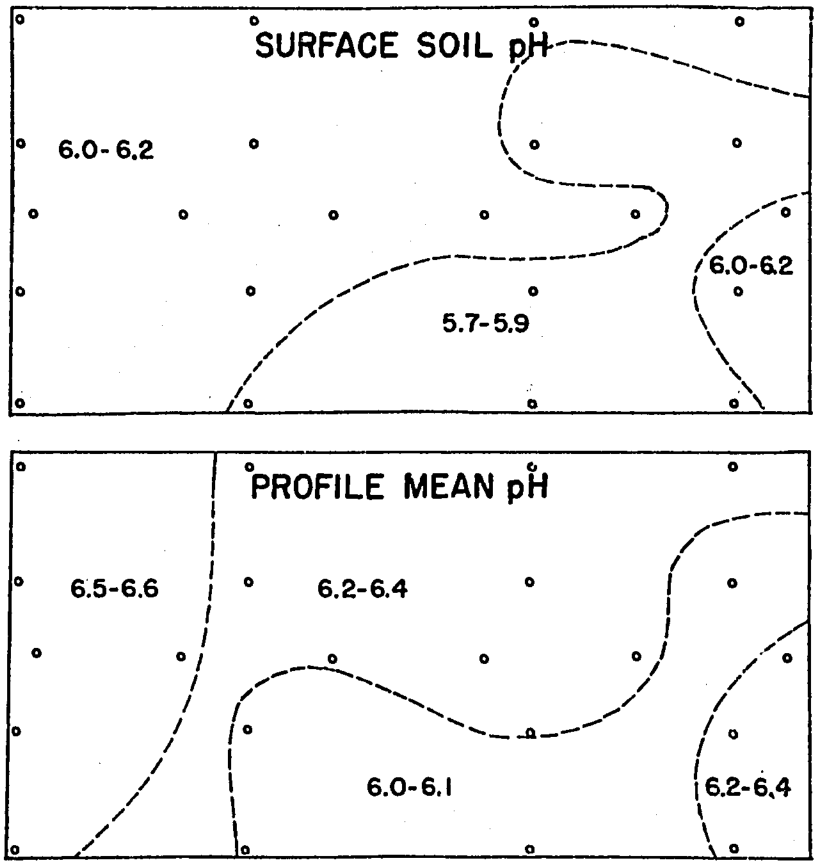

Fig. 5. Soil pH in the winter wheat nursery at the Mead Field Laboratory, Nebraska. Upper chart is for surface soil to 15 cm; lower chart expresses mean pH for the 180 cm profile.

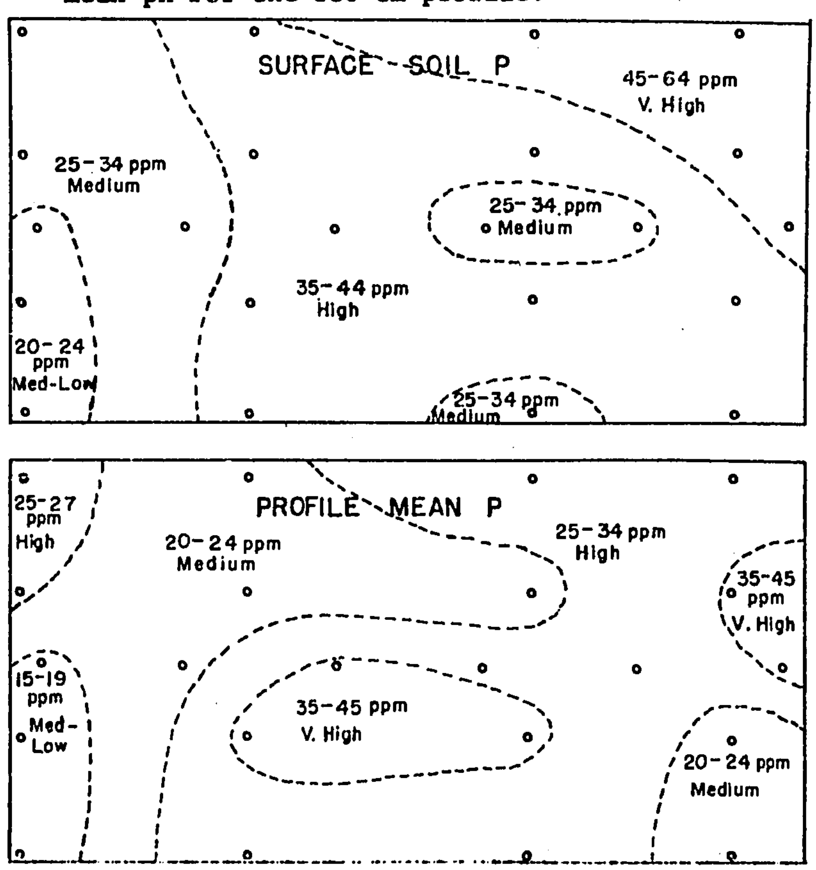

Fig. 6. Available P (Bray & Kurtz #1 levels in soil of the winter wheat nursery at the Mead Field Laboratory, Nebraska. Upper chart is for surface soil to 15 cm; lower chart expresses mean P value for the 180 cm profile.

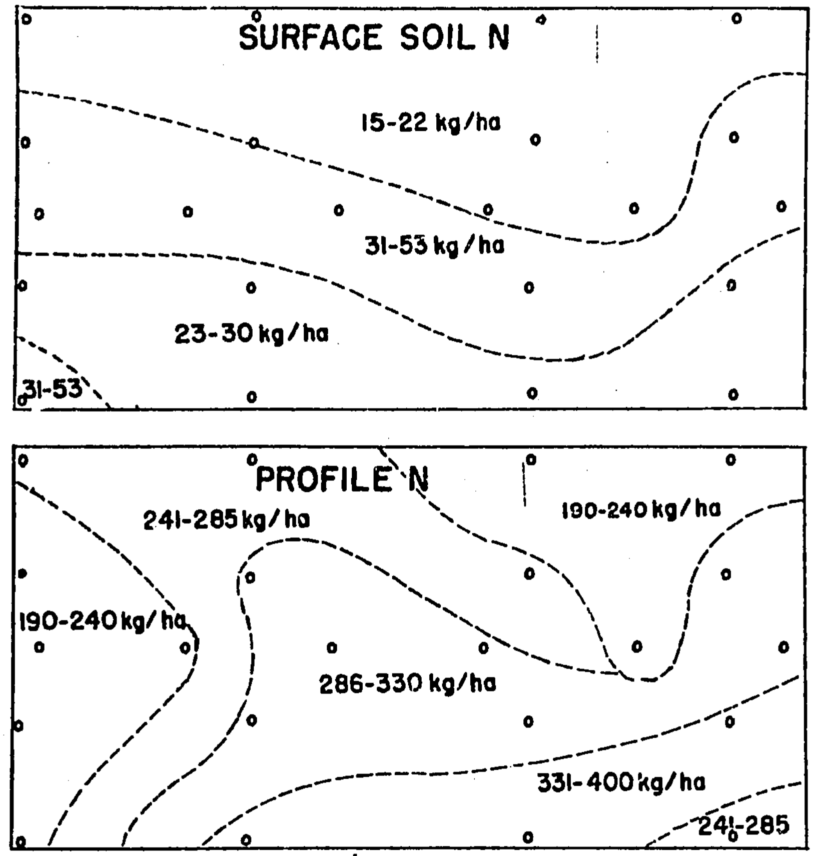

Fig. 7. Mineral soil N (NH_4^+ and NO_3^-) levels in soil of the winter wheat nursery at the Mead Field Laboratory, Nebraska. Upper chart is for surface soil to 15 cm; lower chart expresses total mineral N for the 180 cm profile.

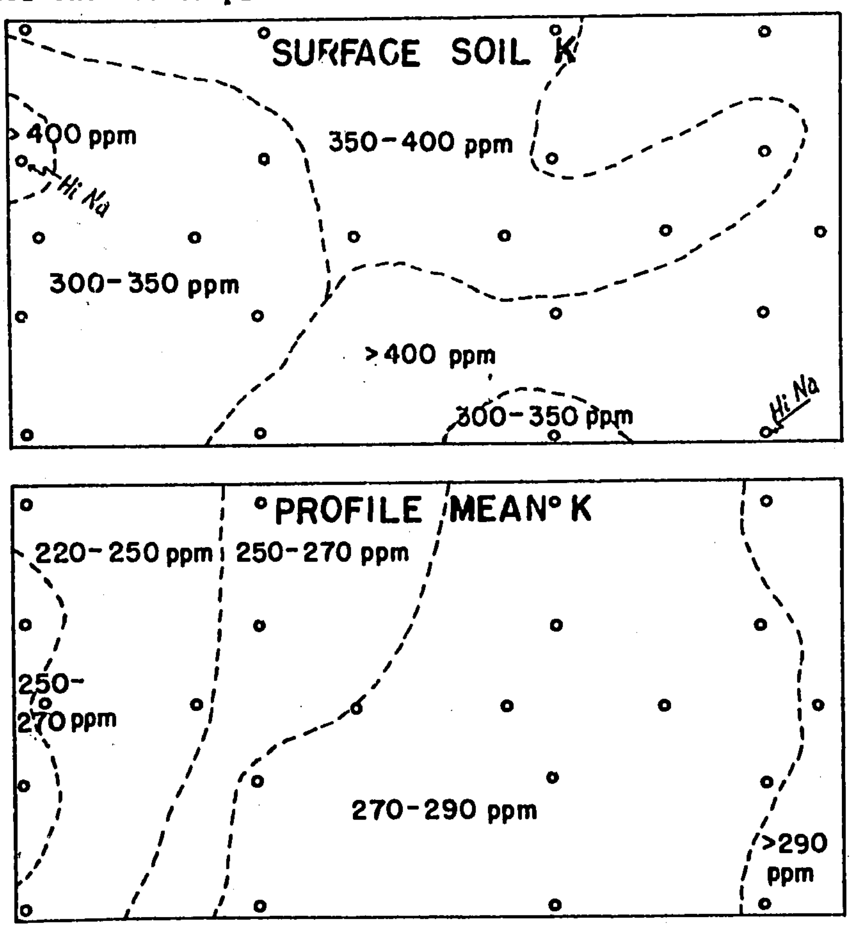

Fig. 8. Exchangeable K levels in soil of the winter wheat nursery at the Mead Field Laboratory, Nebraska. Upper chart is for surface soil to 15 cm; lower chart expresses mean exchangeable K for the 180 cm profile

another essential element of plant nutrition. Nurseries should be established under optimum fertility conditions as it is important for plant breeders to be certain that varietal differences in yield at a given location are not reflections of genotype selectivity in nutrient uptake.

Protein content as a wheat quality factor varies radically with environmental changes, including those associated with soil nutrient levels. With N limiting at a constant level, growth factors like improved moisture availability that result in increased yield cause an inverse effect on protein content due to dilution of the quantity of N available in the higher yield. When residual mineral N in soil is low and with favorable growing conditions otherwise, the predominant effect of the first increments of applied N will be to increase yield, whereas with high residual soil N the dominant effect will be to increase protein content. The low residual N site will not produce the same protein content with any reasonable rate of applied N as the site with high residual N. Explanation proposed is that declining root activity with moisture depletion from the surface downward through the growing season prevents effective utilization of even heavy N treatment to the surface horizon. Some modest quantity of available N must exist in the lower soil horizons where root activity is likely to be greatest during the grain-forming and protein-setting stage.

Thorough sampling and analysis of the soil profile within a proposed wheat nursery area should be accomplished before plot establishment. Such procedure will preclude the possiblity of later experiencing serious variability in measurements of yield and quality due to soil fertility gradients. A close collaboration among plant breeders, nutritionists, and soil fertility personnel will be required for achieving major advances in wheat production potentials henceforth in view of the many interacting factors recognized at this conference.

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NURSERY WINTERHARDINESS PROBLEMS

by

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In considering winterhardiness problems associated with the International Winter Wheat Performance Nursery, it is appropriate that we first consider the results that have been obtained from the nurseries in 1969 and 1970. This may give some clue as to the value of the data and the methods of reporting them.

In 1969 21 sites reported data. Of these 21 sites, 9 reported winter survival data. I have chosen to disregard the spring varieties as these are not indicative of winterhardiness information for purposes of this discussion. Of the 9 locations, only 4 had winter kill that averaged greater than 10 percent. In preliminary studies of the data, correlations were calculated between individual locations and the grand mean for all locations. It was found that there was no correlation between those locations that had greater than 90 percent average survival and the grand mean. Thus, I chose to consider only those locations that had less than 90 percent mean survival. The correlation coefficients between these locations and between the locations and the grand mean are given in Table 1. There was fair positive agreement between Suwon, Sapporo and Svalof. Kabul was definitely different in its evaluation of varieties in the nursery.

Table 1. Correlation coefficients between varieties at several locations and between variety grand mean values and varieties at each location in the 1969 IWWPN.

Location [1/]	2	3	4	Grand mean	Site mean
1	-.06	.55**	.37	.61**	87
2		.09	-.41*	-.06	61
3			.32	.60**	71
4			---	.90**	43

[1/] 1. Svalof, Sweden
2. Kabul, Afghanistan
3. Suwon, South Korea
4. Sapporo, Japan

In 1970 36 locations reported data. Of these, 16 reported winter survival readings. Only 10 locations averaged less than 90 percent. Again, data in nurseries which averaged greater than 90 percent winter survival and the grand mean were not correlated. Correlation coefficients between the varieties at each of the locations with less than 90 percent survival and between the locations and the grand mean are given in Table 2. In 1970 the locations fell into three general groups. Group 1 included Fort Collins, Wageningen and Zagreb. Group 2 included Ithaca, Jokioinen, Weihenstephan and Sapporo. Group 3 included Monsheim and Suwon. As in 1969, Kabul was not associated with any other location. Six of the

Table 2. Correlation coefficients between varieties at several locations, and between variety grand mean values and varieties at each location in the 1970 IWWPN

Location 1/	2	3	4	5	6	7	8	9	10	Grand mean	Site mean
1	.23	.71**	.27	.10	.22	.85**	-.09	.42	.14	.51**	84
2		-.03	.76**	.05	.82**	-.01	.15	.42	.56**	.87**	69
3			.15	.05	.04	.85**	.07	.30	-.02	.28	.77
4				-.08	.74**	.15	-.22	.34	.82**	.83**	29
5					.01	.06	.25	.52**	-.14	.21	81
6						.03	.20	.21	.52**	.81**	75
7							-.11	.32	.06	.36	89
8								.07	-.21	.11	70
9									.26	.64**	79
10									-	.68**	21

1/
1. Fort Collins, U.S.A.
2. Ithaca, U.S.A.
3. Wageningen, Netherlands
4. Jokioinen, Finland
5. Monsheim, W. Germany
6. Weihenstephan, W. Germany
7. Zagreb, Yugoslavia
8. Kabul, Afghanistan
9. Suwon, South Korea
10. Sapporo, Japan

ten locations had significant correlations with the grand mean in 1970.

The correlation between 1969 data and 1970 data was 0.67. This was based on the grand mean of each variety for each year over all locations.

It appears that there is fair agreement between variety performances over years considering all nursery sites. It is obvious that all environments are not testing for the same type of plant response. This is evidenced, for instance, by the difference between Kabul and other locations in both years.

Data would indicate that nurseries having 90 percent survival or better contribute little information to the general winterhardiness picture. These nurseries do screen out the poorest winter habit but do not identify superior genotypes.

One of the stated objectives of this nursery is to identify superior winter wheat genotypes. It appears that a major value in this respect, relative to winterhardiness, is to provide an opportunity for cooperators throughout the world to evaluate the performance of a wide array of germ plasm under specific conditions. It is questionable if we will be successful in identifying outstanding winterhardiness to fit all environments. More success will likely be achieved in identifying general adaptation by virtue of average yield performance. The variety Bezostaia is an outstanding example.

It is interesting to note that there is quite good agreement between winter survival rankings and the grand mean yield rankings. It is likely that the lowest yielders achieve that rank partly because of the contribution of poor winterhardiness. This would occur even at locations with relatively little winter kill. However, the top ranking yielders are not there by virtue of having an additional level of winter survival over a number of other entries in the nursery. It may be that superior winterhardiness is also related to other physiological advantages. Examples of this may be the possible linkage of superior drouth tolerance and winterhardiness, and the relationship of photoperiodism and winterhardiness. It seems that in this nursery superior winter survival alone may be a relatively small contributor to general adaptation after some critical level is reached.

Some specific recommendations might be considered to improve note taking and data collection with respect to spring recovery. The notes we are taking now are estimates of live plants remaining at some point in the spring. This evaluates winter survival. However, it may be possible, also at some point in the spring, to take some kind of note to account for the general color, stand and vigor of the nursery entries. This would likely be in addition to spring survival notes as we now take them. As an example, we are using a general vigor note now at Fort Collins, where winter kill is relatively light. We are finding good agreement between general plot vigor and color, and survival under more rigorous conditions in the Great Plains. A combination of yellow color and erect leaves at a critical point in the spring appears to be a good indicator of poor vigor for us, even though all plants are alive. This requires close observation of the nurseries, as the time period when this condition is observable is quite short.

A second suggestion would be to make a winter survival summary of nurseries with less than 90 percent survival, which would be more meaningful in sorting out outstanding winter survival. This suggestion is made in view of the fact that high survival nurseries have little correlation with the grand mean and tend to obscure the data.

DISEASE PROBLEMS IN THE INTERNATIONAL WINTER WHEAT PERFORMANCE NURSERIES

by

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Wheat diseases have always been a limiting factor in normal or high production of this basic crop for people's nutrition.

The most promising cultivars are being tested in the IWWPN for yield capacity and degree of adaptability throughout the world with special analyses of protein and lysine content. It is not necessary to explain the importance of disease problems in these nurseries, which can reduce the yields of susceptible cultivars. Since the content of protein and lysine in the nursery cultivars also are analyzed, the effect of diseases on the content of these grain constituents can also be determined.

Rusts are known to be the most harmful wheat diseases and much data illustrates clearly the large and even drastic losses in yield. However, the disturbances in normal processes of plant metabolism have to be followed as well as the effect of parasites on the content of the individual nutritional constituents. Doodson, Manners and Myers (1965) found that Puccinia striiformis affects yield primarily by reducing the carbohydrate supply to the developing parts of the plant, and, in particular, to the ear. The reduction of photosynthesis and translocation of assimilates, as well as the increase of respiration are known to be involved. According to Von Sydow and Durbin (1962), much of the assimilated material is incorporated into the stem rust fungus. Others suggested that in the early stages much of the accumulation is in the host cells and around the fungus hyphae (Rohringer, Samborski and Person, 1961). In the study of Blumenbach (1966) the importance of the partial process for the host-parasite relationship is underlined, especially in the metabolism of aromatic compounds and proteins.

If we consider different pathogens of wheat, the physiological manifestations of a disease may be diverse, but, as a rule according to Kiraly et al. (1970), the concentration of ribosomes is increased which explains the increased capacity of the infected cell for protein synthesis. On this basis, it may be expected that, in some cultivars infected with one or more parasites, somewhat higher protein content may occur, but this would have no particular importance concerning the general reduction of the total yield per unit area. Moreover, according to the results of Stroike et al. (1971), the nutritional value of wheat protein is related to the amount and availability of lysine in the protein. It seems that high protein wheats can be expected to have less lysine than the low protein ones. In this respect, it certainly would be necessary to have considerably more experimental data about the effect of the individual diseases on the content of protein and lysine in some representative wheat cultivars.

As far as disease resistance in the nurseries is concerned, it is worthwhile to mention the relative merits of "vertical" versus "horizontal" resistance (Van Der Plank, 1968). Especially in wheat there are known examples of the "vicious circle" which takes place in the alternating prevalence of resistant cultivars and the virulent pathogens.

Some Data on Diseases in the IWWPN

For this occasion we used only the published and available data on reactions of varieties in the IWWPN in 1969 to the parasites of some important diseases (Stroike, et al. 1971). Our review includes only sites where severity and response for each cultivar were reported in order to calculate on this basis the coefficients of infection. Tables 1, 2, 3, and 4 contain the results of leaf, stem and stripe rust, powdery mildew and Septoria. Since the cultivars are arranged according to their average coefficients of infection, the categorization of cultivars in relation to their value for each disease clearly can be seen.

I will discuss summary Table 5 where rankings of cultivars has been arranged according to the average for all four diseases, except Septoria for which there were data from only one site.

NB 67730, whose relative average resistance in this case certainly originates in parent Atlas 66 is in first place. The corresponding advantage for the Atlas 66 parent is noticed in stripe and leaf rust, and inferiority in relation to stem rust and powdery mildew. Bezostaja 1 ranked in the second place with fairly satisfactory reaction to the rusts and somewhat greater susceptibility to powdery mildew. Our experiences here proved that this variety possesses a certain tolerance to powdery mildew and perhaps slight general resistance to some of the rusts. This hypothesis is based on its widespread production over several years with the possibility of selection pressure of the variety on parasite populations and permanent maintainance of certain level of resistance.

The Lancer variety is in the third place with poorer average rankings of infection coefficients of leaf rust. Its rankings to other rusts and mildew were better. I have already mentioned Atlas 66 and its susceptibility to stripe rust. The next variety, Timwin, is even more susceptible to stripe rust, but its fifth place average was due to relatively better resistance to leaf and stem rust and powdery mildew. I want to mention only one more variety, Inia 66, which was the best one in relation to leaf and stem rust but rather weak to other diseases. According to the reaction of its parent Lerma Rojo 64, it can be seen that Inia 66 possesses somewhat superior resistance to the above-mentioned two rusts.

The general categorization of cultivars reflects clearly their rankings for each disease. If we compare the average diseases rankings of cultivars in the tables with average yield rankings in the data of Stroike et al. (1971), the following can be observed. Bezostaia 1 is the first in average yield and the second in average rankings of diseases. Among ten best cultivars to diseases the better yield rankings were shown for Timwin, Benhur, Scout 66, and Arthur, while the other five varieties exhibited no correlation between the two. Average degree of resistance or susceptibility to diseases definitely influenced the yield of cultivars. It is normal that some of them have shown some deviations because of stronger interaction of their other properties with different environments.

Considering the resistances registered for some outstanding cultivars, it is interesting to point out their real value, i.e. the duration of these resistances. Only for the cultivar Bezostaia 1, I suggest the possibility of certain tolerance to powdery mildew and perhaps partial general resistance to the rusts. This should be proved by some experiments. According to past experience, if registered resistances are only of specific character then the majority of them could be short lasting. It is true that general resistance is very often expressed only

Table 1. Leaf rust data from the 1969 IWWPN.

No.	Cultivar	ARGENTINA: Bordenave	ARGENTINA: Pergamino	U.S.: Oklahoma	ITALY: Milano	ITALY: Rieti	YUGO-SLAVIA: Novi Sad	ROMANIA: Fundulea	TURKEY: Ankara	IRAN: Kermanshah	Coeff. of Inf.	Highest Reading
1	Inia 66	10S	5S	--	11MR	0	--	--	1MR	--	4.0	10S
2	Benhur	2R	10S	10MS	15MR	0	21R-MR	12MR-MS	0	5MR	4.9	10S
3	NB 67730	4R	20S	1R	15MR-MS	0	30R-MR	9R-MS	1MR	0	5.9	20S
4	Sturdy	1R	10S	1MR	10MR	0	4R-MS	43MS-S	0	2R	6.7	43S
5	Lerma Rojo 64	8S	1S	--	28MR-MS	30MR	17R	--	1MR	0	6.7	8S
6	Purdue 4930 A6-28-2-1	1MR	60MR	20MS	15MR	0	12R	20MS-S	2MR	2R	7.8	20S
7	Parker	0	20S	20MS	10MR	30MR	22MR-MS	12MR-MS	1MR	2MR	8.9	20S
8	Atlas 66	6MR-MS	80S	1S	9R-MR	0	6MS	5MR	0	1MR	10.7	80S
9	Bezostaja	3R-MR	0	1MR	3MR	0	30MS-S	65S	1MR	0	10.9	65S
10	Stadler	5MR	60S	5MS	18MR	30MS	15R	8MS	0	10S	13.0	60S
11	Gage	1R-MR	0	10MS	25MR	80MS	33R-MR	28MR-MS	0	1MR	13.2	80MS
12	Timwin	11MR-MS	80S	30S	14R-MR	23MR	1R-MR	12MS	0	1R	16.0	80S
13	Riley 67	0	80S	0	75MS	10MR-MS	3S	0	1MR	0	16.8	80S
14	Cappell Desprez	17MR	0	1R	2R-MR	99S	31MS	30S	1MR	4R	18.1	99S
15	Arthur	0	80S	5MR	11MR	60MS	19MS	21MS-S	0	2R-MR	19.0	80S
16	Lancer	21MS	60S	50S	15MR	0	30MR-MS	56S	0	0	23.7	60S
17	Scout 66	16S	80S	50S	13MR	30MR	28MS	61S	2MR	4R-MR	27.7	80S
18	Shawnee	11MS-S	10S	50S	3R-MR	30MR	94S	73S	2MR	2R	28.0	94S
19	Fertodi 293	21MS	0	50S	7MR	30MS	96S	75S	1MR	4MR	28.5	96S
20	Bankuti 1201	13MS	50S	40S	8MR	10MS	80MS-S	76S	2MS	0	29.9	80S
21	Blueboy	11S	25S	50S	8MR	30MR	99S	83S	1MR	5MR	31.8	89S
22	Gaines	1R	80S	20S	14R-MR	60MS	88S	96S	1MR	0	35.3	88S
23	Triumph 64	16MS	80S	50S	6MR	60MS	65MS-S	60S	0	10S	36.4	80S
24	Odin	53S	10S	15S	8MR	99S	78S	90S	1MR	4MR	38.9	99S
25	Heine VII	37S	0	20S	58MR-MS	90S	96S	70S	15MS	9MR-MS	42.1	96S
26	San Pastore	15S	5S	30S	73MS-S	90S	94S	61S	2MS	10S	44.4	94S
27	Felix	37S	5S	30S	63MS-S	99S	99S	80S	10MS	8MR	47.1	99S
28	Yung Kwang	16S	80S	80S	23MR	80MS	99S	78S	0	5MR-MS	47.8	99S
29	Winalta	18S	80S	60S	29MR	99S	94S	66S	2MS	5MR	48.0	99S
30	Yorkstar	7MS-S	30S	60S	53MS-S	99S	94S	85S	0	10S	48.7	99S

Table 2. Stem rust data from the 1969 IWWPN.

No.	Cultivar	ARGENTINA: Bordenave	U.S.: Oklahoma	ITALY: Milano	ITALY: Rieti	YUGOSLAVIA: Novi Sad	ROMANIA: Fundulea	TURKEY: Ankara	IRAN: Karaj	Coeff. of Inf.	Highest Reading
1	Inia 66	0	--	0	0	--	--	0	--	0	0
2	Lerma Rojo 64	0	--	4R	0	0	--	0	--	0.2	4R
3	Timwin	0	0	0	8MR	0	0	1MR	--	0.6	8MR
4	Purdue 4930 A6-28-2-1	7S	1MS	9R	0	0	0	0	--	1.4	7S
5	Arthur	11S	0	8MR	0	0	0	0	0	1.7	11S
6	Shawnee	6MS-S	1MS	0	30MR	0	0	0	0	2.4	6S
7	Triumph 64	6S	1S	3R	80MR	0	0	2MS	0	5.1	6S
8	Atlas 66	7S	1S	9R	40MS	2MS	0	0	0	5.2	7S
9	Yung Kwang	15S	20S	0	0	0	0	2MS	8VS	5.6	20S
10	Lancer	11S	1S	20MR	30MS	0	0	2MS	0	5.7	11S
11	Bezostaja	22S	20S	10R	10MS	0	0	0	8S-VS	7.5	22S
12	NB 67730	4MS-S	0	15R-MR	70MS	0	0	0	0	8.2	70MS
13	Fertodi 293	5MS-S	1S	16R-MR	80MS	0	0	2MS	0	9.7	80MS
14	Winalta	7S	1S	13MR	80MS	0	0	1MR	0	9.7	7S
15	Scout 66	5MS-S	0	13R	99MS	0	0	3S	0	11.2	99MS
16	Gage	7MS-S	1MS	19MR	99MS	2MS	0	0	0	12.0	99MS
17	Sturdy	8S	20S	10MR	80MS	0	0	0	10MS	13.0	20S
18	Bankuti 1201	10S	1S	44MR	99MS	0	0	1MR	8MS	14.5	10S
19	Parker	15S	1S	20MR	99S	0	5S	0	5MS	16.5	89S
20	Benhur	4MS	1S	46MS	90S	0	0	0	--	18.7	90S
21	San Pastore	10S	1S	58S	99MS	2S	0	0	9S	19.9	58S
22	Blueboy	25S	1S	58S	99S	0	0	0	0	22.9	99S
23	Stadler	25S	10S	88MS	99VS	2S	0	0	0	25.7	99VS
24	Yorkstar	22S	1S	97MS-S	99MS-VS	0	0	3MS	0	27.5	99S
25	Cappell Desprez	8S	1S	85S	99S	1S	19S	0	10S	27.9	99S
26	Gaines	42S	5S	99MS	99VS	0	0	0	5VS	27.7	99VS
27	Riley 67	15S	5S	91MS	99S	5S	0	4S	--	28.7	99S
28	Felix	47S	5S	92MS-S	99S	0	0	2MS	11S	32.0	99S
29	Heine VII	25S	20S	80MS-S	99S	0	19S	2MR	13S	33.0	99S
30	Odin	25S	10S	90S	99S	2S	40S	0	0	33.2	99S

Table 3. Stripe rust data from the 1969 IWWPN.

No.	Cultivar	ARGENTINA: Bordenave	CHILE: Temuco	U.S.: Davis	ITALY: Rieti	ROMANIA: Fundulea	TURKEY: Eskisehir	TURKEY: Ankara	IRAN: Karaj	IRAN: Kermanshah	Coeff. of Inf.	Highest Reading
1	Cappell Desprez	1R	10MS	0	0	0	1R	0	20MS-VS	0	3.1	20VS
2	Bankuti 1201	10MS	5MS	0	0	0	4R-MR	3MS	19S-VS	5MR	4.1	19VS
3	Bezostaja	2R-MR	0	10R	0	0	2R-MR	3MR	34MS-VS	0	4.3	34VS
4	Winalta	1R	1MS	5R	0	0	3R-MR	5MS	36MR-VS	0	4.8	36VS
5	Odin	6MS-S	0	0	0	0	0	0	44MR-VS	0	5.5	44VS
6	Fertodi 293	2R	10MS	0	0	0	1R	2MR	43MS-VS	0	5.8	43VS
7	Parker	4R	1MS	20MR	0	3MR	25MR-MS	5MR	20MS-VS	0	5.9	20VS
8	NB 67730	18MS	10MS	5R	0	0	11MR-MS	2MR	21MS-VS	5R-MR	6.2	21VS
9	Sturdy	5R	10MS	5R	0	0	1R	0	52MS-VS	0	6.9	52VS
10	Lancer	2R	10MS	10R	0	0	2R	2MR	53MS-VS	0	7.2	53VS
11	Felix	0	10MS	0	0	0	0	5MR	56S-VS	0	7.3	56VS
12	Scout 66	4R	10S	20MR	0	0	5R	5MR	53MS-VS	0	8.3	53VS
13	Heine VII	0	0	20MR	0	18S	0	0	56VR	0	9.1	56VS
14	Lerma Rojo 64	7MS	70S	5R	0	--	5R-MS	5MS	19S-VS	5MR	13.2	70S
15	Inia 66	0	70S	10R	0	--	11MR-MS	2MR	--	--	13.7	70S
16	San Pastore	0	70S	5R	0	18S	1R	0	45MS-VS	0	14.9	70S
17	Gaines	6R-MR	10MS	30MR	0	12S	36MR-MS	40S	37S-VS	2R	15.7	40S
18	Atlas 66	16MS	40S	5R	30MS	3MR-S	29S	30S	54S-VS	5MR	21.8	54VS
19	Gage	40S	40MS	10R	0	21S	25MS-S	60S	26MS-VS	10S	24.0	60S
20	Blueboy	15S	20MS	80S	0	0	25MR-S	60S	46MS-VS	4MR	27.1	80S
21	Triumph 64	10MS	30S	50MS	30MS	14S	64MS-S	20S	57MR-VS	10MS-S	29.7	64S
22	Benhur	21MS	30S	60MS	0	6S	65MS	70S	62VS	10S	32.8	70S
23	Riley 67	60S	60S	40MS	0	12S	43MS-S	60S	26MR-VS	10S	33.7	60S
24	Timwin	7MS	30S	50S	60MS	11MS-S	29MS-S	60S	87S-VS	10S	36.5	87VS
25	Yung Kwang	72S	60S	90S	0	7S	39S	60S	55MS-VS	10S	43.7	90S
26	Stadler	5MS	20S	70S	80MS	41S	55S	80S	52MS-VS	10S	44.0	80S
27	Arthur	72S	20MS	90S	80S	1MR	25MS-S	60S	44S-VS	10S	44.1	90S
28	Shawnee	52S	50S	80S	80MS	18S	28R-S	25S	81VS	2R	44.2	81VS
29	Purdue 4930 A6-28-2-1	50S	70S	60S	60MS	20S	46MS-S	60S	36MR-VS	10S	44.4	70S
30	Yorkstar	77S	50S	80S	0	30S	36S	80S	93VS	10S	50.7	93VS

Table 4. Powdery Mildew and septoria data from the 1969 IWWPN.

		POWDERY MILDEW				SEPTORIA	
No.	Cultivar	U.S. Oklahoma	SWEDEN Svalof	AVERAGE (Coeff. of Inf.)	Highest Reading	ITALY Rieti	AVERAGE (Coeff. of Inf.)
1	Arthur	1	0	0.5	1	0	0
2	Odin	1	5	3.0	5	0	0
3	Benhur	1	9	5.0	9	0	0
4	Blueboy	10	1	5.5	10	0	0
5	Scout 66	1	10	5.5	10	0	0
6	Lancer	1	10	5.5	10	0	0
7	Timwin	1	11	6.0	11	0	0
8	Riley 67	1	15	8.0	15	0	0
9	Purdue 4930 A6-28-2-1	10	10	10.0	10	60MS	48.0
10	Atlas 66	10	13	11.5	13	30MS	24.0
11	Cappell Desprez	1	25	13.0	25	0	0
12	Gage	10	19	14.5	19	0	0
13	Fertodi 293	10	20	15.0	20	0	0
14	Yorkstar	1	30	15.0	30	70MS	56.0
15	NB 67730	20	20	20.0	20	80MS	64.0
16	Bankuti 1201	20	23	21.5	23	0	0
17	Heine VII	10	43	26.5	43	0	0
18	Bezostaja	20	40	30.0	40	0	0
19	Felix	20	40	30.0	40	0	0
20	Stadler	20	43	31.5	43	0	0
21	Winalta	30	40	35.0	40	0	0
22	Shawnee	20	53	36.5	53	0	0
23	Parker	10	80	45.0	80	30MS	24.0
24	Yung Kwang	20	70	45.0	70	0	0
25	San Pastore	20	73	46.5	73	0	0
26	Gaines	30	63	46.5	63	70MS	56.0
27	Triumph 64	20	75	47.5	75	70MS	56.0
28	Sturdy	30	65	47.5	65	70MS	56.0
29	Lerma Rojo 64	--	83	83.0	83	80MS	64.0
30	Inia 66	--	83	83.0	83	99S	99.0

Table 5. Mean rankings of cultivars in the 1969 IWWPN according to summary data for four diseases.

No.	Cultivar	STRIPE RUST			LEAF RUST			STEM RUST			POWDERY MILDEW		
		Average Coeff. of Inf.	Highest Reading	Coeff. Rankings	Average Coeff. of Inf.	Highest Reading	Coeff. Rankings	Average Coeff. of Inf.	Highest Reading	Coeff. Rankings	Average Coeff. of Inf.	Highest Reading	Coeff. Rankings
1	NB 67730	6.2	21VS	8	5.9	20S	3	8.2	70MS	12	20.0	20	15
2	Bezostaja	4.3	34VS	3	10.9	65S	9	7.5	22S	11	30.0	40	18
3	Lancer	7.2	53VS	10	23.7	60S	16	5.7	11S	10	5.5	10	6
4	Atlas 66	21.8	54VS	18	10.7	80S	8	5.2	7S	8	11.5	13	10
5	Timwin	36.5	87VS	24	16.0	80S	12	0.6	8MR	3	6.0	11	7
6	Inia 66	13.7	70S	15	4.0	10S	1	0	0	1	83.0	83	30
7	Benhur	32.8	70S	22	4.9	10S	2	18.7	90S	20	5.0	9	3
8	Purdue 4930 A6-28-2-1	44.4	70S	29	7.8	20S	6	1.4	7S	4	10.0	10	9
9	Arthur	44.1	90S	27	19.0	80S	15	1.7	11S	5	0.5	1	1
10	Scout 66	8.3	53VS	12	27.7	80S	17	11.2	99MS	15	5.5	10	5
11	Lerma Rojo 64	13.2	70S	14	6.7	8S	5	0.2	4R	2	83.0	83	29
12	Cappell Desprez	3.1	20VS	1	18.1	99S	14	27.9	99S	25	13.0	25	11
13	Fertodi 293	5.8	43VS	6	28.5	96S	19	9.7	80MS	13	15.0	20	13
14	Bankuti 1201	4.1	19VS	2	29.9	80S	20	14.5	10S	18	21.5	23	16
15	Parker	5.9	20VS	7	8.9	20S	7	16.5	89S	19	45.0	80	23
16	Sturdy	6.9	52VS	9	6.7	43S	4	13.0	20S	17	47.5	65	28
17	Gage	24.0	70S	19	13.2	80S	11	12.0	99MS	16	14.5	19	12
18	Odin	5.5	44VS	5	38.9	99S	24	33.2	99S	30	3.0	5	2
19	Blueboy	27.1	80S	20	31.8	89S	21	29.9	99S	22	5.5	10	4
20	Winalta	4.8	36VS	4	48.0	99S	29	9.7	7S	14	35.0	40	21
21	Riley 67	33.7	60S	23	16.8	80S	13	28.7	99S	27	8.0	15	8
22	Shawnee	44.2	81VS	28	28.0	94S	18	2.4	6S	6	36.5	53	22
23	Triumph 64	29.7	64S	21	36.4	80S	23	5.1	6S	7	47.5	75	27
24	Stadler	44.0	80S	26	13.0	60S	10	25.7	99VS	23	31.5	43	20
25	Heine VII	9.1	56VS	13	42.1	96S	25	33.0	99S	29	26.5	43	17
26	Felix	7.3	56VS	11	47.1	99S	27	32.0	99S	28	30.0	40	19
27	Yung Kwang	43.7	90S	25	47.8	99S	28	5.6	20S	9	45.0	70	24
28	San Pastore	14.9	70S	16	44.4	94S	26	19.9	58S	21	46.5	73	25
29	Gaines	15.7	40S	17	35.3	88S	22	27.7	99VS	26	46.5	63	26
30	Yorkstar	50.7	93VS	30	48.7	99S	30	27.5	99S	24	15.0	30	14

in field in the adult stage of wheat, but as Caldwell (1968) showed with some examples, field resistance can be either general or specific, depending upon the particular case.

Our present knowledge indicates the necessity of using general resistance in wheat. However, it is quite clear that for its utilization further intensive investigations are necessary. Many problems have been defined and pointed out in conclusions of the first FAO/IAEA Research Co-ordinating Meeting on Induced Mutations for Disease Resistance in Nairobi (Kenya). I want to mention particularly the practical problem of development of appropriate screening techniques for different components of resistance. Components of resistance to a fungus parasitic on a leaf are: reduced spore germination, delayed host penetration, reduced frequency of penetration, reduced frequency of establishment in the host, stimulation of the formation of antifungal compounds, inactivation of fungal toxins, increasing the time period from infection to symptom production, delayed sporulation, reduced sporulation ability of the plant to thrive and produce even though infected, and other features.

The last component represents a special phenomenon known as tolerance. The genetic basis of this nondefensive protective system nearly always is polygenic since it includes the adaptability of the whole metabolism of host plant. Usually only high tolerance has been pointed out to be useful. In our trials, by applying chemicals there was the possibility of discovering lower degrees of tolerance in some cultivars (Bošković, 1971).

Since in our Experimental Field near Novi Sad the conditions for leaf rust development are very favourable, I show in Table 6 the results of reaction to this disease of varieties in the IWWPN. High infections are indicated by average coefficients which range up to maximum values. The best resistance for all three years was displayed by Timwin and Sturdy, for two years by Riley 67, and for only one year by Inia 66. Good correlation with average higher yields for three years (Borojević, 1972) was shown only by Timwin and Benhur. Moderately susceptible varieties to leaf rust such as Arthur, Parker, Bezostaia 1, Atlas 66 and Scout 66 ranked among the first ten varieties in average yields.

In Tables 7 and 8 there are presented the reactions of seedlings of the 1971 and 1972 IWWPN varieties to some important standard races of <u>Puccinia</u> <u>recondita</u> f. sp. tritici. The most agressive race 77 in both tables is completely virulent on almost all cultivars. From the analyses performed, race 77 is prevalent in most European and Mediterranean countries of Asia and Africa (Bošković, 1972). Thus, if only specific resistance is carried by the cultivars tested, resistance of some of them to particular races in the tables would disappear relatively quickly after broad selection pressure to the population.

This can be expected according to known rules that in specific resistance, in most cases, the same genes condition the resistance of seedlings and adult plants. Our seedling and field tests provide sound evidence of this rule. Namely, almost all cultivars with better evaluations in the field expressed complete or partial resistance to some of the races used in the seedling tests. They are, for example, Winter triticale, Benhur, Lerma Rojo 64, NB 68513, Sava, Scout 66, etc. The exceptions are Sturdy and Timwin which are susceptible to almost all races, but both gave quite good results in the field trials. A reverse situation can be observed only in Blueboy, which was completely susceptible in the field and expressed resistance of seedlings to some races. The same phenomenon can be seen in Table 8 with nearly all the old cultivars, whereas the new ones were in the field trials for the first time this year.

Table 6. Leaf rust reactions of three IWWPN varieties grown in the IWWPN in Novi Sad (Yugoslavia), 1969-1971.

No.	Cultivar	LEAF RUST 1969 Coeff. of Inf.	1969 Highest Reading	1970 Coeff. of Inf.	1970 Highest Reading	1971 Coeff. of Inf.	1971 Highest Reading	Average Coeff. of Inf.	Highest Reading
1	Inia 66	--	--	0	0	--	--	0	0
2	Winter triticale	--	--	--	--	0	0	0	0
3	Timwin	0.6	5R	2.5	10MS	0.2	tMS	1.1	10MS
4	Sturdy	1.2	10MR	4.5	20MR	0	0	1.9	20MR
5	Riley 67	4.0	10S	0	0	--	--	2.0	10S
6	Tx 62 A4793-7	--	--	--	--	2.7	10S	2.7	10S
7	Benhur	5.2	20MR	6.0	20S	0.2	tMS	3.8	20S
8	Lerma Rojo 64	3.5	25R	8.5	20S	2.2	10MS	4.7	20S
9	NS-732	--	--	--	--	5.0	20S	5.0	20S
10	NB 68513	--	--	--	--	7.5	10S	7.5	10S
11	NB 67730	7.2	25MR	8.0	10MS	--	--	7.6	10MS
12	Stadler	12.7	30S	4.2	20MS	--	--	8.4	30S
13	NB 66425	--	--	--	--	10.0	20S	10.0	20S
14	Purdue 4930 A6-28-2-1	5.7	5S	16.0	40S	--	--	10.8	40S
15	Gage	11.2	65MR	11.0	60R	--	--	11.1	65MR
16	Sava (NS-611)	--	--	--	--	11.7	20S	11.7	20S
17	Arthur	--	--	29.0	40S	5.2	10S	17.1	40S
18	Atlas 66	7.5	20S	43.2	100S	5.0	10S	18.6	100S
19	Purdue 5752 A1-1-2	19.2	20S	--	--	--	--	19.2	20S
20	Parker	17.5	45MS	40.0	80S	6.7	10S	21.4	80S
21	Scout 66	23.0	50MS	22.0	40MS	25.0	30S	23.3	40S
22	Lancer	30.5	45MS	24.0	40MS	--	--	27.2	45MS
23	Bezostaja	29.0	25S	27.0	40S	35.0	40S	30.3	40S
24	Strampelli	--	--	--	--	37.5	80S	37.5	80S
25	Cappell Desprez	28.0	45S	70.0	80S	--	--	49.0	80S
26	Triumph 64	54.0	80S	75.0	80S	17.5	20S	42.2	80S
27	Hokuei	--	--	--	--	65.0	80S	65.0	80S
28	Bačka	82.5	90S	--	--	50.0	60S	66.2	90S
29	Bankuti 1205	77.5	90S	60.0	80S	--	--	68.7	90S
30	Probstdorfer Extrem	--	--	--	--	70.0	80S	70.0	80S

Table 6. (continued)

No.	Cultivar	LEAF RUST 1969 Coeff. of Inf.	LEAF RUST 1969 Highest Reading	LEAF RUST 1970 Coeff. of Inf.	LEAF RUST 1970 Highest Reading	LEAF RUST 1971 Coeff. of Inf.	LEAF RUST 1971 Highest Reading	Average Coeff. of Inf.	Highest Reading
31	Gaines	88.7	100S	75.0	100S	--	--	81.8	100S
32	San Pastore	95.0	100S	62.0	80S	90.0	100S	82.3	100S
33	Starke	--	--	--	--	85.0	100S	85.0	100S
34	Fertodi 293	97.5	100S	80.0	80S	90.0	100S	89.2	100S
35	Odin	78.5	90S	100.0	100S	--	--	89.3	100S
36	Shawnee	95.0	100S	85.0	100S	--	--	90.0	100S
37	Winalta	95.0	100S	85.0	100S	--	--	90.0	100S
38	Blueboy	100.0	100S	100.0	100S	75.0	80S	91.7	100S
39	Vakka	--	--	--	--	95.0	100S	95.0	100S
40	Jyva	--	--	--	--	95.0	100S	95.0	100S
41	Yorkstar	95.0	100S	95.0	100S	100.0	100S	96.7	100S
42	Heine VII	97.5	100S	95.0	100S	100.0	100S	97.5	100S
43	Yung Kwang	100.0	100S	95.0	100S	100.0	100S	98.3	100S
44	Felix	100.0	100S	100.0	100S	100.0	100S	100.0	100S

Table 7. Seedling reactions of varieties in the 1971 IWWPN to some races of Puccinia recondita f. sp. tritici.

No.	Cultivar	RACE 77	61	20	61 B	77 A	61 A	57	25
1	Bačka	4	4	4	4	4	4	4	4
2	Red Star	4	4	4	4	4	4	4	4
3	Sava	4	3+	3+/0;-1/50*/	0;-1/3+/10/	0;-1/3+/10/	0;/3+/50/	0;/3+/50/	3+/0;/50/
4	Strampelli	4	4	4/0;/10/	4	4	4	4	4
5	Starke	4	4	4	4	4	4	4	4
6	Hokuei	4	4	4	4	4	4	4	4
7	Probstdorfer Extrem	4	4	4	4	4	4	4	4
8	NB 66425	3+	3+	4	4	0;/3+/20/	4	4	4
9	TX 62 A4793-7	3+	4	4	4	4	4	4	4
10	NB 68513	4	3	0;-1/4/50/	0;-1/4/50/	0;-1/3+/20/	0;-1/4/10/	0;/4/50/	0;/4/50/
11	Winter triticale	0;/3+/30/	0;-1	0;/4/20/	0;-1/3+/30/	4	0;-1/4/5/	0;3+/5/	0;-1
12	Vakka	4	4	4	4	4	4	4	4
13	Jyva	4	4	4	4	4	4	4	4
14	Bezostaja	4	3	0;-1/4/10/	0;-1	0;/4/10/	4	0;/4/10/	0;-1
15	Blueboy	3+	0;/4/10/	3+	0	0;/4/10/	0;-1/4/20/	0;/4/10/	0;/4/20/
16	Timwin	4	4	4	4	0;-1/4/30/	4	4	3+
17	Sturdy	4	4	4	4	4	4	4	4
18	Parker	3+	3+	4	4	0;-1/3+/10/	4	3+	2+
19	Fertodi 293	4	4	0;/4/30/	4	4	4	3+	4
20	Yung Kwang	4	4	4	4	4	4	4	4
21	San Pastore	4	4	4	4	4	4	4	4
22	Atlas 66	4	3	4	4/0;/10/	0;-1/4/10/	0;-1/4/10/	4	3+/0;/10/
23	Benhur	4	3	4	4/1/10	4/0;/10/	0;-1/4/10/	3+	3+
24	Arthur	4	4	4	4	3+	4	4	4
25	Scout 66	4	4	4	4/0;/10/	0;-1/3+/10/	4/0;/10/	0;/4/10/	3+
26	Heine VII	4	4	4	4	4	4	4	4
27	Yorkstar	4	4	4	4	4	4	4	4
28	Triumph 64	4	4	4	4	4	0;	4	4
29	Felix	4	4	4	4	0;	4	4	4
30	Lerma Rojo 64	4	0;/3/30/	4	0;-1/3+/10/	0;-1/4/50/	0;-1/4/5/	0;-1/4/10/	0;

* Percent of the non-dominant mixed reaction.

Table 8. Seedling reaction of the varieties in the 1972 IWWPN to some races of Puccinia recondita f. sp. tritici.

No.	Cultivar	RACE 62	61	20	77
1	Hokuei	4	4	4	4
2	Bezostaja	0;/4/10/*	0;/4(10)	0;/4(10)	4
3	Probstdorfer Extrem	4	4	4	4
4	Blueboy	0;	0;	4	4
5	TX 62 A4793-7	4	4	4	4
6	Atlas 66	0;/3+(10)	0;/4(10)	4/0;(10)	4
7	NB 68513 (C.I.150/4)	0;/4(50)	0;/3+(5)	0;/4(50)	4
8	Jyva	4	4	4	4
9	Centurk (NB 66425)	4	3+	4	4
10	Vakka	4	0;/4(5)	4	4/0;(10)
11	Starke	4	4	4	4
12	Sava (NS-611)	4	4	0;/3+(30)	4
13	Strampelli	4	4	0;/3+(30)	4
14	Lerma Rojo 64	0;/4(10)	4/0;(10)	4	4
15	Bačka	4	4	4	4
16	Clarion	0;/4(20)	0;/4(10)	4	0;/3+(30)
17	Victor I	4	4	4	4
18	Marimp 3	4	4	4	4
19	Dacia	0;/3+(10)	4	0;/3+(10)	4
20	Golden Valley ZG 5994/66	4	4	4	4
21	Maris Nimrod	4/0;(10)	0;/4(30)	4/0;(10)	4
22	Zenith	4	4	4	4
23	Roussalka	0;/3+(10)	0;/3+(10)	0;	4
24	Caribo	4	4	4	4
25	Diplomat	4	4	4	4
26	Kirac 66	4	4	4	4
27	Lilifen	0;/3+(5)	0;/3+(20)	4	4
28	NE 701132	0;/4(10)	0;/4(10)	0;/3+(10)	4
29	Carifen 12	4	4	4	4
30	Moldova	3+/0;(20)	0;/3+(5)	0;/3+(10)	4

* Percent of the non-dominant mixed reaction.

Research intentions for improving specific (horizontal) resistance should be mentioned also. After the well-known gene for gene theory first formulated by Flor (1956) in flax rust, several authors have discussed new approaches for improving specific resistance to some wheat diseases (Person, 1959, Rowell and Loegering 1963, Loegering 1966, Browder 1971, etc.).

MacKey (1966) suggested starting with host resistance genes known to cover and overlap each other in effect. Genes possessing only a wide spectrum of resistance not only to the existing but perhaps to newly found virulences have to be selected and isolated. Isogenic lines are formed in which the recurrent parent possesses separately each of the genes transferred. By applying convergent crossing, the corresponding single genes covering the population of the parasite can be accumulated in one genotype. This would be the source of resistance for creating new commercial varieties. The necessary genes could be manipulated by interspecific and intergeneric gene transfers.

Conclusion

Evaluation of the wheat cultivars in the IWWPN for resistance to the main diseases is very important, since diseases are a limiting factor in expression of yield potential.

Further investigations are necessary to determine the effect of the individual diseases on the content of protein and lysine in some representative wheat cultivars

Based on the results of some available disease data from the IWWPN, it seems that the specific (vertical) resistance is still worth using, because in appropriate cases it could be reinforced with some useful level of general (horizontal) resistance or tolerance. In the breeding process some lower, or medium degrees of tolerance could be combined with other kinds of resistance.

Intensive investigations are necessary before general resistance and tolerance can be widely used. The IWWPN should be coordinated with the scientific institutions dealing with this problem in order that cultivars with proved general resistance or tolerance can be tested in the nursery.

In new assumptions of the mutual relationship between the genes of host resistance and the genes of parasite virulence, there should be created first of all adequate sets of isogenic wheat lines for use in broader epidemiologic studies of individual diseases. These lines should serve as the basis for both virulence differentiation within the parasite populations and for combining and accumulating corresponding genes in the sources of resistance, which would be efficient in the wide spectrum of pathogen variation.

Any new resistant cultivars based on the above gene concept which might be created in future should be tested in the IWWPN.

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INTERNATIONAL WINTER WHEAT PERFORMANCE NURSERY VARIETIES AND PRELIMINARY WINTER WHEAT PERFORMANCE NURSERY CULTIVARS SUBMITTED TO THE REGIONAL DISEASE & INSECT SCREENING NURSERY

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Within the wheat growing area from India to Morocco there is a need in some localities for winter wheats or wheats with winter hardiness. The International Winter Wheat Performance Nursery (IWWPN) provides an excellent vehicle for testing of varieties that can satisfy this requirement.

A number of countries that deal exclusively with winter wheats are anxious to submit their best varieties for testing in the IWWPN. Because of the nature of the nursery the number of varieties that can be replaced each year is limited. Usually the number of varieties submitted far exceeds the number that can be accommodated.

Frequently, the varieties included in the IWWPN are subjected to severe disease problems which limits the value of the individual cultivars. In trying to determine which varieties should be advanced from the preliminary nursery to the IWWPN the general disease resistance of a variety may be a useful criterion in helping to make selections.

The IWWPN and the Preliminary Nursery were submitted to the Regional Disease and Insect Screening Nursery (RDISN). This nursery is sown in the region from India to Morocco at sites where disease epidemics occur naturally on a regular basis.[1]

The testing of varieties at such locations or "hot spots" offer an opportunity to test the potential resistance of a variety or line to a number of pathogen populations. The information obtained can be useful in deciding which varieties or lines can be introduced for more critical evaluation and in identifying sources of resistance. Decisions regarding the release of varieties are also facilitated through such a testing procedure.

In table 2 a summary of the disease reaction data collected is presented for your information.

[1]Saari, E. E. 1972. Regional Disease and Insect Screening Nursery: Objectives and Mode of Operation In Regional Wheat Workshop, Vol. I, The Ford Foundation, Beirut. 15 p.

Table 1. Varieties entered in the 2nd Regional Disease & Insect Screening Nursery (RDISN) 1971-72 from the International Winter Wheat Performance Nursery 1971-72 and Preliminary Winter Wheat Performance Cultivars for 1971-72.

RDISN no.	Variety or Cross	Pedigree	Type[1]	Origin 1970-71	Submission no.[2]
1613	NS732		WW	Yugoslavia	1
1614	Mura		"	"	2
1615	Excelsior		"	Romania	3
1616	Favrit		"	"	4
1617	Sort 12-13		"	Bulgaria	5
1618	Sort 315-16		"	"	6
1619	Sort 11-32-1145		"	"	7
1620	Local Red Durum (Susceptible check variety)				
1621	Manella		"	Netherlands	8
1622	Jubilar		"	W. Germany	9
1623	Demar 4		"	Italy	10
1624	Yektay 406		"	Turkey	11
1625	Bolal		"	"	12
1626	Rashid		"	Iran	13
1627	Likafen		"	Chile	14
1628	Galiafen		"	"	15
1629	Victor III		"	Italy	16
1630	Oscar I		"	"	17
1631	Oscar II		"	"	18
1632	ZG 5996/66		"	Yugoslavia	19
1633	NB68435	Sut/4/Qy/2/Tm/3/Mql/Oro	"	Nebraska	20
1634	Dwarf Bezostaia		"	USSR	21
1635	NB68510	Wrr/2/At166/Cmn/3/Lancer	"	Nebraska	22
1636	NB68570	C.I.13548/2/At166/Cmn/3/ Lancer Sel.	"	"	23
1637	NE701134	At166/Cmn/Lancer	"	"	24
1638	NE701136	" " "	"	"	25
1639	NE701137	" " "	"	"	26
1640	Blueboy-Hessian fly check				
1641	NE701139	At166/Cmn/Lancer	"	"	27
1642	NE701152	Wrr/2/At166/Cmn3/Lancer	"	"	28
1643	NE701154	" " " "	"	"	29
1644	NE701147	" " " "	"	"	30
1645	NE701124	At166/Cmn/Lancer	"	"	31
1646	Jo-03045		WW	Finland	32
1647	Jo-03021		"	"	33
1648	Jo-03057		"	"	34
1649	Nisu		"	"	35
1650	Atlas 66		"	N.Carolina	36
1651	Bezostaia		"	USSR	37
1652	Hokuei		"	Japan	38
1653	Probstdorfer Extrem		"	Austria	39
1654	Blueboy		"	N.Carolina	40
1655	TX62A4793-7		"	Texas	41
1656	NB68513 (C.I.15074)		"	Nebraska	42
1657	Jyva		"	Finland	43
1658	Centurk (NB66425)		"	Nebraska	44
1659	Vakka		"	Finland	45

Table 1. (concluded)

RDISN no.	Variety or Cross	Pedigree	Type	Origin 1970-71	Submission no.
1660	H.G. Susceptible check variety				
1661	Starke		WW	Sweden	46
1662	Sava (NS611)		"	Yugoslavia	47
1663	Strampelli		"	Italy	48
1664	Lerma Rojo 64		SW	Mexico	49
1665	Backa		WW	Yugoslavia	50
1666	Clarion		"	Netherlands	51
1667	Victor I		"	Italy	52
1668	Marimp 3		"	"	53
1669	Dacia		"	"	54
1670	Golden Valley (ZG5994/66)		"	Yugoslavia	55
1671	Maris Nimrod		"	England	56
1672	Zenith		"	Switzerland	57
1673	Roussalka		"	Bulgaria	58
1674	Caribo		"	W. Germany	59
1675	Diplomat		"	" "	60
1676	Kirac 66		"	Turkey	61
1677	Lilifen		"	Chile	62
1678	NE701132		"	Nebraska	63
1679	Carifen 12		"	Chile	64
1680	Tossan Susceptible check variety				
1681	Moldova		"	Romania	65

[1]Type: Spring Wheat SW; Winter Wheat WW.
[2]Entry number as submitted by cooperator.

Table 2. Disease reactions of varieties entered in the 2nd Regional Disease & Insect Screening Nursery (RDISN) 1971-1972 from the International Winter Wheat Performance Nursery 1971-1972 and Preliminary Winter Wheat Performance Cultivars for 1971-1972.

RDISN no.	Entry no.	Yellow rust[1] Av. coeff	Yellow rust[1] High score	Yellow rust[1] Location	Leaf rust[1] Av. coeff	Leaf rust[1] High score	Leaf rust[1] Location	Stem rust[1] Av. coeff	Stem rust[1] High score	Stem rust[1] Location	Septoria[2] Av. score	Septoria[2] High score
1613	1	0.47	5MR	Turkey	13.50	100S	Turkey	47.86	100S	Turkey	7.2	9
1614	2	0.10	TMR	Nepal	29.67	100S	"	37.50	100S	"	4.6	7
1615	3	14.00	38S	Turkey	14.33	80S	"	45.13	80S	Egypt	3.4	5
1616	4	0.84	5MS	Nepal	13.60	100S	"	39.14	100S	Turkey	3.2	6
1617	5	0.03	TR	India	7.67	80S	"	13.14	60S	"	4.0	6
1618	6	0.03	TR	Turkey	8.90	80S	"	14.46	80S	"	4.4	7
1619	7	0.70	5MS	Nepal	8.93	60S	"	10.33	60S	"	5.0	7
1620	Ch	80.00	100S	Turkey	73.33	100S	Yugo.	40.00	60S	Italy	5.6	8
1621	8	0.00	0	-	33.80	80S	Italy	23.33	80S	Turkey	2.5	4
1622	9	0.00	0	-	34.53	100S	"	39.17	100S	"	2.0	4
1623	10	0.08	TMR	Nepal	35.89	100S	"	45.17	100S	"	2.5	3
1624	11	0.00	0	-	39.84	100S	Turkey	50.00	100S	"	3.3	5
1625	12	8.40	40S	Lebanon	51.78	100S	"	52.86	100S	"	3.3	5
1626	13	20.80	100S	Egypt	63.56	100S	Yugo.	53.00	100S	"	5.8	7
1627	14	3.83	20S	Turkey	28.16	100S	Turkey	46.67	100S	"	3.8	5
1628	15	2.00	10MS	Lebanon	1.74	25MR	Nepal	1.47	5S	India	3.3	4
1629	16	2.00	10S	Turkey	29.11	80S	Italy	27.14	60S	Turkey	1.0	1
1630	17	1.60	10MS	Nepal	50.22	100S	"	31.46	80S	"	2.3	4
1631	18	0.37	5MR	"	46.30	100S	"	37.14	80S	"	2.0	3
1632	19	2.00	10MS	"	7.60	60S	Turkey	23.50	60S	"	3.8	7
1633	20	1.60	10MS	"	19.14	80S	Yugo.	29.08	80S	Egypt	2.5	4
1634	21	0.40	5MR	"	12.93	100S	Turkey	30.00	100S	Turkey	4.0	6
1635	22	5.76	25MS	Turkey	1.37	10MS	Nepal	4.04	20S	Egypt	1.8	3
1636	23	12.00	40S	Lebanon	0.28	TMS	Italy	17.20	80S	"	3.5	4
1637	24	10.40	40S	"	22.18	100S	Turkey	30.94	100S	Turkey	3.3	5
1638	25	10.00	20S	"	9.82	70S	"	30.33	80S	"	3.5	5
1639	26	10.40	20S	Turkey	7.69	60S	"	21.60	60S	"	3.0	4
1640	Ch	8.44	40S	Lebanon	11.00	40S	Yugo.	45.00	80S	Egypt	3.3	4
1641	27	0.54	5MR	Nepal	13.13	80S	Egypt	36.11	80S	"	2.5	5
1642	28	4.34	20MS	Turkey	5.58	30S	"	21.17	60S	"	2.8	3
1643	29	2.40	10MS	Lebanon	13.78	80S	Turkey	23.50	80S	Turkey	2.8	4
1644	30	0.40	5MR	Nepal	6.03	40S	"	15.97	40S	"	3.5	6
1645	31	6.40	30MS	"	2.38	20MS	Egypt	10.17	40S	Egypt	3.5	5
1646	32	0.07	TMR	"	34.13	100S	Turkey	44.17	100S	Turkey	3.3	5
1647	33	1.34	10MS	Turkey	25.56	100S	"	36.67	100S	"	2.8	6
1648	34	1.67	10MS	"	38.93	100S	"	46.67	100S	"	2.8	6
1649	35	0.37	5MR	Nepal	29.64	100S	"	43.50	100S	"	2.8	5
1650	36	18.13	80S	Lebanon	2.28	20MS	Egypt	23.86	60S	Egypt	3.3	5
1651	37	10.67	40S	Turkey	3.44	20MS	Turkey	36.08	100S	Turkey	4.4	7
1652	38	5.80	30MS	Nepal	17.44	80S	"	41.00	100S	"	4.2	7
1653	39	0.70	5MS	"	3.94	25MS	"	31.67	80S	"	3.4	5
1654	40	6.67	20S	India	13.28	100S	"	57.14	100S	"	4.3	7
1655	41	14.00	40S	"	4.40	40MS	"	42.86	100S	"	4.2	8
1656	42	14.00	30S	Nepal	4.05	30S	"	41.87	100S	"	3.2	6
1657	43	3.34	20S	Turkey	29.40	80S	"	29.33	100S	"	2.8	4
1658	44	1.20	10MR	Lebanon	1.96	30MR	"	26.83	100S	"	5.4	8
1659	45	1.34	10MS	Turkey	15.00	60S	Italy	18.83	60S	Italy	2.4	4
1660	Ch	20.04	100S	Egypt	41.47	100S	"	26.73	60S	Egypt	8.2	9
1661	46	0.17	TS	Turkey	21.14	80S	Yugo.	35.00	100S	Turkey	4.0	6

Table 2 (concluded).

RDISN no.	Entry	Yellow rust Av. coeff	Yellow rust High score	Yellow rust Location	Leaf rust Av. coeff	Leaf rust High score	Leaf rust Location	Stem rust Av. coeff	Stem rust High score	Stem rust Location	Septoria Av. score	Septoria High score
1662	47	0	0	-	4.68	40S	India	25.83	60S	Italy	3.8	5
1663	48	0	0	-	10.22	50S	Yugo.	26.80	60S	Egypt	5.5	8
1664	49	4.13	20MS	Nepal	5.96	30S	India	22.57	60S	Turkey	6.6	9
1665	50	6.34	20MS	Turkey	13.20	60S	Italy	49.00	100S	"	3.6	4
1666	51	1.34	10MS	"	12.72	60S	Algeria	49.29	100S	"	3.8	6
1667	52	1.47	10MS	Nepal	30.10	100S	Italy	30.00	80S	"	3.8	8
1668	53	0.40	5MR	"	21.20	100S	"	39.43	100S	"	3.4	7
1669	54	1.20	10MR	India	4.80	20MS	Turkey	54.17	100S	"	3.5	6
1670	55	4.34	20MS	Lebanon	1.04	10S	"	36.46	100S	"	4.0	8
1671	56	0.03	TR	Turkey	8.60	40S	India	52.86	100S	Egypt	2.4	5
1672	57	0.67	5MS	"	17.15	80S	Italy	49.29	100S	"	3.4	8
1673	58	0.37	5MR	Nepal	1.08	20MR	Algeria	25.67	100S	Turkey	4.5	6
1674	59	0	0	-	21.10	60S	Italy	50.71	100S	Egypt	3.0	5
1675	60	1.60	10MS	Turkey	34.02	100S	Algeria	24.17	100S	"	3.0	5
1676	61	0.40	5MR	Nepal	46.40	100S	Yugo.	57.14	100S	"	5.2	7
1677	62	1.00	10MR	Lebanon	0.16	TMS	India	5.74	20S	India	3.8	7
1678	63	0.84	10MR	Turkey	7.89	80S	Algeria	26.71	100S	Turkey	5.0	7
1679	Ch	0.04	TR	India	24.44	50S	India	53.33	100S	"	4.0	8
1680	64	23.24	100S	Lebanon	52.13	100S	Egypt	49.00	65S	Nepal	6.2	8
1681	65	4.04	20S	India	0.11	TMR	Nepal	45.00	100S	Turkey	5.4	6

[1]Average of coefficients from all locations. YR: 7 locations. LR: 11 locations. SR: 7 locations.

[2]Average Septoria score on 0-9 scale: 4 locations. All high scores from North Africa.

2nd Regional Disease and Insect Screening Nursery 1971-72.

MILLING AND BAKING QUALITY OF VARIETIES IN THE INTERNATIONAL WINTER WHEAT PERFORMANCE NURSERY CULTIVATED AT SVALÖF

by

ista Olsson
Sweden

Milling and baking quality of the varieties in the IWWPN cultivated at Svalöf in 1969-1971 have been investigated.

Falling number gives information about the viscosity in a starch water suspension heated in a boiling water bath. A low falling number indicates high alfa-amylase content and that the starch is destroyed to dextrin. In regions such as Sweden with much rain during harvest time, the wheat often starts sprouting in the ear. Therefore, it is desirable to introduce more sprouting resistance or seed dormancy into our varieties. Low alfa-amylase content or a high falling number is wanted.

Milling quality is determined as flour yield in a Brabender Quadrumat senior laboratory mill at 16.5% water. The flour yield for varieties tested all three years is shown in Table 1. There are very clear differences in flour yield between years. The variety differences are much greater in the laboratory mill than in a large industry mill, but the rank between varieties is the same.

Table 1. Flour yield of some winter wheat varieties grown in the IWWPN at Svalöf, Sweden.

Variety	Flour Yield % 1969	1970	1971	Mean
Parker	73	72	70	72
Scout 66	71	70	70	70
Bezostaia 1	67	71	70	69
Triumph 64	71	66	65	67
Fertodi 293	71	65	66	67
Arthur	63	63	63	63
Blueboy	68	60	56	61
Timwin	66	59	55	60
Heine VII	67	55	51	58
Benhur	64	55	54	58
Yorkstar	65	53	52	57

Selections for milling quality are made at Svalöf by means of a wheat pearler. Pearling resistance is determined on 10-gram samples and the values given are the weight of the pearls. A high value indicates a hard wheat. In this material there is a good correlation between pearling resistance and flour yield with a correlation coefficient of $r = 0.80^{xxx}$ in 1971 (Figure 1).

At Svalöf protein contents are determined according to the Kjeldahl method. The values presented for 1969 are from analyses made at Nebraska. The value for 1970 refers to flour but for 1971 to the kernel and, therefore, there are large differences between these years. Protein contents for varieties tested three years are

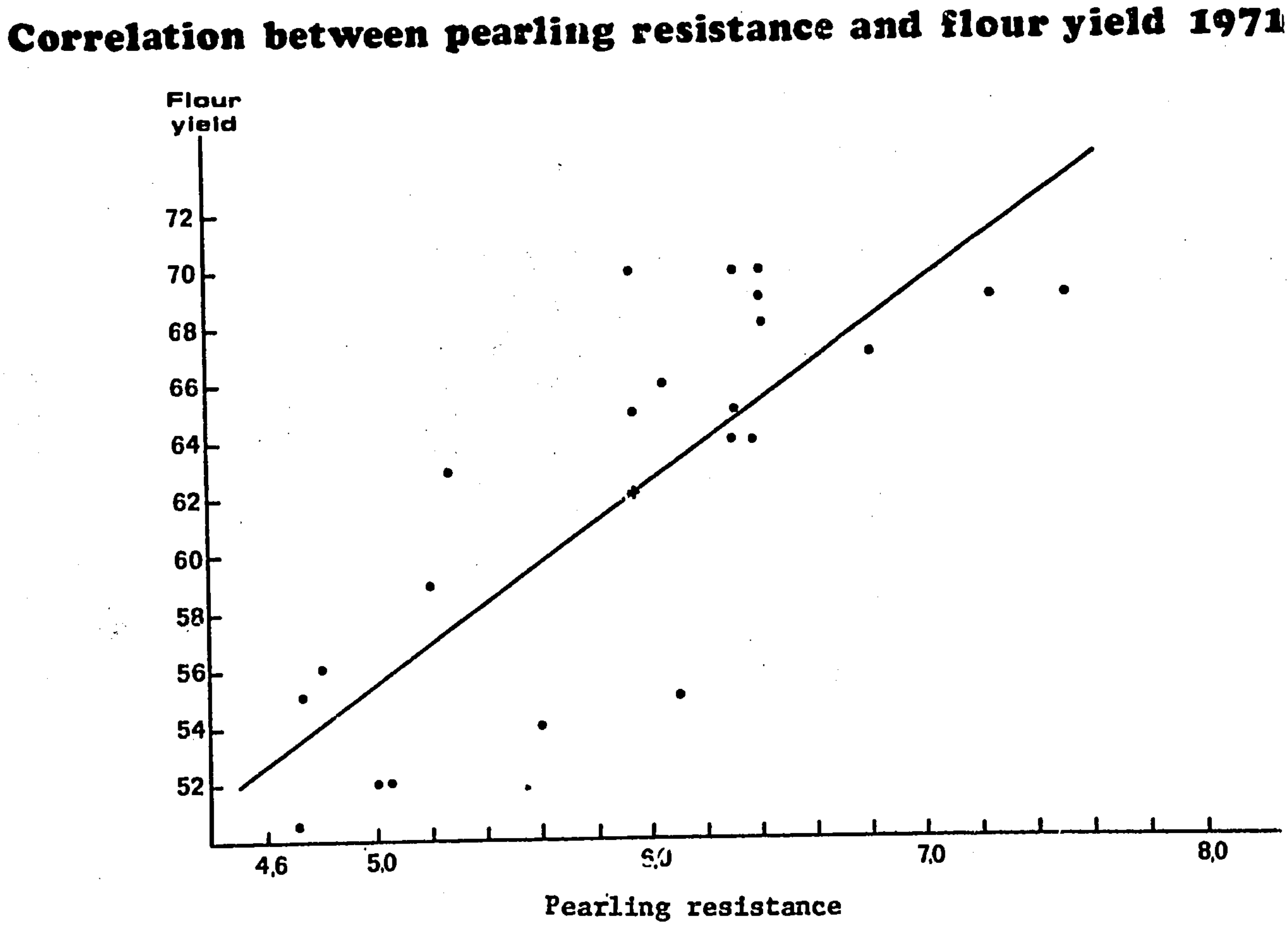

Figure 1.—Correlation between pearling resistance and flour yield in 1971.

presented in Table 2. There are very great differences between varieties with a mean value of 17.8 for Scout 66 and Triumph 64 but only about 12.8 for Heine VII and Felix. In Table 3, protein content, Zeleny's sedimentation value, and content of wet gluten are compared for 11 varieties. In most cases there are good correlations between the different values, but Benhur and Arthur have a remarkably low and Bezostaia 1 a remarkably high Zeleny value in proportion to protein content.

Table 2. Protein content in some winter wheat varieties grown in the IWWPN at Svalöf, Sweden.

	Protein Content %			
Variety	1969	1970	1971	Mean
Scout 66	18.3	16.0	19.1	17.8
Triumph 64	16.7	16.4	20.2	17.8
Benhur	17.5	16.9	18.0	17.5
Yung Kwang	17.8	15.2	17.8	16.9
Arthur	17.4	15.9	17.2	16.8
Fertodi 293	17.0	16.2	17.0	16.7
Parker	16.9	15.3	17.5	16.6
Sturdy	15.3	14.7	17.6	15.9
Blueboy	17.3	13.3	14.4	15.0
Bezostaia 1	14.1	14.9	15.4	14.8
Timwin	15.7	12.6	15.9	14.7
Yorkstar	15.1	13.3	13.9	14.1
Heine VII	14.2	10.8	13.6	12.9
Felix	13.9	11.3	12.9	12.7

Table 3. Protein content, Zeleny value and gluten content of 11 varieties grown at Svalöf, Sweden.

Variety	Protein content %	Zeleny value	Gluten content %
Scout 66	17.8	69	56.1
Triumph 64	17.8	70	54.6
Benhur	17.5	49	55.7
Arthur	16.8	50	49.7
Fertodi 293	16.7	61	50.6
Parker	16.6	67	54.9
Blueboy	15.0	27	44.9
Bezostaia 1	14.8	66	45.2
Timwin	14.7	32	40.2
Yorkstar	14.1	20	42.1
Heine VII	12.9	15	38.1

There are very large differences in rheological characters between different varieties (Figure 2). In 1971 it was a variation in valorimeter value from 40 in Yorkstar up to, for instance, 72 in Bezostaia 1 and NB 66425 and with a maximum value of 76 for Probstdorfer Extrem.

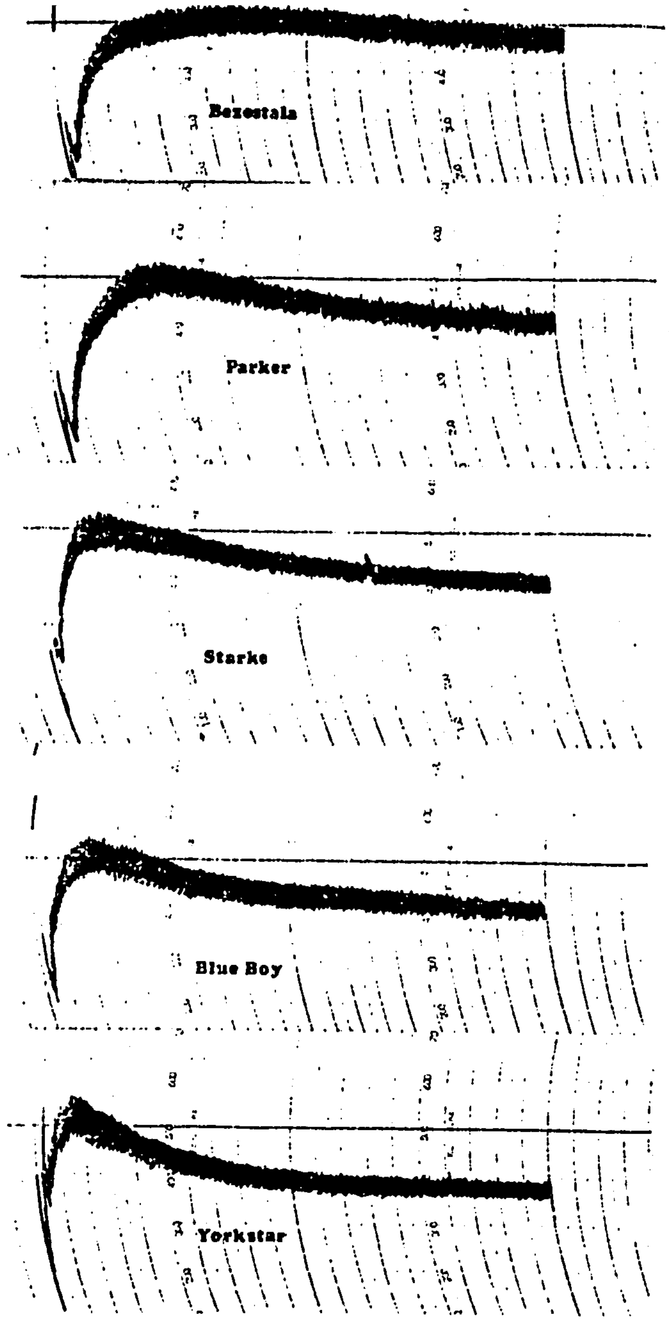

Figure 2.--Farinograms for some varieties in 1971.

The baking quality is tested by baking form bread as shown in Figure 3. In the mean values of three years of tests there are differences in loaf volumes from 690 to 938 ml (Table 4). Arthur and Benhur, which have high protein contents but relatively low Zeleny values, have also low loaf volumes. With large differences among the varieties there is a relatively high correlation between Zeleny value and loaf volume (Figure 4).

Table 4. Loaf volume of ten winter wheat varieties grown in the IWWPN at Svalöf, Sweden.

	Loaf Volume			
Variety	1969	1970	1971	Mean
Triumph 64	899	913	1003	938
Parker	884	877	859	873
Fertodi 293	874	790	893	852
Scout 66	817	782	850	816
Blueboy	929	782	726	812
Bezostaia 1	749	838	819	802
Arthur	843	561	941	782
Benhur	762	684	837	771
Yorkstar	684	701	781	722
Heine VII	656	664	750	690

Until now we have only tested technical quality at Svalöf but now we are also interested in starting investigations on nutritional value.

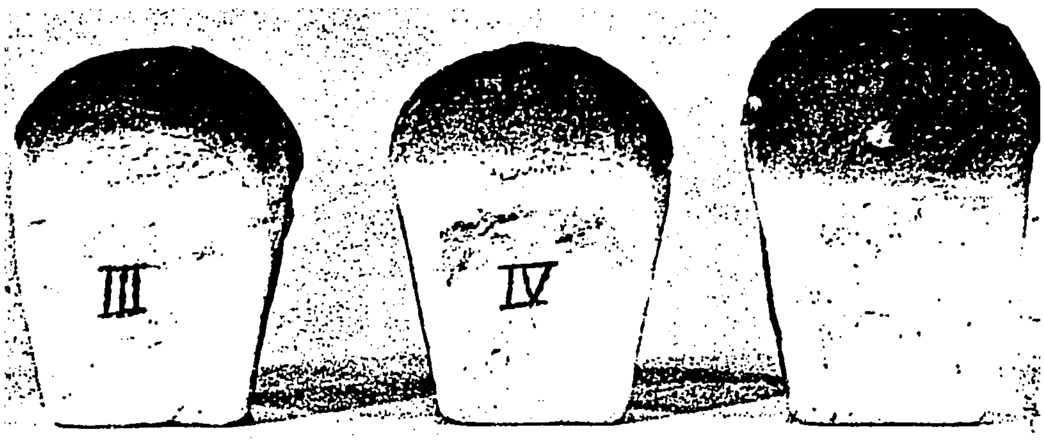

Figure 3.--Form breads of the winter wheat varieties

Starke - Seba - Extrem.

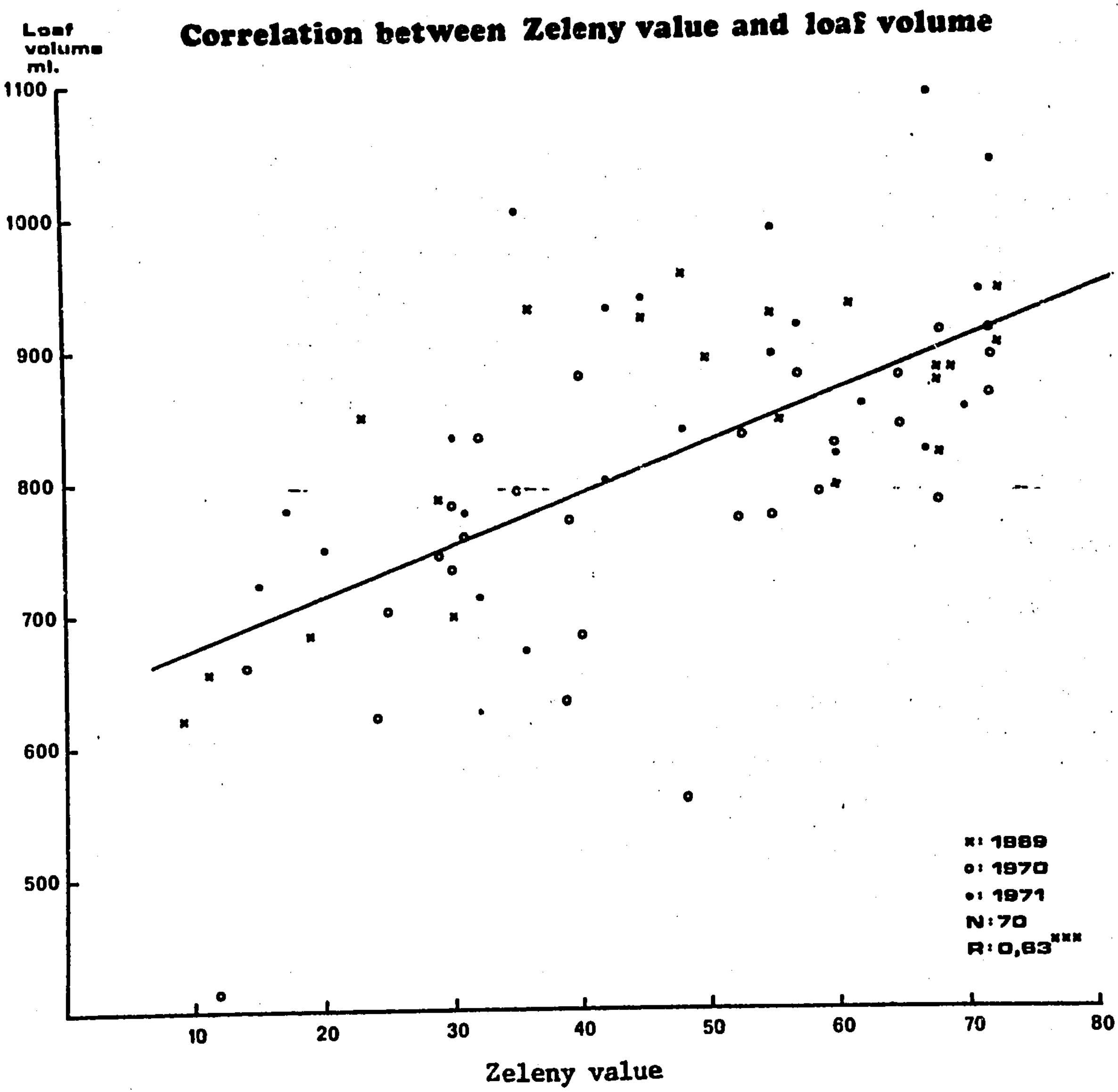

Figure 4.--Correlation between Zeleny value and loaf volume.

ASSOCIATION OF CHARACTERS IN THE IWWPNS GROWN AT WEIHENSTEPHAN, GERMANY

by

G. Fischbeck
West Germany

The IWWPNs were planted at Weihenstephan in 1969-70 and 1970-71. Data to characterize the station, the two seasons and the layout of the trials are summarized in table 1.

The results obtained show very large differences in kernel yield and other characters between the two years (table 2). These differences were caused not only by different weather conditions which favored the development of wheat much more in 1971 than in 1970, but were enhanced to a large extent by foot rots in the 1970 nursery induced by the preceding barley crop compared with field beans in 1971.

From the 1970 nursery, data are available for 12 characters; in 1971 we observed 10 plant-characters. In all characters rather large differences between varieties were found (table 2).

We used these data to study the association of plant characters in both years by calculating the coefficients of correlation between all possible combinations. Such data not only characterize prevailing genotypic correlations within the group of varieties selected for this nursery, but also may indicate the relative importance of the characters studied for adaptation to the prevailing growing conditions, since a wide range of differences occurred in each set of varieties including well-adapted and non-adapted entries as well.

The results obtained are summarized in tables 3 and 4. Calculations were made on a single plot basis (n = 120) as well as with the variety means (n = 30) with the general result (with a few exceptions which will be mentioned later) of reaching the level of significance more often in the first case, but higher r-values in the latter.

In 1971 (table 4) rather low correlations were obtained for kernel yield. This justifies the conclusion that favorable growing conditions offered the opportunity to express genetic differences in yield potential in very different plant types. Nevertheless, the coefficients of correlation indicate higher yields with lateness, higher test weight, and long straw. Diseases, lodging or winter damage did not significantly influence kernel yield. More distinct is the association of earliness, short straw, increasing amount of winter-damage and better resistance towards lodging which characterizes a rather large group of short straw varieties of southern origin. Somewhat below the level of significance there are indications for this type of varieties to be more liable to glume blotch attack.

Table 1. Growing conditions for the IWWPNs at Weihenstephan, Germany.

Latitude: 48°24'
Height above sea level: 467 m NN
Soil type: brown forest soil

Weather conditions:	III	IV	V	VI	VII	VIII	Year
1970 temperature	1.0	5.4	10.4	16.9	16.3	16.1	7.2
rainfall	22.4	79.6	90.6	108.5	80.0	148.4	899.0
1971 temperature	-0.7	8.8	13.5	13.5	17.2	17.7	7.3
rainfall	24.1	37.4	125.6	175.6	45.3	76.1	685.5
long year average							
temperature	3.1	7.8	11.8	15.0	16.6	16.1	7.3
rainfall	42.0	51.0	83.0	107.0	126.0	87.0	814.0

		1969-70	1970-71
Preceding crop		barley	V. faba
fertilization (kg/ha)	N	45	45
	P_2O_5	80	80
	K_2O	160	160
plot size		$2.5m^2$	$1.5m^2$
replications		4	4
rate of sowing (kg/ha)		149	176
drill width (cm)		19	19
date of sowing		10.X.	2.X.
date of emergence		2.-20.VI.	18.V.-9.VI.
beginning of harvest		29.VII.	27.VII.
end of harvest		13.VIII.	10.VIII.

Table 2. Mean values for plant characters in the IWWPNs at Weihenstephan

	1970					1971				
	1	2*	3**	4	5	1	2*	3**	4	5
1. Yield (dz/ha)	22.1	30.9	13.9	34.0	7.5	57.8	70.9	43.0	73.5	39.9
2. Test weight (kg)	76.9	74.9	77.1	80.1	73.4	77.1	77.9	76.4	82.2	63.3
3. Date of heading	160.0	164.8	156.1	171.0	153.5	146.0	150.3	143.3	159.7	138.0
4. Date of ripeness	212.0	217.9	207.1	222.0	205.0	214.0	217.8	212.0	225.0	208.0
5. Height (cm)	89.8	83.3	86.7	109.2	68.0	92.9	95.3	81.0	136.2	59.5
6. Lodging (%) (26 VI.)	45.7	8.7	41.7	82.5	0.0	30.5	26.0	5.5	92.5	0.0
7. Winter survival (%)	76.0	70.7	60.5	90.0	20.0	86.7	87.7	86.5	100.0	73.7
8. Growth type	5.10	3.95	6.95	8.25	2.00	4.30	4.15	4.65	6.00	3.50
9. <u>Cercosporella</u>	2.90	2.40	4.20	6.75	1.00	-	-	-	-	-
10. <u>Ophiobulus</u>	1.80	2.50	3.05	5.00	2.00	-	-	-	-	-
11. Mildew	3.30	3.05	2.75	4.75	1.25	3.20	3.05	3.10	5.00	1.50
12. Leaf rust	4.7	3.0	1.3	4.5	1.0	-	-	-	-	-
13. Glume blotch	-	-	-	-	-	3.5	3.6	3.5	4.5	2.75

1 overall mean
2 mean of the 5 highest yielding varieties
3 mean of the 5 lowest yielding varieties
4 highest variety mean for each character
5 lowest variety mean for each character
* 1970 Heine VII, Cappelle Desprex, Gaines, Felix, San Pastore
1971 Starke, NS611, Heine VII, Yorkstar, NB66425
** 1970 INIA 66, Lerma Rojo 64, NB67730, Scout 66, Stadler
1971 Lerma Rojo 64, NB68513, Sturdy, TX62A4793-7, Parker

Table 3. Correlation (r-values) of characters in the IWWPN, Weihenstephan, 1970.

Y		E		H		L		TW	
E	70**	R	98**	C	51**	C	97**	R	-56**
R	68**	GT	-80**	L	48**	O	64**	E	-54**
GT	-61**	Y	70**	W	44**	R	-54**	Y	-51**
TW	-51**	TW	-54**	O	29	E	-52**	GT	45**
LR	48**	L	-52**	M	-27	W	52**	LR	-35 (**)
L	-34 (-41**)	C	-42**	GT	-18 (*)	H	48**	W	-34 (**)
C	-25 (-33**)	LR	35 (**)			Y	-34 (-41**)	L	28 (**)
O	-24 (-34**)	W	28			GT	32 (**)	M	22 (*)
W	27					LR	-30 (**)		
						TW	28 (**)		

W		LR		C		O	
C	60**	Y	48**	L	97**	L	64**
O	54**	O	-37*	O	64**	C	64**
L	52**	TW	-35 (**)	W	60**	W	54**
H	44**	E	35 (**)	H	51**	LR	-37*
GT	-41*	R	35 (**)	R	-47**	Y	-24 (-34**)
TW	-34 (**)	L	-30 (**)	E	-42*	H	29
E	28 (*)	M	23(*)	LR	-26 (*)	R	-22
Y	27	GT	-23 (*)	Y	-25 (-33**)		
R	25 (*)			GT	20 (*)		

Table 4. Correlation (r-values) of the characters in the IWWPN, Weihenstephan, 1971.

Y		E		R		H	
E	45**	R	76**	E	76**	R	73**
R	32 (**)	H	47**	H	73**	W	67**
TW	29 (**)	Y	45**	W	52**	L	61**
H	23 (**)	W	38*	L	40**	E	47**
M	-26	GT	-32	Y	32 (**)	Y	23 (**)
GT	-20	GB	-27	GB	-32	GB	-29
		L	20 (*)				
		TW	19 (*)				

L		TW		W		GB	
H	61**	Y	29 (**)	H	67**	R	-32
R	40**	W	-22 (*)	R	52**	H	-29
W	41**	E	19 (*)	L	41*	E	-27
GT	-31	GT	-31	E	38*	L	22
E	20 (*)			TW	-22 (*)		
GB	-29			GT	-18		

Y - yield
E - date of heading
R - date of ripeness
H - height
L - lodging (%)
W - winter survival (%)

TW - test weight
LR - leaf rust
C - <u>Cercosporella</u>
O - <u>Ohpiobulus</u>
M - mildew
GT - growth type
GB - glume blotch

** significant at P<0.01 mean of varieties (4 reps) df = 28
* significant at P<0.05 mean of varieties (4 reps)
(**) P<0.01 single plot data df = 118
(*) P<0.05 single plot data

The unfavorable growing conditions in 1970 caused much more disturbance in the expression of genetic yield potential (see table 3). The correlation between kernel yield and late heading or ripening basically leads to the same association of plant characters as described for 1971. In addition, the early, short straw varieties either were more heavily attacked by Cercosporella causing stem break and lodging, or suffered winter damage to a yield decreasing extent. In such thin stands Cercosporella was of minor importance, no lodging occurred, and the kernels of the surviving plants reached higher test weights.

Lodging definitely decreased yield in the 1970 trial, almost completely correlated with degree of Cercosporella attack, highly correlated also with the occurrence of Ophiobulus. Uneven distribution of these diseases within the trial field caused higher r-values between these characters after calculation on a single plot basis than on the basis of variety mean. Low winter damage apparently increased the occurrence of Cercosporella and lodging as well as of Ophiobulus, demonstrating increased infection pressure within the better stands of the more hardy, later and taller varieties of northern origin early in the season. This partially explains the negative correlation between kernel yield and test weight observed in the 1970 trial.

A final remark may be required for interpreting the positive correlation between yield and leaf rust attack. The rust appeared late in the season and did not reach epidemic dimensions. There is a more prevailing appearance on later varieties and also a negative correlation of leaf rust with Ophiobulus. This leads to the interpretation that appearance of leaf rust in this case indicates more healthy plants, not disturbed by Ophiobulus, which also may add to the explanation of the association of higher yield and lower test weight.

I do not want to overemphasize the meaning of the results from only two trials. Nevertheless it seems to be worthwhile to continue this type of study. Extended to all IWWPN trials, they may provide basic information for regionalization in calculating the stability parameters. Determination of yield components, which will be analyzed in our future trials,also may contribute valuable data for interpretation of the results obtained.

The results obtained seem to indicate:

1. the possibility of realizing high yield potential under favorable growing conditions with very different plant types;
2. the extent of modification exerted by adaptational characters if unfavorable growing conditions are to be met.

RESULTS OF THE INTERNATIONAL WINTER WHEAT PERFORMANCE NURSERIES IN 1969 AND 1970 AT S. ANGELO LODIGIANO (ITALY): RELATIONSHIP BETWEEN YIELD AND SOME COMPONENTS

by

A. Alessandroni and M. C. Scalfati
Italy

Important interest for the breeder is a knowledge of the relationships between yield and other plant characters as well as a measure of the influence of environment on such relationships. Therefore, an analysis was conducted in order to obtain pertinent information from data provided by the material of IWWPN grown at S. Angelo Lodigiano in the years 1969 and 1970.

Yield, even considering the importance of qualitative traits, is always a fundamental purpose of breeding programs. As the resultant of a series of factors and conditions, it has been the subject of a large number of researches by breeders.

Investigations have dealt with overall simple correlations of yield with quantitative characters and with environmental components. Yield is mainly correlated with number of heads per m^2, number of seeds per head, number of heads per plant, 1000-seed weight, and head length. (Engledow and Wadham, 1923; Singh and Pratap, 1967; Jha and Ram, 1968; Jain, Khan and Singh, 1969; Tipton, Sagrer and Henderson, 1969.) In recent studies many workers have taken into account morphological and physiological traits, which also play an important role in total yield. (Thorne, 1966; Voldeng and Simpson, 1967; Simpson, 1968; Lupton 1969; Smocek, 1969; Walton, 1969, 1971; Hsu and Walton 1970a, b, 1971).

In connection with the fundamental problem of adaptation, the recognition of characters involved in yield and the study of stability of their expression can be considered important objectives. The varieties included in the IWWPN, to some extent representative of the most important wheat producing countries, and therefore of different origin and pedigree, seemed particularly suitable for a statistical analysis to obtain, in *Triticum vulgare*, either useful indications about environment of the trials or effective responses of general interest about yield and other agronomic traits.

Therefore the objectives of this study can be summarized as follows:

1) Evaluation of the results of the IWWPN at S. Angelo Lodigiano.
2) Study of variability of various characters, and varietal comparisons among the results of two years.
3) Study of the relation between yield and other characters which were scored.
4) Investigation of the contribution to yield of some components as well as the interrelationships among these.

Materials and Methods

The Research Station of S. Angelo Lodigiano is a Section of the Experiment Institute for Cereal Research in Rome. The place, latitude 45° 13' N, longitude 9° 25' E, and altitude 73 m, is in Northern Italy near Milan where the winter is cold and damp and where the species of wheat most widely grown is T. vulgare.

A few climatic conditions, during two years of trials in 1969 and 1970 such as temperature and rainfall from October to July, appear in the figure 1.

In 1969 the general climatic conditions were not very favourable during the winter because of low temperatures after early snowfall in the latter part of November, which caused formation of an ice sheet that persisted until the end of February. The year 1970 was characterized by reduced rainfall after the seeding, but the winter was cold only in December with temperatures constantly under 0° C and a minimum of -12° C. Temperatures were sufficiently high in January and in February to favour tillering.

The characteristics of the trials were those of the international program, a randomized block design with four replications, and plots of 4.50 square meters with a seeding rate of 90 kg/ha, as used in the standard trials. The varieties included in the nurseries numbered 30, of which 28 were winter wheats and 2 were spring wheats. In this study all of the varieties were included because, in our environment, spring wheats may be sown in autumn as well.

The soil, where the trials were made, is sandy loam, of good fertility, and was previously cropped to maize. The seeding date was in both years October 23 during good weather. Emergence was regular except for the variety Blueboy in the second year of the trial.

The fertilizers used were: 100 kg/ha of N, 106 of P_2O_5 and 106 of K_2O. The distribution was 1/3 at seeding with a complex fertilizer 8-24-24, and 2/3 in three subsequent applications, from the stage of the third leaf to the shooting phase with $Ca(NO_3)_2$, NH_4NO_3 and with another complex fertilizer 10-10-10.

The traits scored were the following:

1) Yield of grain: determined from the 4 central rows of the plot, corrected to 12% moisture, and reported in quintals per hectare.
2) Days to flowering: number of days from seeding to the anther extrusion for 50% of heads in the plot.
3) Days to ripening: number of days from seeding to the physiological maturity.
4) Plants per m^2: on the basis of 3 samples of 1 meter per plot.
5) Heads per m^2: on the basis of 3 samples of 1 meter per plot.
6) Heads per plant: on the basis of 3 samples of 1 meter per plot.
7) Head fertility: average from the scoring of 3 samples of 5 heads per plot.
8) Spikelet fertility: scrutinized on the basis of 3 samples of 5 heads per plot.
9) Fertile spikelets per head: average from counting 3 samples of 5 heads per plot.

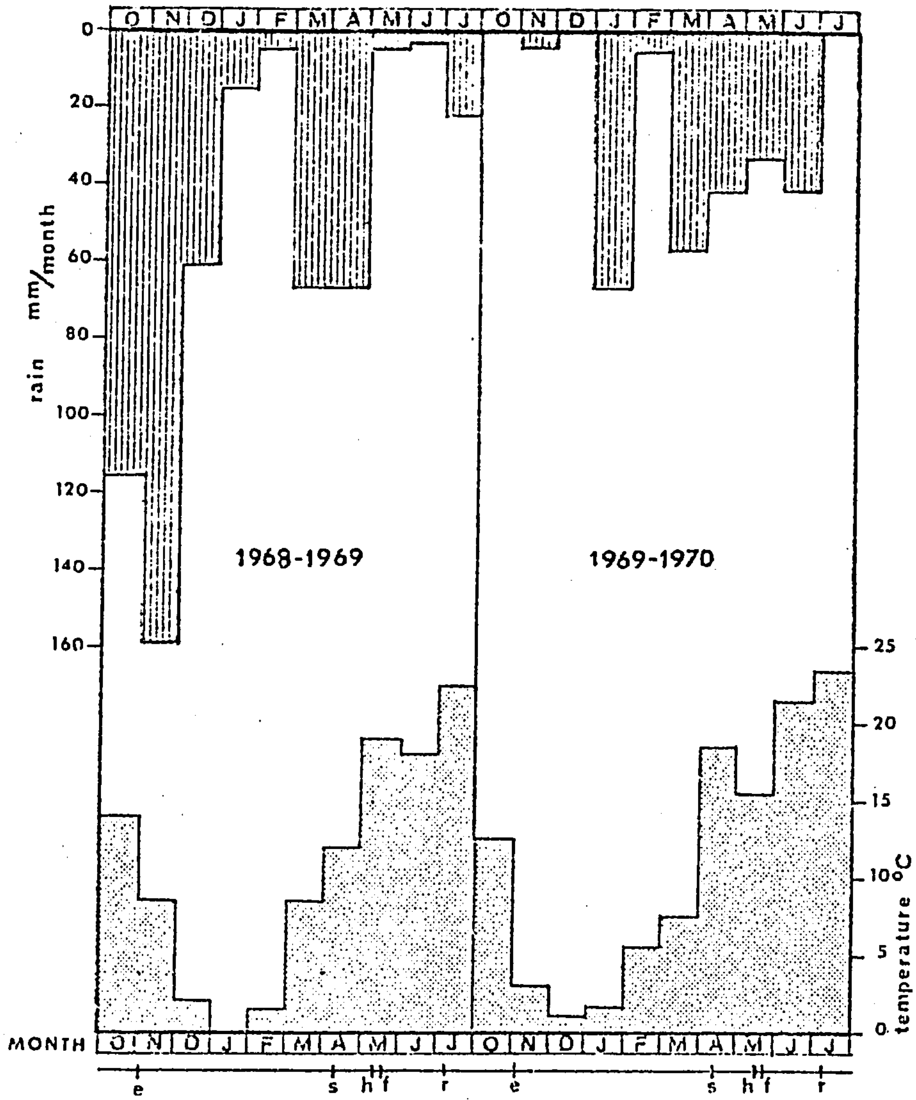

Figure 1. Climatic traits and wheat development phases in the 2-year nurseries at S. Angelo Lodigiano. (e=emergence; s=shooting; h=heading; f=flowering; r=ripening)

10) Straw/seed yield ratio: calculated from the whole products, straw and grain, of 3 samples of 1 meter per plot.
11) Seed weight per head: determined from the seed weight of all the heads counted in 3 samples of 1 meter per plot.
12) 1000-seed weight: determined on the basis of 2 samples of 25 g taken from each plot.
13) Test weight: kg/hl determined on the basis of 2 samples of 25 g obtained from each plot.
14) Shrivelled seeds %: percentage of shrivelled seeds in the total number of seeds of 2 samples of 50 g per plot.
15) Winter survival %: calculated from a count at germination time and at the end of winter in 2 samples of 1 meter per plot.
16) Plant height: measured from the roots insertion to the head.
17) Leaf rust: reported as coefficient of infection as used by Dr. W. Q. Loegering, in the U. S. Department of Agriculture's International Rust Nurseries, and calculated by multiplying the severity in percent by a response value.
18) Stem rust: evaluated like leaf rust.
19) Lodging: reported as a coefficient, calculated in relation to the degree of damage intensity, and to the period in which it occurred.

For statistical treatment the percentage data of shrivelled seeds and rust damage were transformed respectively in $\sqrt{x + 0.5}$ and in ^{2} arc sine $\sqrt{x}$, to improve the normality of the distributions.

Statistical treatment

All data dealing with the characters collected were averaged for each variety and for the two years.

Statistical treatment of data included the calculation of means, standard error, coefficient of variation, and least significant difference.

Variance analysis was performed for each character from two years of data.

The varieties were arranged according to their yield per hectare and significance of differences was estimated by the Duncan's multiple range test.

Also, for the other characters, the significance of differences was evaluated by the Duncan's multiple range test.

To obtain useful information on yield stability, the averages of a single year for each variety were compared using the Student's "t" test.

For the study of the relation between yield and the characters collected, as well as among the characters themselves, all of the simple correlations were calculated.

Subsequently, in order to study the contribution to yield of some components, multiple regression analysis was performed using the 11 variables considered most important, and corresponding to the following numbers of the list: 2-4-5-6-7-8-9-11-12-13-16. For this purpose Newton and Spurrell's method (1967) was applied, as already used in a study of *T. durum* (Alessandroni and Scalfati, 1972). The method permits selection of variables for the best multiple regression equation of yield on the basis of their contribution to yield and in the absence of significant interrelationships among them. The contribution is evaluated by calculation of "elements" ($=b^2i/c_{ii}$), which represent the sum of squares increase contributed by each variable included in the regression equation.

A further selection of the variables was made by determination of the coefficiei R^2.

Because of the magnitude of the calculation work for the statistical analysis a computer was used. The programs for various analyses were written for the IBM 1130-8 K computer available at the Institute.

Results and Discussion

In table 1 2-year averages for yield and other characters are reported for all the varieties. The Duncan's multiple range test is indicated only for yield; for the other characters asterisks indicate the varieties forming the top group Table 2 reproduces the ranks of varieties relative to their yield in each year of the trials. These data reflect the less favourable for the crop in the firs year. Significant variation in the means of the yield with 43.3 q/ha in 1969 and 53.4 q/ha in 1970, was the result of environmental differences that also affected the other characters studied. The "t" test applied to two-year means showed no significant differences for the following traits: seed weight per head, 1000-seed weight, plant height, winter survival, and rust resistance. For all the other characters the differences were significant at the .01 level. The year influence was confirmed also by the results of variance analysis applied to the 2-year pooled data (Table 3).

Significant Variety x Year interaction was detected at .01 level for most of the traits. However, a large amount of variability (significant at .01 level) was found also among varieties which shows that some cultivars are significantl different from others and possess valuable traits.

Examining the ranks relative to single years for the yield, it is possible to see that many varieties behaved in similar way in both years. Considering the two-year data, the statistical evaluation of yield differences revealed seven cultivars with high performance: Timwin, Yung Kwang, Blueboy, Arthur, San Pastore, Yorkstar and Shawnee. To obtain indications of the stability of results for these varieties, the "t" test was separately used for the two-year yield means. The difference was not significant for Yorkstar only.

As to the other characters, of the seven high-yielding varieties, low values were found in straw/seed yield ratio, although they possess only moderately short plant height. A trait important for differentiation is the seed weight per head. A low shrivelling percentage and good resistance to stem rust also appear to be important factors affecting yield.

In the varieties Yung Kwang and Arthur, a very good 1000-seed weight was found. Arthur, with Timwin, showed high values for the number of plants per m^2, and Blueboy for number of heads per plant. It is interesting that this trait was evident in 1970 when Blueboy had very poor emergence but nonetheless made a good yield slightly over the mean.

Table 1. Two-year means for yield and other traits of 30 varieties in the International Winter Wheat Performance Nurseries 1969 and 1970 grown at S. Angelo Lodigiano, Italy.

Cultivar	Yield q/ha	Plants per m^2	Heads per m^2	Heads: per plant	Head fertility	Spikelet fertility	Fertile spikelets per head	Seed wt. per head	1000 seeds wt., g	Test weight kg/hl
Mean 1968-69	43.3	160	418	2.7	31.5	2.0	15.7	1.0	40.9	78.5
Mean 1969-70	53.4	118	488	4.3	35.8	2.2	16.5	0.9	39.4	78.2
Timwin	58.7	150	479	3.3	30.2	1.9	15.6	1.0	42.6	77.9
Yung Kwang	58.0	130	391	3.1	35.3	2.2	15.9	1.3*	49.2*	78.8
Blueboy	57.6	110	394	4.6*	36.4	2.1	17.1	1.3*	40.0	74.0
Arthur	56.5	156*	496	3.3	29.7	2.0	15.0	0.9	49.5*	80.5
San Pastore	56.4	122	354	3.1	42.0	2.6*	16.3	1.3*	45.5	78.2
Yorkstar	54.1	126	363	3.0	42.6	2.2	18.8	1.2*	38.2	72.7
Shawnee	53.7	137	524	3.9	31.0	2.0	15.4	0.8	37.4	81.5
Parker	53.2	146*	612*	4.4*	27.4	1.9	14.4	0.7	38.9	82.8*
Lerma Rojo 64	53.1	141*	415	3.0	31.7	2.3	13.8	1.1	48.8*	80.4
Stadler	52.9	146*	432	3.2	39.0	2.2	18.1	1.0	34.0	79.4
Fertodi 293	52.4	137	466	3.6	30.0	1.9	15.6	0.9	41.7	79.8
Bezostaia	51.6	145*	386	2.7	32.0	1.9	1[illegible].8	1.2*	47.2	81.8*
Sturdy	51.1	159*	553	3.6	31.2	2.3	13.7	0.8	40.9	79.6
Heine VII	51.0	128	347	2.9	39.3	2.1	18.4	1.2*	39.7	73.5
Benhur	50.0	137	413	3.3	34.9	2.2	15.9	1.1	39.8	80.7
Triumph 64	48.8	148*	538	3.7	26.5	1.9	13.3	0.7	49.5*	80.9
Gage	47.3	150*	521	3.6	29.3	1.9	14.9	0.8	37.8	80.1
Purdue 4930 A6-28-2-1	45.8	141	396	2.9	33.2	2.1	16.1	0.9	40.3	81.7
Scout 66	45.6	140	529	3.9	26.3	1.9	13.8	0.7	41.7	80.4
Bankuti 1201	45.1	135	439	3.5	31.4	2.0	15.5	0.9	40.8	81.4
Cappell Desprez	44.5	115	352	3.1	33.0	1.9	16.9	1.1*	44.3	73.2
Atlas 66	44.3	161*	470	3.1	32.6	2.1	15.6	0.8	37.3	77.6
Riley 67	44.2	137	435	3.4	34.1	2.2	15.8	0.9	34.7	77.5
Gaines	43.3	152*	573	3.9	36.9	2.1	17.2	0.8	29.4	71.2
Felix	41.4	112	352	3.2	43.0	2.1	20.8	1.1*	33.4	71.4
INIA 66	41.1	141*	397	2.8	36.3	2.6*	13.8	1.0	41.9	79.3
Lancer	39.5	145*	637*	4.5*	25.5	1.7	15.4	0.5	34.0	79.0
Winalta	39.0	136	545	4.2*	28.8	1.9	14.9	0.7	38.3	81.3
Odin	35.6	140	324	2.5	49.9*	2.3	21.8	1.1*	38.3	72.3
NB67730	35.3	140	461	3.4	29.1	1.9	15.0	0.7	36.7	80.0

Table 1. (continued)

Cultivar	Yield q/ha	Plants per m²	Heads per m²	Heads per plant	Head fertility	Spikelet fertility	Fertile spikelets per head	Seed wt. per head	1000 seeds wt., g	Test weight kg/hl
Mean	48.4	139	453	3.4	33.6	2.1	16.1	1.0	40.1	78.3
Standard error	0.64	1.96	6.73	0.07	0.48	0.02	0.14	0.02	0.37	0.23
Coefficient of variation	20.5%	21.9%	23.0%	31.3%	22.3%	14.6%	13.8%	26.1%	14.4%	4.6%
Least significant difference, 5%	4.5	16.4	44.5	0.4	4.2	0.2	0.9	0.1	1.6	1.1

- The yields unjoined differ significantly at the .05 level of Duncan's Multiple Range test.

* Varieties of the top group on the basis of Duncan's Multiple Range test (at the .05 level).

Table 1. (continued)

Cultivar	Shrivelled seeds %	Days to flowering	Days to ripening	Plant height cm	Straw/seed yield ratio	Lodging coef.	Winter survival %	Rust coef. leaf	Rust coef. stem
Mean 1968-69	3.1	209	255	105	2.0	2.3	95.4	0.6	1.0
Mean 1969-70	3.8	217	257	104	1.8	4.1	95.0	0.7	0.9
Timwin	5.2*	213	258	83	1.4*	2.6	95.8*	7.9	0.5*
Yung Kwang	11.4	210	258	108	1.6*	3.4	95.3*	26.3	3.8*
Blueboy	18.9	215	259	92	1.7*	0.0*	93.7*	1.8*	43.3
Arthur	8.0	210	256	106	1.6*	3.6	93.2	8.3	1.9*
San Pastore	5.2*	207	251	96	1.4*	0.3*	93.0	74.0	57.5
Yorkstar	15.7	215	258	103	1.7*	2.8	94.5*	31.3	50.0
Shawnee	5.4*	213	257	117	1.7*	2.9	93.2	1.1*	0.0*
Parker	4.5*	210	256	100	1.9	1.6*	96.5	6.3	22.0
Lerma Rojo 64	9.8	205	249	88	1.4*	0.7*	92.4	7.5	0.9*
Stadler	7.0*	212	256	116	1.9	3.8	96.6*	41.0	72.5
Fertodi 293	6.7*	212	255	120	1.8	3.0	94.6*	1.8*	3.8
Bezostaia	8.8	210	257	93	1.6*	0.8*	94.7*	0.5*	0.9*
Sturdy	16.0	209	255	74	1.8	0.4*	96.4	2.8*	2.3*
Heine VII	22.0	220	260	103	1.7*	0.7*	94.6*	60.5	45.8
Benhur	4.4*	208	254	108	1.9	1.5*	93.7*	4.3*	36.0
Triumph 64	6.6*	209	252	113	1.9	6.5	97.1*	1.9*	12.3
Gage	11.9	213	255	113	1.9	5.5	96.0	10.0	9.8
Purdue 4930 A6-28-2-1	3.1*	211	255	123	2.2	2.1	94.1*	3.1*	0.9*
Scout 66	10.3	211	256	113	1.9	7.7	95.4*	3.3*	1.8*
Bankuti 1201	5.6*	214	258	128*	2.2	5.5	95.5*	24.5	45.0
Cappell Desprez	30.5	221	261	95	2.4	1.3*	96.6*	3.0*	58.5
Atlas 66	11.8	213	259	127*	2.5	8.5	94.7*	2.3*	2.0*
Riley 67	7.9	212	253	106	1.7*	4.4	96.9*	47.5	69.5
Gaines	41.9	216	256	73*	1.9	0.1*	96.5*	6.1	74.0
Felix	28.6	221	259	92	2.1	0.0*	96.0*	74.5	87.0
INIA 66	22.5	203*	248*	73*	1.4*	0.3*	92.3	2.3*	2.9*
Lancer	12.6	214	257	116	2.4	9.9	96.3*	7.0	5.6
Winalta	10.1	216	258	115	2.1	7.6	95.8*	34.3	17.0
Odin	45.7	224	263	121	2.5	1.3*	96.1*	2.5*	83.8
NB67730	10.8	211	255	122	2.4	7.3	95.9*	5.3*	6.4

Table 1. (concluded)

Cultivar	Shrivelled seeds %	Days to flowering	Days to ripening	Plant height cm	Straw/seed yield ratio	Lodging coef.	Winter survival %	Rust coef. leaf	Rust coef. stem
Mean	3.4[1]	213	256	104	1.9	3.2	95.1	0.7[2]	0.9[2]
Standard error	0.10	0.40	0.25	1.04	0.03	0.22	0.21	0.05	0.06
Coefficient of variation	44.5%	2.9%	1.5%	15.5%	24.4%	-	3.4%	-	93.%
Least significant difference, 5%	0.7	0.4	0.5	4.0	0.3	1.4	2.9	0.2	0.2

- The yields unjoined differ significantly at the .05 level of Duncan's Multiple Range test.

* Varieties of the top group on the basis of Duncan's Multiple Range test (at the .05 level).

[1]Mean of data transformed $\sqrt{x + 0.5}$

[2]Mean of data transformed 2 arc sine $\sqrt{x}$

Table 2. Mean yields in 1968-69 and 1969-70.

Yield (q/ha) 1968-1969

Cultivar	Mean	2-year rank
Blueboy	61.3	3
Timwin	54.5	1
Yorkstar	50.7	6
Heine VII	49.2	14
Arthur	48.3	4
Yung Kwang	48.3	2
S. Pastore	48.1	5
Stadler	47.8	10
Parker	46.7	8
Sturdy	46.6	13
Fertodi 293	46.3	11
Bezostaia	45.3	12
Benhur	44.4	15
Gaines	44.1	24
Lerma Rojo	43.9	9
Gage	43.2	17
Shawnee	42.7	7
Atlas 66	42.6	22
Triumph 64	41.6	16
Bankuti 1201	39.2	20
Felix	39.1	25
Capelle Desprez	38.8	21
Scout 66	38.8	19
Riley 67	38.6	23
Purdue 4930 A6-28-2-1	38.5	18
Winalta	37.1	28
Odin	35.7	29
Lancer	34.9	27
NB67730	33.3	30
INIA 66	30.5	26
Mean	43.3	

Yield (q/ha) 1969-1970

Cultivar	Mean	2-year rank
Yung Kwang	67.7	2
Shawnee	64.8	7
Arthur	64.7	4
S. Pastore	64.7	5
Timwin	63.0	1
Lerma Rojo	62.4	9
Parker	59.8	8
Fertodi 293	58.5	11
Stadler	58.0	10
Bezostaia	57.9	12
Yorkstar	57.6	6
Triumph 64	56.0	16
Sturdy	55.7	13
Benhur	55.6	15
Blueboy	54.0	3
Purdue 4930 A6-28-2-1	53.1	18
Heine VII	52.9	14
Scout 66	52.3	19
INIA 66	51.6	26
Gage	51.5	17
Bankuti 1201	51.1	20
Capelle Desprez	50.2	21
Riley 67	49.7	23
Atlas 66	45.9	22
Lancer	44.2	27
Felix	43.7	25
Gaines	42.6	24
Winalta	40.9	28
NB67730	37.2	30
Odin	35.5	29
Mean	53.4	

- The yields unjoined differ significantly at the .05 level Duncan's Multiple Range test.

Table 3. Summary of the variance analyses[1].

Traits	Variety	Year	Interaction V x Y	Error
Degrees of freedom	29	1	29	177
Yield	17.21**	294.04**	4.44**	2075.682
Days to flowering	1133.14**	27092.90**	24.75**	0.148
Days to ripening	378.99**	2208.39**	100.84**	0.227
Plants per m^2	4.69**	378.04**	3.41**	276.866
Heads per m^2	27.80**	145.59**	3.31**	2041.508
Heads per plant	14.01**	978.76**	6.18**	0.158
Head fertility	14.44**	64.39**	2.62**	17.842
Spikelet fertility	8.06**	47.05**	2.11**	0.042
Fertile spilelets per head	35.79**	48.46**	2.30**	0.877
Straw/seed yield ratio	8.37**	21.68**	0.79	0.105
Seed wt per head	17.74**	2.72	1.72	0.020
1000 seeds wt	84.89**	46.26**	7.20**	1.755
Test wt	76.57**	2.68	4.16**	1.245
Seeds shrivelled, %	23.38**	67.53**	9.09**	0.470
Winter survival, %	1.79**	1.22	1.97**	8.702
Plant height	123.23**	0.13	3.58**	16.123
Leaf rust	47.28**	21.06**	10.67**	0.063
Stem rust	93.97**	2.91	12.75**	0.055
Lodging	31.57**	98.42**	4.51**	2.096

[1]For the source of variations "F" values are reported, for the error the mean square.

** Significant at the 1% level.

As to the yield of other varieties, good results were obtained with Parker (high number of heads per m^2 and with a good shrivelling resistance), Stadler, and Lerma Rojo which certainly was more adapted to this environment than INIA, the other spring variety. The varieties that exhibited poor yielding capacities during the two years of nurseries were N.B.67730, Odin, Winalta, and Lancer. Their poor performance appears to be the result of low number of heads per m^2, head fertility, seed weight per head, and susceptibility to shrivelling.

Yield Components

In table 4 are reported simple correlation coefficients computed between yield and other characters and between combinations of the characters themselves, calculated on the basis of the two-year mean data.

1000-seed weight and head weight which were significant at the .01 and .05 level respectively, appear associated with yield. Significant and inverse correlations were found with straw/seed ratio, lodging and shrivelled seed percentage.

Relationships among other traits such as flowering and ripening are closely correlated and the same appear concomitantly associated with other characters. For example, earliness shows a positive influence on 1000-seed weight and on test weight, while lateness in flowering and in ripening appears associated with higher number of fertile spikelets per head, with higher straw/seed ratio, and with shrivelled seeds percentage. Late flowering increased also the susceptibility to stem rust.

There was also a close association between number of heads per m^2 and number of plants per m^2 and number of heads per plant. Moreover, these three characters appeared to be negatively correlated with head and spikelet fertility, with number of fertile spikelets per head and with seed weight per head.

Interesting relationships were detected for seed weight per head that, positively associated with yield, is affected by fertility values and is not associated with 1000-seed weight. Also, it shows the same negative relations provided by the fertility traits as mentioned above, with both head and plant number per m^2, with head number per plant, and with lodging.

Other associations, as was anticipated, occurred between head fertility and seed shrivelling, and between plant height with straw/seed yield ratio and lodging. As regards leaf rust and stem rust, these traits appear closely correlated and have shown a real influence on test weight. Stem rust influenced 1000-seed weight as well as shrivelled seed percentage. Other unexpected associations were found for number of plants and heads per m^2 and for fertility traits.

The multiple regression analysis was performed using only 11 characters in the first regression equation. In table 5 are reported data relative to this analysis. The regression was detected to be significant at the .01 level. The multiple correlation with yield was 0.867. The "t" test significance of the partial regression coefficients indicated the importance of the component seed weight per head, and was confirmed by the other regression data, $R^2 = 0.676$ and the highest value in the sum of squares increase (b^2i/c_{ii} = 19428.98).

Table 4. Correlations between the means of 19 variables for the 'International Winter Wheat Performance Nurseries' grown at S. Angelo Lodigiano, Italy, in 1969 and 1970.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2	-.33																	
3	-.14	.89**																
4	-.06	-.37*	-.25															
5	-.08	-.21	-.16	.61**														
6	.04	-.00	.03	.01	.75**													
7	-.04	.41*	.26	-.44*	-.75**	-.57**												
8	.14	-.30	-.42*	-.18	-.55**	-.52**	.66**											
9	-.15	.76**	.63**	-.47**	-.61**	-.39*	.84**	.16										
10	-.72**	.54**	.54**	.03	.13	.11	-.06	-.46**	.24									
11	.44*	.07	.08	-.61**	-.88**	-.59**	.67**	.57**	.50**	-.46**								
12	.56**	-.54**	-.37*	-.01	-.13	-.17	-.35	.07	-.51**	-.48**	.32							
13	.16	-.68**	-.48**	.47**	.44*	.20	-.70**	-.27	-.75**	-.12	-.42*	.44*						
14	-.43*	.63**	.44*	-.25	-.26	-.19	.54**	.21	.58**	.25	.21	-.42	-.84**					
15	-.36*	.45*	.40*	.16	.36	.26	-.16	-.50**	.12	.50**	-.46**	-.39	-.16	.22				
16	-.26	.21	.31	.06	.05	.04	-.16	-.43*	.05	.59**	-.30	-.14	.32	-.35*	.14			
17	.05	.26	.07	-.45**	-.33	-.15	.47**	.25	.44*	-.14	.32	-.17	-.35*	.07	.09	-.02		
18	-.23	.60**	.35	-.50**	-.41	-.13	.71**	.26	.75**	.22	.32	-.55**	-.70**	.53**	.32	-.06	.59**	
19	-.38*	-.02	.09	.35*	.52**	.35*	-.57	-.57	-.37*	.49**	-.66**	-.09	.37*	-.31	.35*	.68**	-.12	-.32

1 - yield
2 - days to flowering
3 - days to ripening
4 - plants per m^2
5 - heads per m^2
6 - heads per plant
7 - head fertility
8 - spikelet fertility
9 - fertile spikelets per head
10 - straw/seed yield ratio
11 - seed wt per head
12 - 1000 seeds wt
13 - test wt
14 - shrivelled seeds %
15 - winter survival %
16 - plant height
17 - leaf rust
18 - stem rust
19 - lodging

* significant at the 5% level
** significant at the 1% level

Table 5. Multiple regression of yield on 11 components.

	R^2	b	t	b^2_i/c_{ii}
Days to flowering	-0.007	0.312	0.066	7.700
Plants per m^2	-0.028	2.541	1.560	4336.037
Heads per m^2	-0.052	0.514	1.040	1925.454
Heads per plant	0.022	69.136	1.402	3499.064
Head fertility	0.008	- 2.263	- 0.062	9.154
Spikelet fertility	0.022	51.102	0.098	16.952
Fertile spikelets per head	-0.045	10.045	0.137	33.412
Seed wt per head	0.676	500.043	3.303**	19428.984
1000 seeds wt	0.165	3.621	1.027	1880.049
Test wt	0.025	3.040	0.572	581.917
Plant height	-0.034	0.564	0.609	660.575

Y Intercept	-1514.98
Multiple R	0.867
F test	4.98**

**Significant at the 1% level

For other traits, the comparison of the magnitude of the determination coefficients (R^2) revealed that only the entry into stepwise regression function of 1000-seed weight increased moderately the multiple correlation coefficient. The differences in R^2 values determined by the other components were negligible or negative.

The selection of variables were performed proceeding from every combination with "n" variables to a following series with "n-1" variables, excluding one after the other, all those for which the contribution in the regression analysis was masked by interrelationships. This procedure, through a large series of analyses, led to a strong reduction of variables to be included in the regression equation.

Further selection by the determination coefficient R^2 pointed out some models suitable for yield estimate such as seed weight per head associated with one of the following variables: number of heads per m^2, number of heads per plant, head fertility, number of fertile spikelets per head, and test weight. The multiple regression data relative to these combinations, are reported in table 6 and indicate that the best model, on the basis of our data and according to the method applied in the yield function calculation, is seed weight per head - number of heads per m^2 with the highest value for the multiple correlation coefficient ($R = 0.783$).

The results, moreover, support the assumption that seed weight per head is the most important factor determining yield. The importance of this variable has already been pointed out in the course of this work. The mean data have indicated it as the most frequently responsible for the best yields, and the correlation analysis has revealed its direct association with yield. The variance analysis, which shows the stability of expression of seed weight per head, should also be considered.

Conclusions

The results of the IWWPN at S. Angelo Lodigiano (Italy) with varieties representative of winter wheats from important producer countries, have isolated some varieties with very similar and remarkable performance such as Timwin, Yung Kwang, Blueboy, Arthur, Yorkstar and Shawnee. Their performance is not significantly different from that of the San Pastore variety still widely grown in Italy. Yorkstar, particularly, with the high yields which were not statistically different in two years was shown to have more stability than the other varieties.

Considering the behavior of these varieties with regard to agronomic traits, the yield results appear dependent on the highest value in seed weight per head, or on 1000-seed weight, or on number of plants per m^2, or, as for Blueboy, on number of heads per plant.

From a detailed study of the relations between the yield and its components on the basis of simple correlations and the multiple regressions, the most important component appears to be variable seed weight per head. Also, the best model for yield estimate is represented by: seed weight per head-number of heads per m^2.

These results, which confirm a similar conclusion achieved in *Triticum durum*, are additional information for the cereal worker and appear useful for breeding programs in *Triticum vulgare*, especially if we consider the high heterogeneity of the genotypes included in the nurseries.

Table 6. Multiple regressions of yield on its most important components.

Variables	R	F	R^2	b	t	b^2i/c_{ii}
Seed wt per head	0.783	21.42**	0.613	533.865	6.510	78622.063
Heads per m^2			0.109	1.076	5.403**	54152.992
Seed wt per head	0.576	6.70**	0.313	231.381	3.651**	42746.852
Heads per plant			0.019	57.622	2.347*	17665.332
Seed wt per head	0.637	9.21**	0.380	281.255	4.283**	52213.047
Head fertility			0.025	- 7.306	-3.089**	27223.082
Seed wt per head	0.617	8.29**	0.305	225.330	3.945**	46269.164
Fertile spikelets per head			0.076	-16.733	-2.840**	23997.031
Seed wt per head	0.586	7.05**	0.275	203.089	3.610**	41074.984
Test wt			0.608	8.199	2.464*	19141.578

* Significant at the 5% level
** Significant at the 1% level

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DETERMINATION OF WET GLUTEN AND SWELLING NUMBER IN AUSTRIA

by

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In Austria quality wheat is produced under contract on an acreage of 55.000 hectares. The contracting parties are on the one hand, individual farmers and on the other hand, the cooperative and private commercial firms. The contracts have to be made according to governmental regulations and are supervised by the Agricultural Chambers (Verordnung, 1968). Storage and distribution of certified quality wheat is supervised by governmental authorities. The producer of quality wheat has a right to get additional payment.

For production of quality wheat a few selected varieties are approved, for example Probstdorfer Extrem, Record, and Erla Kolben. Use of certified seed is prescribed. For each lot of quality wheat, wet gluten content and gluten quality are determined (Waltl 1971). The official method for gluten quality evaluation is the determination of the swelling number (Berliner and Koopmann 1929). As minimum standards for certified quality wheat, 28% wet gluten and a swelling number (Q_0) of 14 ml have been fixed (Verordnung 1968).

Because of the wheat market regulations, breeders of quality wheat varieties have to rate their material and prospective crossing parents according to wet gluten content and swelling number evaluations. Wet gluten and swelling number show close correlations to baking tests (Waltl 1971).

Table 1 shows the respective figures for the 3rd International Winter Wheat Performance Nursery grown at the Fuchsenbigl Experiment Station of the Federal Institut of Plant Growing and Seed Testing in Vienna. The trial field at Fuchsenbigl is located near Vienna and has heavy soils and an average annual precipitation of 541 mm. The vegetation year 1970-71 was characterized by severe drought and a total precipitation of 436 mm.

Acknowledgement

Quality analyses were made by Dr. K. Waltl, Federal Institute for Plant Growing and Seed Testing in Vienna.

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Table 1. Quality determinations in 3rd IWWPN, Vienna, 1971.

Variety	Wet gluten %	Swelling number Q_o/Q_{30}	1000-kernel weight g dry matter
Backa	39.4	10/3	38.2
Red Star	38.6	8/3	34.6
Sava (NS611)	35.4	18/12	31.3
Strampelli	38.8	14/10	33.6
Starke	47.8	9/2	35.1
Hokuei	37.6	12/6	31.9
Probstdorfer Extrem	48.0	16/12	35.2
NB66425	37.2	21/17	27.7
TX62A4793-7	36.6	13/9	27.0
NB68513	47.8	22/18	28.9
Winter Triticale	37.9	16/12	47.4
Vakka	41.0	18/14	32.7
Jyva	39.8	16/12	32.8
Bezostaja 1	33.6	23/18	41.3
Blueboy	33.4	13/9	37.7
Timwin	31.4	12/8	35.1
Sturdy	34.6	18/13	30.2
Parker	37.4	14/10	31.6
Fertödi 293	40.4	18/14	39.0
Yung Kwang	40.8	11/7	40.6
San Pastore	37.4	3/0	36.4
Atlas 66	50.8	8/2	34.0
Benhur	41.6	18/12	38.9
Arthur	38.8	20/16	38.1
Scout 66	38.4	20/15	35.3
Heine VII	33.4	2/0	38.8
Yorkstar	33.6	8/2	37.1
Triumph 64	38.6	24/20	33.0
Felix	31.0	26/22	36.6
Lerma Rojo 64	44.0	12/8	37.0

THE INTERNATIONAL WINTER WHEAT PERFORMANCE NURSERY IN CZECHOSLOVAKIA

by

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On the basis of a personal discussion with Dr. Johnson in Lincoln, Nebraska, in February 1970, we arranged the cooperation of Czechoslovakia in growing the IWWPN. We started last fall in October. I have the pleasure of giving you partial information on the conditions of our trials at this time.

The nursery is grown at the Central Checking and Examining Institutes for Agriculture in Prague and Bratislava at two agroecologically different stations in Sedlec, Bohemia and Malé Ripňany, Slovakia. Sedlec is situated 10 kilometres north of Prague in very mild climatic conditions influenced by the Atlantic climate. Malé Ripňany is located 16 kilometres north of our Agricultural University in Nitra, Slovakia. In my presentation I will discuss this place. It is in an area influenced by a continental climate. It is 140 km NE of Vienna, 200 km N of Mártonvásár, 400 km N of Novi Sad and 400 km E Sedlec.

The characteristics of Malé Ripňany are as follows: The longitude is 17° 59' 30" E, the latitude is 40° 29' 30" N, the elevation is 172 m, the 50-year precipitation average is 600 mm, the average temperature is 92°C, and the soil is heavy sand loam. The depth of arable soil can be as much as 60 cm.

The agrochemical characteristic of the experimental field is:

The soil reaction	The need to lime	The content of reasonable nutrients mg/1 kg of soil		
pH/KCl	CaO a/ha	P_2O_5	K_2O	MgO
6,4	5	18	160	292

The nursery followed alfalfa.

Fertilizer application from 1969:

Year	Crop	Nutrients in kg/ha		
		N	P_2O_5	K_2O
1969	Alfalfa	50	80	120
1970	Alfalfa	50	85	120
1971	Wheat-nursery	30 + 30	54	130

Half of Nitrogen was applied before the seeding time as ammonium sulfate and half as calcium nitrate at the end of the winter at the change from the 2nd to the 3rd stage of morphogenesis.

Cultural practices:

August 10	Tillage, dragging
September 5 to October 8	fertilization, double dragging double harrowing
October 8	seeding
March 17	light harrowing
April 10	weed control with the herbicide "Dicotex"

The conditions of our tiral can be seen in Tables 1, 2, and 3. From these tables you will see that we had exceptionally favorable climatic conditions. The conditions of the wheat trials are very good and we are expecting useful results. My presentation will include several slides from the trials at Malé Ripňany.

At the present time, we have recorded large differences in the winter survival, mildew infections, height of plants, and the beginning of flowering. These differences may be seen in Tables 2 and 3.

For the next trials we recommend:

1. Inclusion of the new Soviet high yielding cultivars, Kavkaz, Aurora, Jubilejnaja, and Iljičovka, in the fifth nursery.
2. The fertilization to be fixed on a yield of 60 q/ha.
3. Results should be completely elaborated in relation to agroecological conditions. The results should be extended to all collaborators.
4. Provide genetic and agronomic characteristics of all cultivars of the nursery.
5. The next conference, if possible, should be held in a South-east European country in order to make a visit to all experimental places in a distance of 500 km.

Table 1.

Precipitations / decade - mm

Decade / mm	VIII.	IX.	X.	XI.	XII.	I.	II.	III.	IV.	V.	Remark
1 - 10	4.6	5.3	---	5.1	10.4	25.8	1.0	22.7	8.4	52.9	Very good for vegetative growth and diseases
11 - 20	4.0	1.2	---	7.6	7.4	0.7	4.7	1.5	58.5	63.1	
21 - 30/31/	17.1	31.6	3.0	17.8	13.9	14.3	2.6	2.9	8.6	20	
Summary	30.7	38.1	3.0	30.5	31.7	40.8	8.3	27.1	75.5	135.0	August-May 420.7
50 year average	60	52	52	54	48	38	36	40	42	64	August-May 479
%	51.2	73.3	0.6	56.5	66.0	131.6	23.1	67.7	179.8		

Average decade temperature °C

Decade °C	VIII.	IX.	X.	XI.	XII.	I.	II.	III.	IV.	V.	Remark
1 - 10	22.9	13.9	9.4	8.1	2.6	1.6	4.3	7.2	11.3	13.2	
11 - 20	20.5	11.0	8.1	4.5	2.5	-4.1	4.4	5.0	11.6	12.9	
21 - 30/31/	18.2	14.7	6.6	-1.4	2.2	-1.5	6.9	7.4	8.5		
Monthly average	20.4	13.2	8.0	3.8	2.4	-2.6	5.1	6.6	10.2		
50 year average	18.6	14.8	9.5	4.2	0.3	-2.6	-0.8	3.6	9.2	14.7	
warmer - w	w	-	-	-	w	-	w	w	w	-	
colder - c	-	c	c	c	-	-	-	-	-	c	

Table 2. Winter survival.

Cultivar	Group	Winter survival % at Malé Ripňany Slovakia	 % at Sedlec Bohemia
Mironovská 808	90-100%	99.8	100
Zora		97.4	100
Jubilar		96.2	100
Kavkaz		94.8	100
Starke		92.7	100
Dacia		92.4	85
Bezostaja		91.4	100
Maris Nimrod		90.4	100
Blueboy		90.2	90
Diplomat	80-90%	88.4	100
NB 68513		88.4	100
Probstdorfer		86.3	100
Centurk		86.1	100
Hokuei		85.6	100
TX 62A 4793-7		84.8	100
Jyva	70-80%	79.1	85
Clarion		78.2	80
Zenith		74.8	100
Moldavia		73.9	80
Caribo		72.2	100
Carifen 2		71.8	85
Rusalka		70.6	85
Vakka		70.2	100
Zg	60-70%	69.4	85
Kirac		69.4	80
Sava		67.3	75
Bačka		66.4	80
NE 701132		64.2	100
-	50-60%	--	--
Atlas 66	40-50%	46.3	75
Marimp 3	30-40%	34.5	45
-	20-30%	--	--
-	10-20%	--	--
Lilifen	0-10%	8.1	70
Victor I.		6.6	20
Strampelli		5.6	45
Lerma Rojo		0.8	40

Table 3. Preliminary agronomic data for cultivars grown in the Fourth International Winter Wheat Nursery in 1972 at Malé Ripňany - Slovakia - Czechoslovakia.

Cultivar	Germination	Fall growth speed	Tillering-date beginning	Winter survival	Spring growth speed	Beginning of jointing	Beginning of boot	Mildew
Hokuei	22.10.	6	10.1.	85.6	6	19.4.	25.5.	98.3
Bezostaja	23.10.	8	10.1.	91.4	8	16.4.	23.5.	86.5
Probstdorfer	23.10.	7	10.1.	86.3	6	17.4.	29.5.	54.1
Blueboy	22.10.	8	9.1.	90.2	7	19.4.	23.5.	97.6
TX 62A4793-7	24.10.	8	9.1.	84.8	8	16.4.	21.5.	96.5
Atlas 66	22.10.	6	8.1.	46.3	5	20.4.	26.5.	40.1
NB 68513	22.10.	6	10.1.	88.4	6	15.4.	24.5.	53.2
Jyva	23.10.	5	9.1.	79.1	6	19.4.		86.3
Centurk	25.10.	7	10.1.	86.1	7	18.4.	24.5.	24.6
Vakka	22.10.	6	10.1.	70.2	7	17.4.		95.3
Starke	22.10.	6	11.1.	92.7	6	18.4.		31.7
Sava/NS 611/	24.10.	6	7.1.	67.3	7	16.4.	22.5.	1.2
Strampelli	23.10.	7	6.1.	5.6	3	20.4.	24.5.	17.4
Lerma Rojo 64	24.10.	7	8.1.	0.8	3	20.4.	23.5.	23.1
Bačka	22.10.	7	7.1.	66.4	7	16.4.	21.5.	1.3
Clarion	24.10.	6	7.1.	78.2	5	17.4.		16.1
Victor I.	22.10.	6	7.1.	6.6	3	17.4.	24.5.	1.0
Marimp 3	22.10.	6	8.1.	34.5	7	17.4.	20.5.	46.3
Dácia	22.10.	8	7.1.	92.3	7	15.4.	20.5.	58.4
Zg/5994/66	23.10.	8	7.1.	69.4	6	17.4.	19.5.	0.8
Maris Nimrod	23.10.	7	9.1.	90.4	5	18.4.	31.5.	0.6
Zenith	23.10.	8	8.1.	74.8	6	19.4.	31.5.	5.4
Rusalka	23.10.	7	5.1.	70.6	8	15.4.	13.5.	2[illegible].8
Caribo	23.10.	7	10.1.	72.2	6	19.4.		71.4
Diplomat	22.10.	7	11.1.	88.4	6	16.4.		82.3
Kirac	24.10.	7	8.1.	69.4	5	17.4.	26.5.	98.9
Lilifen	22.10.	7	7.1.	8.1	4	17.4.	26.5.	61.3
NE 701132	23.10.	8	7.1.	64.2	7	16.4.	24.5.	11.4
Carifen 12	22.10.	6	10.1.	71.8	7	18.4.	29.5.	97.6
Moldavia	23.10.	8	5.1.	73.9	7	16.4.	17.5.	69.5
Kavkaz	24.10.	9	9.1.	94.8	8	17.4.	29.5.	0
Mironovská	24.10.	7	8.1.	99.8	7	16.4.	28.5.	36.3
Jubilar	24.10.	7	11.1.	96.2	7	18.4.		24.7
Zora	22.10.	8	10.1.	97.4	8	17.4.		67.6

Table 4. Preliminary agronomic data for cultivars grown in the Fourth International Winter Wheat Performance Nursery in 1972 at Sedlec - Bohemia - Czechoslovakia.

Cultivar	Germination	Fall growth speed	Tillering-date beginning	Winter survival	Spring growth speed	Beginning of jointing
Hokuei	5.11.	1	19.3.	100	2	5.5.
Bezostaja	6.11.	1	20.3.	100	1	1.5.
Probstdorfer Extrem	4.11.	2	23.3.	100	2	3.5.
Blueboy	3.11.	2	25.3.	90	1	1.5.
TX 62A 4793-7	4.11.	1	27.3.	100	2	2.5.
Atlas 66	3.11.	1	30.3.	38	2	6.5.
NB 68513/CI 15074	5.11.	2	20.3.	100	3	4.5.
Jyva	4.11.	1	19.3.	83	3	8.5.
Centurk/NB 66425/	5.11.	1	20.3.	100	3	3.5.
Vakka	5.11.	1	22.3.	100	2	7.5.
Starke	5.11.	1	25.3.	100	3	7.5.
Sava/NS 611/	3.11.	0	18.3.	78	3	2.5.
Strampelli	3.11.	0		8	4	2.5.
Lerma Rojo 64	3.11.	0		12	3	1.5.
Bačka	3.11.	1	10.4.	26	2	1.5.
Clarion	4.11.	1	28.3.	82	3	6.5.
Victor I.	2.11.	0		80	4	5.5.
Marimp 3	3.11.	1		14	4	4.5.
Dácia	5.11.	1	25.3.	84	2	3.5.
Golden Valley	2.11.	1	28.3.	53	3	4.5.
Maris Nimrod	4.11.	1	19.3.	100	5	8.5.
Zenith	6.11.	1	30.3.	100	2	7.5.
Rusalka	5.11.	1	28.3.	45	1	1.5.
Caribo	4.11.	1	25.3.	100	3	6.5.
Diplomat	5.11.	2	22.3.	100	4	8.5.
Kirac 66	5.11.	2	28.3.	78	5	7.5.
Lilifen	4.11.	1		18	3	3.5.
NE 701132	6.11.	2	28.3.	100	2	4.5.
Carifen 12	4.11.	0	30.3.	67	2	8.5.
Moldova	4.11.	1	28.3.	80	1	2.5.

RESULTS OF TWO-YEAR TESTING OF VARIETIES FROM THE INTERNATIONAL WINTER WHEAT PERFORMANCE NURSERY (IWWPN), AT THE INSTITUTE OF WHEAT AND SUNFLOWER, TOLBOUHIN, BULGARIA

by

I. Todorov
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Presented by N. Donchev

Our Institute is honoured to participate in growing the International Winter Wheat Performance Nursery (IWWPN). During the autumn of 1969, the testing was accomplished according to standard methodology. In 1970, we proposed and it was disposed that the space between the rows should be narrowed from 30 cm. (~12.6 inches) to 15 cm. (~6 inches), thus approaching the international row spacing of wheat, which has been practiced in this country.

Conditions of climate for both years of experimentation are shown in Table 1.

Because of severe drought in the summer and autumn months of 1969, we were compelled to resort to dry-soil sowing. Total emergence appeared late in the winter, on the 30th of January, 1970, to be precise. Then we had a warm spring with good rain that promoted an accelerated wheat growth. The height of all the varieties remained a bit lower than that of the standard. These conditions caused some variance in density among the varieties, since they tillered only in the spring. The highest yields were obtained from those varieties whose tillering ability was high.

In 1970, the testing was carried out in moist soil. The autumn was warm and wet. The varieties showed good development. Then came a mild winter, producing conditions for renovation of vegetation. The rainfalls of May caused heavy lodging of the wheat. Lodging resistance of the varieties became the basic factor on which the 1970-71 yields depended.

Because of the mild winter seasons of the two years, all varieties overwintered well. Conditions for estimating winter hardiness occurred in January, 1972, when the minimum temperature reached -20,7°C, with lack of snow coverage. The varieties from Mexico, Italy, Yugoslavia, Chile and Turkey appeared most susceptible to cold. The rest of the varieties showed good overwintering.

During two years of testing, the conditions offered a possibility for estimating resistance to leaf rust and powdery mildew. There was no infection of yellow rust, while stem rust appeared at time of ripening and attacked varieties with highly manifested late ripening.

The most resistant varieties to leaf rust (0 - 5%) proved to be Sturdy, Parker, Timwin, Benhur, Arthur, Atlas 66, Gage, Riley 67, Lancer, Stadler, Purdue 4930 A6 28-2-1, NB 67730, NB 66425, TX 62A4793-7, NB 68513 from the U.S., the French variety Cappell Desprez, the Mexican Inia 66, and the Yugoslav varieties Backa, NS732 and NS611. Arthur, NB 66425 and Probstdorfer Extrem were the more resistant varieties to powdery mildew.

At these conditions, the following varieties yielded, in 1970, higher than the base (determined as the average yield percent from all varieties): Arthur - 56%; Scout 66 - 46%; Atlas 66 - 39%; Timwin - 38%; Gage - 36%; Lancer - 34%; Benhur - 34%; NB 67730 - 25%; Parker - 23%; Riley 67 - 15%; Purdue 4930 A6-28-2-1 - 12%;

Table 1. Some meteorological data.

Year	October	Jan.	Feb.	March	April	May	June
			MONTHS				
			RAINFALL (mm.)				
1969-1970	0	Total sum from Oct. to March, incl. -301			16.9	139.6	60.9
1970-1971	51.7	Total sum from Oct. to March incl. -246,8			19.1	119.5	26.8
			Period-of-years Average				
	37.3	Total sum from Oct. to March incl. -216			43.9	53.4	71.5
			TEMPERATURE (CENTIGRADE)				
			Average Monthly Temperature (°C)				
1969-1970	10.7	1.6	1.9	5.7	11.8	13.3	18.3
1970-1971	9.5	2.7	0.8	3.3	8.6	15.6	18.5
			Period-of-years Average				
	12.4	-1.2	0.6	2.1	8.5	14.2	18.3
			ABSOLUTE TEMPERATURE				
			Minimum			Maximum	
1969-1970		-9.0	-9.3	-5.0		29.6	28.0
1970-1971		-7.3	-9.7	-10.2		28.0	31.0
1971-1972		-20.7	-11.7	-10.2			
			15-year Average				
		-23.7	-20.3	-16.1		32.9	32.9

able 2. Phenological observations.

ariety	Date of Flowering		Date of Ripening		Date of Lodging		Ht. (cm.)		Winter Survival	Attacking of l. r. %		Attacking of s. r. %		Attacking of p. m. %	
ear: 19....	70	71	70	71	70	71	70	71	70	70	71	70	71	70	71
ung Kwang	152	144	189	191	2.5	80	97.5	107.8	88	65	100	0	0	80	tr
turdy	146	142	187	190	0	75	70.3	89.9	36	5	0	0	0	80	45
lueboy	167	146	199	192	0	75	91.3	106.5	85	65	10	0	0	20	5
arker	150	140	190	190	0	75	91.0	107.7	73	5	tr	0	0	30	85
riumph 64	146	140	187	185	7.5	95	86.0	109.1	42	40	25	0	0	80	tr
imwin	153	145	192	191	0	95	75.7	94.4	77	5	tr	0	0	65	85
elix	172	156	202	200	0	75	95.5	100.4	64	40	40	0	tr	40	tr
orkstar	161	148	192	193	20	80	96.7	109.9	70	80	40	25	0	30	65
ertodi 293	158	146	192	192	20	75	101.1	111.7	34	80	100	0	0	25	45
enhur	145	142	187	185	0	75	84.1	110.3	92	5	0	0	0	40	25
rthur	149	143	190	185	0	60	83.0	110.6	61	5	tr	0	0	5	25
an Pastore	147	139	184	185	0	80	74.5	96.9	34	65	10	0	0	65	85
ezostaya	153	146	191	192	0	75	76.6	102.6	77	65	25	0	0	60	45
tlas 66	160	146	195	192	16.5	80	96.1	107.6	29	tr	0	0	0	50	85
cout 66	155	143	190	185	75	80	93.3	108.9	70	25	5	0	0	45	65
eine VII	166	154	198	197	0	80	95.1	99.9	39	80	80	0	tr	65	25
erma Rojo 64	139	137	133	184	0	95	79.8	93.0	0	10	5	0	0	80	5
appell Desprez	171	---	201	---	0	--	95.4	----	22	5	--	0	-	15	--
inalta	163	---	197	---	70	--	117.1	----	90	65	--	0	-	70	--
age	158	---	194	---	10	--	105.2	----	91	5	--	0	-	30	--
iley 67	153	---	189	---	0	--	96.3	----	90	tr	--	0	-	65	--
aines	162	---	194	---	0	--	75.0	----	63	65	--	40	-	40	--
ancer	160	---	194	---	65	--	109.0	----	86	5	--	0	-	30	--
hawnee	159	---	193	---	0	--	108.1	----	75	65	--	0	-	80	--
tadler	153	---	189	---	0	--	95.4	----	93	5	--	tr	-	65	--
urdue 4930 A6-28-2-1	155	---	190	---	0	--	101.5	----	66	5	--	0	-	30	--
din	172	---	202	---	40	--	117.1	----	77	65	--	0	-	40	--
B 67730	154	---	190	---	50	--	104.8	----	66	5	--	0	-	40	--
ankuti 1201	158	---	192	---	57	--	90	----	40	25	--	0	-	65	--

Table 2. (continued)

Variety	Date of Flowering		Date of Ripening		Date of Lodging		Ht. (cm.)		Winter Survival	Attacking of l. r. %		Attacking of s. r. %		Attacking of p. m. %	
Year: 19....	70	71	70	71	70	71	70	71	70	70	71	70	71	70	71
Inia 66	138	---	182	---	0	--	68.4	----	0	tr	--	0	-	80	--
Backa	---	142	---	188	--	50	----	92.4	--	--	tr	-	0	--	65
NS732	---	137	---	186	--	0	----	68.7	--	--	tr	-	0	--	45
NS611	---	140	---	185	--	0	----	90.9	--	--	tr	-	0	--	85
Strampelli	---	139	---	185	--	95	----	92.4	--	--	5	-	0	--	65
Starke	---	163	---	203	--	0	----	111.2	--	--	65	-	25	--	85
Hokuei	---	146	---	192	--	95	----	98.2	--	--	25	-	tr	--	25
Probstdorfer Extrem	---	147	---	193	--	90	----	110.5	--	--	25	-	0	--	tr
NB 66425	---	146	---	186	--	95	----	103.8	--	--	0	-	0	--	0
TX 62A4793-7	---	143	---	185	--	95	----	96.7	--	--	5	-	0	--	25
NB 68513	---	145	---	188	--	90	----	108.8	--	--	5	-	0	--	25
Winter triticale	---	145	---	198	--	75	----	117.5	--	--	tr	-	tr	--	85
Vakka	---	152	---	195	--	60	----	109.5	--	--	65	-	tr	--	25
Jyva	---	155	---	197	--	75	----	103.7	--	--	80	-	65	--	45

Yorkstar - 2% (all these from the USA); the South Korean Yung Kwang - 29%, as well as the two Hungarian varieties Fertodi 293 and Bankuti 1201 with 20 and 9%, respectively, and the Italian San Pastore - 3% (Table 3).

Late-ripening varieties from countries of the North like Felix from The Netherlands, Heine VII from Germany, Odin and Starke from Sweden, Vakka and Jyva from Finland showed in the conditions of this country, late ripening and very low yields with shrivelled grain.

In 1971, the rains in May promoted conditions of heavy lodging and occurence of fusariosis and bacteriosis. There was no lodging in NS732 and Sava (NS611) from Yugoslavia and Starke from Sweden, while in the other 27 varieties lodging ranged from 50 to 90%. The high lodging resistance percent the two Yugoslav varieties was due to their short stem -- 68,7 cm. (~27 inches) and 90,9 cm. (~40 inches) respectively, while in Starke, one of the tallest varieties with 111,2 cm. (~44,5 inches), height was due to the very thick stem.

Fusario-bacteriosis attacked all varieties with the late-ripening ones most affected.

Under these conditions the earliest and most lodging-resistant varieties gave the highest yields. The Yugoslav NS732, Sava (NS611) and Backa surpassed the base with 78%, 41%, and 29%, respectively. Among the U.S. varieties, TX 62A4793-7 was 34% over the base; Yorkstar overmatched it with 29%, Atlas 66 - with 16%, Sturdy - 12%, NB 66425 - with 10%, and Timwin - with 4%. The Soviet Bezostaya 1 overtopped the base with 16% and South Korean Yung Kwang - with 17%. In the second year also, the late-ripening varieties gave very low yields (Table 3).

From the view-point of selection, the testing of winter wheat is of great interest. It may give rise to new varieties with valuable characteristics, which would serve as the starting material for selection.

This year we have sown the varieties in a disease nursery for testing their field resistance to diseases in the presence of high infection. We will check their resistance to the most prevalent races of leaf rust, stem rust, and powdery mildew.

The seeds obtained from the IWWPN will be used for an analysis of baking qualities in our technological laboratory. Their cold-resistance is checked in a cooling chamber. By accomplishing these analyses, we shall complete the characteristics of the varieties. It would be best if these analyses were required where, of course, facilities are available. In the future there needs to be more differentiating of varietal stands. We ought to do this by including varieties from more countries.

Table 3. Yield data.

Variety	Origin	1970 Yield (kg/dka)	1970 Over Base-%	1971 Yield (kg/dka)	1971 Over Base-%	Average Yield (kg/dka)
Yung Kwang	S. Korea	456.6	129.4	356.7	119.6	406.6
Sturdy	U.S.A.	339.2	96.1	333.3	111.7	336.2
Blueboy	U.S.A.	257.5	73.0	286.7	96.1	272.1
Parker	U.S.A.	432.5	122.5	293.3	98.4	362.9
Triumph 64	U.S.A.	331.7	94.0	296.7	99.4	314.2
Timwin	U.S.A.	485.8	137.7	310.0	103.9	397.9
Felix	Netherlands	182.5	51.7	250.0	83.8	216.2
Yorkstar	U.S.A.	358.3	101.5	383.3	128.5	370.8
Fertodi 293	Hungary	424.1	120.2	226.7	76.0	325.4
Benhur	U.S.A.	471.6	133.7	246.7	82.7	359.1
Arthur	U.S.A.	549.1	155.6	293.3	98.3	411.2
San Pastore	Italy	361.7	102.5	323.3	108.4	342.5
Bezostaya	U.S.S.R.	344.2	97.6	346.7	116.2	345.4
Atlas 66	U.S.A.	490.0	138.9	346.7	116.2	418.3
Scout 66	U.S.A.	515.8	146.2	256.7	86.0	386.2
Heine VII	Germany	270.8	76.8	236.7	79.3	253.7
Lerma Rojo 64	Mexico	275.0	77.9	216.7	72.6	245.8
Cappell Desprez	France	335.0	94.9	---	---	---
Winalta	Canada	331.7	94.0	---	---	---
Gage	U.S.A.	480.0	136.0	---	---	---
Riley 67	U.S.A.	405.8	115.0	---	---	---
Gaines	U.S.A.	215.8	61.2	---	---	---
Lancer	U.S.A.	473.3	134.2	---	---	---
Shawnee	U.S.A.	328.3	93.0	---	---	---
Stadler	U.S.A.	333.3	94.5	---	---	---
Purdue 4930 A6-28-2-1	U.S.A.	395.8	112.1	---	---	---
Odin	Sweden	101.7	28.8	---	---	---
NB 67730	U.S.A.	440.8	124.9	---	---	---
Bankuti 1201	Hungary	385.8	109.3	---	---	---

Table 3. (continued)

Variety	Origin	YEAR 1970 Yield (kg/dka)	1970 Over Base-%	1971 Yield (kg/dka)	1971 Over Base-%	Average Yield (kg/dka)
Inia 66	Mexico	268.3	76.0	---	---	---
Backa	Yugoslavia	---	---	383.3	128.5	---
NS732	Yugoslavia	---	---	530.0	177.7	---
NS611	Yugoslavia	---	---	420.0	140.8	---
Strampelli	Italy	---	---	276.7	92.7	---
Starke	Sweden	---	---	210.0	70.4	---
Hokuei	Japan	---	---	173.3	58.1	---
Probstdorfer Extrem	Austria	---	---	300.0	100.6	---
NB 66425	U.S.A.	---	---	326.7	109.5	---
TX 62A4793-7	U.S.A.	---	---	400.0	134.1	---
NB 68513	U.S.A.	---	---	223.3	74.8	---
Winter triticale	U.S.A.	---	---	260.0	87.1	---
Vakka	Finland	---	---	216.7	72.6	---
Jyva	Finland	---	---	223.3	74.8	---
BASE		352.8	100.0	298.2	100.0	339.0

RESULTS OF THIRD IWWPN GROWN AT ANKARA, TURKEY

by

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Ankara is located at 40°N latitude at an elevation of 848 meters. The region is representative of the Anatolian Plateau which grows the majority of the 7.0 million hectares of winter wheat in Turkey. The average rainfall is 380 mm but distribution and yearly precipitation fluctuate widely.

The Ankara location is typical of the colder Central Anatolia. This region requires a winter wheat with relatively good cold resistance. Varieties with resistance to drought and diseases, especially stripe rust, are required.

Another important characteristic is earliness. Yield potential of late varieties is generally reduced by the dry conditions in June and July. Varieties later than Bezostaya are too late; varieties 7-10 days earlier than Bezostaya are preferred.

The top 5 varieties for the 1968-69 and 1969-70 nurseries were as follows:

1968-1969		1969-1970	
Variety	Yield bu/acre	Variety	Yield bu/acre
Bezostaya	41.2	Yorkstar	46.8
Scout 66	40.0	Bezostaya	44.0
Timwin	37.5	Shawnee	43.1
Fertodi 293	35.4	Timwin	42.7
San Pastore	34.7	Scout 66	42.3

In 1970-71 the 3rd IWWPN was seeded on an area affected by salt. The salt caused large variations between replications and also between plots, rendering the yield data unsuitable for statistical analysis. However, the performance of Bezostaya was again excellent. Scout 66 and San Pastore also performed well. Other varieties showing promise were TX 62A4793-7, Yung Kwang, Arthur, Benhur, Atlas 66, and Centurk.

Because of the outstanding performance of Bezostaya, it has recently been recommended and released to the farmers of Turkey. Its acreage has been increasing each year on the Anatolia Plateau and currently this variety occupies approximately 10% of the acreage. In Thrace (Western European Turkey), Bezostaya is the leading variety, occupying approximately 60% of the total acreage. Several of other best yielding varieties have not been recommended because of their susceptibility especially to stripe rust. However, these varieties are currently being used extensively in the breeding program.

REPORT OF IWWPN GROWN AT THE ESKISEHIR AGRICULTURAL RESEARCH STATION

by

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Turkey

Introduction

In this report will be summaried the performance of the varieties in the nursery with regard to yield and winter survival. Data for height, lodging, shattering are also given in the tables without any comment. Rust scoring for the varieties also was recorded.

The IWWPN in Eskisehir Agricultural Research Station has been grown for 4 years. Its location is on the high Plateau with an elevation 789 m. above the sea level. The nursery was planted in the month of October with 60 kg/h of super phosphate and 20 kg/h of ammonium sulphate applied. Usually 2,4-D was applied twice during the season for weed control. In the 1968-69 crop year, rainfall was 467.9 mm with a favorable fall, mild and dry winter, cool and rainy spring, but unfavorable dry early summer. Conditions were very favorable for stripe rust, but practically no leaf and stem rust developed.

Rainfall was 477.8 mm in the 1969-70 growing season. During that year the fall was unfavorably dry, the winter very mild and rainy, and the spring and early summer very dry and cool. Conditions were somewhat favorable for late stripe rust. There was very little leaf rust and no stem rust.

The 1970-71 crop year had a rainy fall, a very rainy winter and spring and a late summer with a total of 344.8 mm of rainfall. Although annual rainfall was less than in the preceding two years, the distribution was well suited to stages of plant growth. Disease development was very heavy with late stripe rust, leaf rust, but no stem rust development.

Yield Results

<u>1968-1969</u>: Thirty varieties were in the nursery. Yield ranged from 2.5 to 5.6 tons per hectare. From the lowest to highest the outstanding varieties in the nursery were San Pastore, Parker, Fertodi 293, Sturdy, Blue Boy, Lancer, Capelle Desprez, Bankuti, Scout 66, Odin, and Bezostaja with a yield of grain more than 5 tons per hectare. Felix, Lerma Rojo 64, Heine VII, Winalta, Timwin, Shawnee, and Purdue 5752 Al-IP-2 yielded 5 to 4 tons of grain per hectare.

<u>1969-1970</u>: Yield of grain of the varieties ranged from 1 to 2.6 tons per hectare. Outstanding varieties were Heine VII, Parker, and Bezostaja with a production of more than 2 tons. Other varieties in the nursery gave less than 2 tons of grain.

<u>1970-1971</u>: Production ranged from 1.8 to 4.5 tons per hectare. San Pastore, Felix, Probstdorfer Extrem, Heine VII were very good yielders and gave 4.5 tons to 4.2 tons per hectare.

Winter survival

1968-1969: This year winter was mild. Bezostaja, Winalta, Gaines, Parker, Shawnee, Lancer, NB67730 were best for winter hardiness. Lerma Rojo 64 and INIA 66 were very weak. Other varieties in the nursery were good too regarding winter survival.

1969-1970: Since winter of this year was very mild, no differences were observed among the varieties.

1970-1971: No differences were found among the varieties.

Conclusion

As it is seen in the tables these successive three years' results do not give any indication of the best varieties for yield and winter survival because of large variations in rainfall and winter climate. Only Heine VII gave a uniform and high performance in the trials.

There were differences between the varieties for maturity. San Pastore, Triumph 64, Red Star and NS 611 were earliest. Gaines, Capelle Desprez, Gage, and Heine VII were the latest varieties.

Out of these results some varieties were selected for use as parents in crossing work at Eskisehir.

1968-1969

Variety	Yield T/h	Height cm.	Lodging %	Winter survival	Puccinia S	Puccinia R
Felix	4.7	95	0	1	R	R
Heine VII	4.6	105	0	1	R	R
Odin	5.0	110	0	1	R	R
San Pastore	5.6	100	0	2	TR	R
Capelle Desprez	5.1	105	0	1	R	R
Bezostaia	4.9	115	0	0	TR	TR
Bankuti 1201	5.1	120	5	1	R	R
Fertodi 293	5.3	110	0	1	R	R
Yung kwang	3.3	105	5	1	25S	n
Winalta	4.6	110	5	0	R	R
Blueboy	5.2	105	2	2	40ms	TR
Benhur	3.9	105	0	1	65mS	n
Riley 67	3.8	115	5	1	40mS	n
Timwin	4.1	85	0	1	25mS	n
Stadler	3.2	110	5	1	25S	n
Yorkstar	2.8	95	0	2	25S	n
Gaines	3.3	70	0	0	25mR	oe
Triumph 64	3.9	115	5	1	60mS	n
Scout 66	5.0	125	5	1	5R	R
Parker	5.3	110	0	0	10mR	R
Gage	3.9	110	3	1	10mS	oe
Sturdy	5.2	85	0	1	R	TR
Shawnee	4.1	110	0	0	25mS	n
Lancer	5.2	120	0	0	R	R
Atlas 66	2.4	130	3	2	25S	R

Variety	Yield T/h	Height cm.	Lodging %	Winter survival	Puccinia S	R	G.T.
			1968-1969				
Purdue 4930A6	2.4	125	5	2	40mS	n	
NB67730	3.8	135	10	0	5mR	R	
Purdue 5752 A1	4.0	105	0	1	25S	n	
Lerma Rojo 64	4.7	85	0	4	R	TR	
INIA 66	2.4	70	0	4	MR	u	
			1969-1970				
Yung Kwang	1.2	56	0	1	10S	tR	
Sturdy	1.0	48	0	1	tR	tR	
Capelle Desprez	1.6	72	0	1	R		
Winalta	1.6	78	5	0	tR	tR	
Blueboy	1.4	50	0	2	10S	tms	
Gage	1.3	60	3	1	10S	R	
Parker	1.9	60	0	0	10mR	tmR	
Riley 67	1.2	55	0	1	10mS	tmS	
Triumph 64	1.7	55	0	1	tR	tR	
Timwin	1.6	50	0	1	10S	R	
Gaines	1.6	45	0	0	80mS	tmS	
Lancer	1.6	78	3	0	R	tmS	
Felix	1.1	75	0	1	R	tmR	
Shawnee	1.5	78	5	0	80S	R	
Yorkstar	1.7	75	0	2	100S	tR	
Fertodi 293	1.2	80	3	1	R	tmR	
Stadler	1.6	75	5	1	80S	R	
Benhur	1.2	54	0	1	40mS	R	
Purdue	1.0	74	5	1	40S	R	
Arthur	1.4	64	0	1	40mS	R	
San Pastore	1.6	68	0	2	R	tmR	
Odin	1.0	66	3	1	R	tmS	
Bezostaia	1.9	66	0	0	R	R	
Atlas 66	1.5	94	0	2	80S	R	
Scout 66	1.4	74	0	1	R	tmR	
Heine VII	2.6	66	0	1	R	tmS	
NB67730	1.7	82	5	0	10mS	R	
Bankuti 1201	1.6	70	5	1	tmR	tmR	
Lerma Rojo	2.0	60	0	4	R	tmR	
INIA 66	1.0	56	0	4	R	R	
			1970-1971				
Banka	2.1	80	0	6	5mR	tR	0
Red Star	2.0	60	0	5	5mR	tr	0
NS611	3.3	70	0	5	tr	tr	0
Strampelli	2.6	85	0	5	tr	tr	0
Starke	2.7	110	0	4	tr	10mR	10S
Hokuei	3.3	105	0	4	tr	10mR	0
Probstdorfer Extrem	4.3	125	0	4	5mR	5mR	0
NB66425	3.0	115	10	4	5mR	5mR	0
TX62A4793-7	2.6	105	0	4	5mR	10mR	0
NB68513	2.2	130	0	4	80S	n	0
Winter triticale	2.2	160	15	3	10mR	10mS	0

Variety	Yield T/h	Height cm.	1970-1971 Lodging %	Winter survival	Puccinia S	R	G.T.
Vakka	2.4	130	0	4	10mR	10mS	0
Jyva	2.4	115	0	4	10mS	10mS	10mS
Bezostaia	1.8	110	0	4	tr	tr	5mR
Blueboy	1.9	120	0	4	10mR	tr	0
Timwin	3.4	95	0	3	80S	n	0
Sturdy	2.7	100	0	4	tr	tr	5mR
Parker	1.8	120	10	3	25mS	tr	0
Fertodi 293	2.9	130	0	4	10mR	10mR	0
Yung Kwang	2.9	125	15	3	80S	n	0
San Pastore	4.5	110	0	5	tr	5mS	0
Atlas 66	2.5	120	80	6	65S	5mR	0
Benhur	2.8	120	10	4	65S	n	0
Arthur	3.5	120	0	4	65S	5mR	0
Scout 66	2.6	120	20	4	5mR	5mR	0
Heine VII	4.2	115	0	4	tr	40S	0
Yorkstar	3.2	115	0	3	80S	tr	0
Triumph 64	2.0	110	0	3	tr	tr	10mS
Felix	4.3	105	0	4	tr	40S	10mS
Lerma Rojo 64	2.1	90	20	8	10mS	10mS	0

0 = very good
1, 2 = good
3, 4 = bad
5 = very bad

RESULTS OF INTERNATIONAL WINTER WHEAT NURSERIES IN IRAQ, 1969-1971

by

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Iraq

Introduction

Location and Climate: The country is located between 29°-37°Lat. N, and 39°-48°Long. E, with a rainfall varying from 50 mm in the Southern desert to about 1000 mm in the Northern hills and it is almost exclusively received during the winter months. The absolute minimum and maximum temperatures range between -11° and 51°C except during abnormal years, when these limits are exceeded to some extent. Some of the relevant meteriological data (Normal = average of 30 years) for Mosul (North), Baghdad (Middle) and Basrah (South) is briefly summarized below.

Summary of Normal Meteriological Data

Place	Temperature (°C)		Rainfall (mm)		Humidity %		Rainy days	Snow-fall	Hails	Remarks
	Highest	Lowest	Total	Max. 1 day	Max.	Min.				
Mosul	51.1	-11.1	390.8	86.3	100++	7	65.3	0.9	2.1	++ morning
Baghdad	50.2	- 8.5	150.8	71.0	100	5	33.4	0.2	0.7	
Basrah	50.5	- 4.7	162.5	87.5	100	13	31.1	0.0	0.9	

Area and Production: The total area of the country is approximately 175,000 sq. miles (438446 sq. kms) with an estimated cultivable area being about 12 million hectares or 48 million donums (Annual Abs. of Statistics-1970), of which about 5½ million hectares (22 million donums) are reported to be presently cultivated. About 50% of this cultivated area is rain-fed and the rest irrigated through floods, canals, pumps, wells, springs, etc. Of the cultivated area about 3.4 million hectares (13.6 million donums) are under crops, the rest being gardens, pastures and forests, etc.

Of the cropped area, about 3¼ million hectares are usually occupied by cereals, wheat alone occupying about 2 million hectares (about 8 million donums) with an average production of about one million tons annually.

The actual area and production along with hectare yields, for the quinquennium 1966-67 to 1970-71 was as follows:

Area, Production and Yield in kg/ha
(1966-67 to 1970-71)

S. No.	Year	Yield (Hectares)	Production (Tons)	Yield (kg/ha)	Remarks
1	1966-67	1,843,631	866,428	468	
2	1967-68	2,010,095	1,361,009	676	Good rainfall.
3	1968-69	2,088,980	1,188,560	568	
4	1969-70	2,033,426	1,058,891	520	
5	1970-71	2,574,985	813,595	587+	+severely dry harvested area of 813,595 ha only.
	Average	2,110,228	1,057,936	501	

Thus the wheat crop, which alone occupies about 60% of the cropped area, is by far the most important food grain crop of the country, where it has been under cultivation since time immemorial. Further, the crop is grown under varied soil, climatic and water supply conditions. In the North, where the major wheat area (60-65%) is located, it is grown under rain-fed conditions, while in the Middle and South zones, it is invariably irrigated, thus about 2/3 of the crop is grown under dry-farming conditions. Usually spring wheat varieties like Saber-beg (Local), Qandharia, Italia, Florence Aurore, S. Capelli, and some Mexi-Pak in the North, and Ajeeba, Kenya Gular, and Mexi-Pak in the Middle and South are grown. INIA 66 and Jori C-69 have recently been introduced.

The crop is planted in October-November (although in the dry-farming areas plantings sometimes start in the latter half of September) in dry land and germinates after irrigation or rainfall. Harvesting starts in mid-May in the Middle and South, and continues to mid-June, or even later, in the North where cooler temperatures prevail. It is in such areas that the winter or semi-winter types can have some chances of success. Hence the International Winter Wheat Performance Nursery, since its inception, has been grown in the North at the Field Crop Research Station, Bakrajo, in Sulemaniya Mohafza.

International Winter Wheat Nursery Results, 1969-1971

The Nursery, from its very start, has been grown at Bakrajo (Sulemaniya) according to the instructions received from the Coordinator concerned, and the results reported. They are detailed in Appendix I for the years 1969-1971. The yield and other relevant characters of the top ten varieties, are summarized in the following table:

Average yield and other characters of top ten varieties (1969-1971 nurseries)

Variety	Yield 1968-69 q/ha	R.	1969-70 q/ha	R.	1970-71 q/ha	R.	Av. q/ha	R.	Plant ht. (cms)	Maturity	Grain color	Rusts Resp. Str.	Leaf	Stem
L.R. 64	23.8	2	31.8	2	27.2	2	24.2	1	100	E	LR	VR	VR	R
Bezostaia	21.6	4	34.1	1	16.4	4	24.0	2	110	M	R	VR	VR	R
Sturdy	24.2	1	26.0	6	13.9	16	21.4	3	90	M	LR	VR	VR	R
San Pastore	20.0	7	27.4	5	14.5	12	20.6	4	100	M	R	R	MS	VR
INIA 66	12.7	24	28.2	4	-	-	20.5	5	90	E	R	MR	VR	R
Scout 66	16.6	14	29.3	3	15.6	7	20.5	6	130	M	LR	MR	VR	MR
Lancer	17.3	13	23.5	10	-	-	20.4	7	120	L	R	VR	VR	MR
Blueboy	23.7	3	21.3	13	15.7	5	20.2	8	110	M	W	MR	VR	VR
Shawnee	14.5	20	23.2	11	-	-	18.8	9	85	L	R	MS	VR	R
Strampelli	-	-	-	-	18.7	1	18.7	10	-	-	-	-	-	-

Apart from yield, timely maturity; grain color and its quality; appropriate plant height; disease and drought resistance and non-shattering are some other desirable requisites of a variety for it to be successful. Despite some very cold temperatures, spring varieties of comparatively long duration, taking about 200-205 days from seeding (germination) to maturity, are being successfully grown. A plant height of 100-110 cm. is considered desirable to suit mechanized harvesting (and provide some dry fodder), which is practiced on large scale. The country possesses over 2000 combines, most of which are located in the North. Since wheat is mainly consumed in the form of unleavened bread (locally called Khubz), the people are very conscious of color (white or amber being preferred) and good quality.

Considering the above as well as the results given in Appendix I, it may be seen that varieties having early to medium maturity, 90-110 cms. plant height, reasonable rust resistance, have scored over the others. Such varieties can be a success in this country.

On the basis of 1969-70 Nursery results, three varieties viz., Bezostaia, Sturdy, and Scout 66, showing fairly good yield performance and possessing some other desirable characters, were selected for large-scale testing against Mexi-Pak, the highest-yielding variety so far, during 1970-71 at Neneva (Mosul), Bakrajo (Sulemaniya) and Talafaar (Mosul), all of which are in the colder region of Iraq. The crop at Talafaar failed due to severe drought, while the results obtained at the other two places are given in the following table.

Yield and other characters of 3 winter wheats vs. M-Pak
1970-71

No.	Variety	Yield q/ha at: Naneva	Yield q/ha at: Bakrajo	Other characters noted at Bakrajo: Date of Flowering	Date of Maturity	Plant ht. (cms)	Wt. of 1000 g (gms)	Grain color	Consistency
1	Bezostaia	33.2	29.0	10/5	10/6	110	35.7	red	hard (201 days)
2	Sturdy	32.2	21.9	11/5	11/6	90	27.7	l.red	hard (202 days)
3	Scout 66	23.5	26.1	7/5	9/6	120	31.1	l.red	hard (200 days)
4	Mexi-Pak(C)	46.9	38.8	6/5	9/6	105	27.1	w. (amber)	m.hard (200 days)

It may be seen from the above, that despite its cold susceptibility, the variety Mexi-Pak out-yielded the winter types included in the test at both places. This, to some extent, indicates that because of mild short winters and shortage of irrigation water, late long duration true winter types may not fit even the colder regions of the country. It seems that what is required are somewhat long-duration spring or medium-duration winter types, taking 200-205 days from seeding (germination) to maturity, possessing medium plant height and a fair resistance to rusts (mainly leaf), drought and shattering. In addition they should also have medium hard to hard, white to light red (amber) grain both in Vulgare and Durum types. If possible, more of such varieties should be introduced into future nurseries and a locally-grown best variety should invariably be kept as a check.

The Winter Barley Nursery should also be mentioned, as barley is also an important crop in many countries, and is very often grazed (at least in the Middle East) before allowing the crop to seed, thus requiring long duration types. The current year's IWWPN Nursery is progressing well. Judging from the early growth and cold tolerance, the varieties Diplomat, Hokuei, Bezostaia, Blueboy and Atlas appear promising. This year being abnormally wet and cold (down to -13°C at Bakrajo), the crop will not be ready for harvest before the end of June or early July.

Appendix I. Yield and other characters of wheat varieties in the IWWPN at Bakrajo (Iraq).

Variety	Yield q/ha and rank during years								Maturity	Height (cms.)	Grain color	Rust response		
	1968-69		1969-70		1970-71		Average					Stripe	Leaf	Stem
	q/ha	rank	q/ha	rank	q/ha	rank	q/ha	rank						
Sturdy	24.2	1	26.6	6	13.9	16	21.4	3	M	90	LR	VR	VR	R
Lerma Rojo 64	23.8	2	31.8	2	17.1	2	24.2	1	E	100	LR	VR	VR	R
Blueboy	23.7	3	21.3	3	15.7	5	20.2	8	M	110	W	MR	VR	VR
Bezostaia	21.6	4	34.1	1	16.4	4	24.0	2	M	110	R	VR	VR	R
Timwin	20.2	5	17.3	17	15.6	6	17.7	16	M	90	R	VS	MS	R
Arthur	20.2	6	17.8	16	12.7	20	16.9	17	M	105	LR	VS	R	R
San Pastore	20.0	7	27.4	5	14.5	12	20.6	4	M	100	R	R	MS	VR
Gage	19.6	8	17.2	18	-	-	18.4	12	M	115	R	VS	VR	MR
Fertodi 293	18.9	9	18.6	15	12.7	21	16.7	19	M	130	R	MS	VS	S
Triumph 64	18.4	10	24.1	8	12.8	19	18.4	13	M	110	R	VS	VS	MR
Benhur	17.6	11	16.8	19	13.8	17	16.1	20	M	105	R	VS	VR	MS
Parker	17.5	12	24.0	9	14.5	13	18.6	11	M	110	R	MS	R	S
Lancer	17.3	13	23.5	10	-	-	20.4	7	L	120	R	VR	VR	MR
Scout 66	16.6	14	29.3	3	15.6	7	20.5	6	M	130	LR	MR	VR	MR
Atlas 66	16.1	15	14.7	23	9.7	26	13.5	28	M	130	R	VS	VR	S
NB67730	16.1	16	20.2	14	-	-	18.1	15	M	135	R	MS	MS	MS
Bankuti 1201	15.2	17	9.7	29	-	-	12.5	32	M	130	R	MR	MR	VS
Yorkstar	15.2	18	13.6	24	14.8	10	14.5	25	L	100	W Dull	VS	VS	VS
Riley 67	14.8	19	16.8	20	-	-	15.8	21	M	120	R	S	MR	VS
Shawnee	14.5	20	23.2	11	-	-	18.8	9	L	85	R	MS	MR	R
Yungkwang	13.3	21	13.2	26	13.8	18	13.4	29	L	115	R	VS	VS	S
Purdue 4930A6-28-2-1	13.2	22	9.5	30	-	-	11.3	37	M	100	R	VS	R	S
Heine VII	12.7	23	25.2	7	16.5	3	18.1	14	L	100	R	VR	S	VS
INIA 66	12.7	24	28.2	4			20.5	5	E	90	R	MR	VR	R
Stadler	12.4	25	11.4	28	-	-	11.9	35	M	120	R	VS	VS	S
Winalta	11.9	26	21.7	12	-	-	16.8	18	L	130	R	VR	S	MS
Gaines	10.9	27	13.3	25	-	-	12.1	34	L	80	W	VS	MR	VS
Cappell Desprez	10.3	28	15.6	21	-	-	12.9	30	VL	95	R	VR	R	VS
Felix	8.2	29	14.7	22	9.6	27	10.8	38	VL	85	R	VR	MS	S
Odin	5.1	30	12.5	27	-	-	8.8	41	VL	100	R	VR	MS	VS

Appendix I (concluded).

Variety	Yield q/ha and rank during years								Maturity	Height (cms.)	Grain color	Rust response		
	1968-69		1969-70		1970-71		Average							
	q/ha	rank	q/ha	rank	q/ha	rank	q/ha	rank				Stripe	leaf	Stem
Strampelli	-	-	-	-	18.7	1	18.7	10						
Backa	-	-	-	-	15.1	8	15.1	22						
Red Star	-	-	-	-	14.9	9	14.9	23						
TX62A4793-7	-	-	-	-	14.6	11	14.6	24						
NB66425	-	-	-	-	14.5	14	14.5	26						
NS611	-	-	-	-	14.3	15	14.3	27						
NB68513	-	-	-	-	12.6	22	12.6	31						
Hokuei	-	-	-	-	12.2	23	12.2	33						
Probstdorfer Extrem	-	-	-	-	11.9	24	11.9	36						
Winter Triticale	-	-	-	-	10.7	25	10.7	39						
Vakka	-	-	-	-	9.1	28	9.1	40						
Jyva	-	-	-	-	7.6	29	7.6	42						
Starke	-	-	-	-	5.1	30	5.1	43						

REPORT ON THE RESULTS OF THIRD INTERNATIONAL WINTER WHEAT PERFORMANCE NURSERY GROWN AT SIMLA (INDIA)

by

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The nursery was grown at Wheat Breeding Sub-station Simla, Indian Agricultural Research Institute located at an altitude of 1900 meters. The latitude and longitude are 32°N and 77°E respectively. The soil is loam in texture with greyish-brown color and normal in soil reaction. The wheat crop is sown in mid-October to mid-November and is harvested in the months of May and June. The average annual rainfall is 1500 mm. Rainfall during the period of crop growth was 300 mm and snowfall 42 cm. Information on average temperature, rainfall and snowfall from November 1970 to May 1971 is presented in Table 1.

The area sown to wheat in the northern hills of India is 144 thousand hectares approximately, and at present, spring wheat varieties are under cultivation. However, the possibility of cultivation of winter wheats above 2,000 meters exists and is being explored. Keeping this objective in view, the Third International Winter Wheat Nursery was planted at Simla on the 27th of October, 1970. Kalyansona, a spring wheat, was included as local check variety. The nursery was grown under high fertility conditions. Information on yield, disease reactions and other ancillary characters is presented in Table 2.

A perusal of the data shows that Kalyansona, Strampelli, NS611, Atlas 66, Blueboy, San Pastore and Arthur gave higher yields than Lerma Rojo. Backa, Atlas 66, Triumph 64 and Red Star, in that order, were the earliest to flower among the winter wheats. The North European varieties Starke, Felix, Vakka, Jyva and Heine VII were latest flowering and were also low yielders.

Varieties with the shortest plant height were Red Star, Backa, Kalyansona and Strampelli. Winter Triticale, Starke, Probstdorfer Extrem, Fertodi 293 and Triumph 64 were the tallest varieties in the nursery. Backa, Red Star, Strampelli, Heine VII, Felix, Lerma Rojo 64 and Kalyansona did not lodge while Yung Kwang, San Pastore, Benhur and Arthur lodged heavily.

A few seeds of each variety of the International Winter Wheat Nursery were also grown at Fagu which is at a distance of 30 kms. from Simla. Only rust reactions were recorded at Fagu and the maximum infection recorded at the two locations is presented in Table 2. It will be observed from the data that no winter wheat was free to all three rusts. Strampelli and Sturdy were free from stripe rust and leaf rust. Timwin, Yung Kwang and Benhur were free from leaf rust and stem rust. However, these three varieties showed high degree of susceptibility to stripe rust which is an important disease of the higher hills. Backa, Red Star and Winter Triticale were free from powdery mildew. It is thus evident that most of the winter wheats are susceptible to Indian races of rusts and powdery mildew.

It will be observed from the data that Kalyansona, a spring wheat, was the top yielder despite its cold susceptibility. This may be due to the fact that the winter was not severe at Simla. However, Strampelli, NS611, Atlas 66, Blueboy and San Pastore were statistically at par in yield with Kalyansona. Kalyansona is a two-gene dwarf, medium late in maturity, ears awned, bold and erect. Strampelli possesses short, stiff straw, tolerance to stripe and leaf rust and is medium late in maturity. This variety seems to fit in well under the conditions prevalent in this region and is being extensively tested in the Coordinated Trials. The results also indicated that late and long duration winter types may not be suitable for cultivation in higher hills of India because the winters are not very severe or prolonged. It seems that long duration spring or medium duration winter types possessing medium plant height, resistance to stripe rust, leaf rust, and drought with amber, bold and hard grains will be most suitable for cultivation in the higher hills of India.

Table 1. Precipitation and average temperature during the period November, 1970 to May, 1971 at the Simla (India) Wheat Breeding Station.

Month	Rainfall (mm)	Snowfall (cm.)	Minimum temperature	Maximum temperature
November 1970	NIL	NIL	8.0°C	19.6°C
December 1970	NIL	NIL	3.4°C	18.5°C
January 1971	NIL	22	1.7°C	14.2°C
February 1971	52.5	20	0.4°C	16.5°C
March 1971	NIL	NIL	5.7°C	20.5°C
April 1971	66.5	NIL	13.4°C	24.4°C
May 1971	181.0	NIL	13.3°C	24.3°C

Table 2. Yield and other characters of wheat varieties included in the Third International Winter Wheat Performance Nursery grown at Simla (India).

Variety	Yield q/ha	Rust stripe	Rust leaf	Rust stem	Powdery mildew	Heading in days	Maturity in days	Height cms.	Lodging %	Grain color	Grain texture	1000-grain weight, gms.
Kalyansona	31.0	F	F	LS	HS	100	145	80	0	A	H	38
Strampelli	28.1	F	F	MS	HS	98	148	85	10	R	S	28
NS 611	28.0	F	TX	VHS	TS	102	152	90	50	R	H	34
Atlas 66	27.2	F	LX	LX	TS	96	146	105	60	LR	SH	32
Blueboy	26.5	MS	LS	VHS	HS	103	154	115	60	R	S	40
San Pastore	25.5	F	MS	VHS	TS	98	148	86	90	R	S	36
Arthur	21.2	F	LS	TS	HS	102	148	85	85	R	SH	38
Lerma Rojo 64	21.1	F	F	F	LS	73	135	100	10	R	S	40
Yorkstar	18.1	HS	HS	VHS	TS	115	161	115	10	WH	S	26
Hokuei	17.3	F	HS	HS	LS	110	159	112	70	R	S	28
NB66425	17.2	F	TX	HS	103	154	154	98	50	R	H	32
Winter Triticale	16.6	F	LS	HS	F	112	159	145	20	R	S	48
Bezostaia	16.3	F	TX	TX	MS	105	154	88	80	R	SH	40
TX62A4793-7	16.2	MS	LS	HS	HS	103	154	100	50	R	H	30
Triumph 64	16.1	HS	LS	HS	MS	96	148	120	20	R	H	34
Parker	16.0	LS	MS	HS	HS	100	153	105	75	R	H	34
Fertodi 293	15.7	LS	LS	VHS	MS	102	154	120	60	R	SH	38
Backa	15.6	F	LX	VHS	F	96	152	75	0	R	S	38
Timwin	15.6	VHS	F	F	MS	109	156	90	70	R	SH	34
Scout 66	15.2	F	TS	MS	HS	104	153	110	65	R	H	36
Probstdorfer Extrem	14.9	F	LS	MS	HS	115	159	120	70	R	H	38
Yung Kwang	14.9	VHS	F	MS	MS	109	159	110	90	R	SH	44
Sturdy	14.3	F	F	MS	HS	102	154	98	70	R	SH	26
Red Star	14.0	F	LS	MS	F	97	152	63	0	R	SH	30
NB68513	14.0	MS	TS	MS	HS	104	156	105	80	R	H	30
Benhur	13.8	VHS	F	F	LS	98	146	95	85	LR	SH	32
Heine VII	11.9	F	MS	VHS	TS	122	163	105	0	R	SH	44
Felix	10.7	F	HS	VHS	TS	126	166	110	0	R	S	34
Vakka	7.1	F	TS	HS	HS	121	161	105	20	R	H	28
Jyva	3.8	F	LS	HS	LS	122	161	85	75	R	H	26
Starke	1.9	F	MS	VHS	HS	130	163	120	20	R	SH	24

C.D. at 5% level: 8.43

C.V. 24.99

A = amber; R = red; LR = light red; WH = white; H = hard; S = soft; SH = semi-hard.

SOME PROBLEMS OF WHEAT PRODUCTION IN BRAZIL AND THE ROLE THE INTERNATIONAL WINTER WHEAT PERFORMANCE NURSERY MAY PLAY IN THEIR SOLUTION

by

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Introduction

Brazil has had a dramatic increase in wheat production from 0.36 million tons in 1967 to 2.03 million tons in 1971. This last crop fulfills almost 70% of the country needs for consumption.

This rather spectacular increase was due to a good support price, government acquisition, and immediate cash payment of the entire crop and the development of a successful rotation of wheat and soybeans that is giving good cash returns to the farmers and stimulating them to grow bigger acreages.

The average production per area, in the same period, increased from 7.5 q/ha to 10.5 q/ha, mainly due to good weather conditions with consequent minor diseases problems, better cultural practices, and new released varieties. But, the big increase in production was due more to the increase in acreage than to an increase in production per area.

Wheat Production Regions in Brazil

Brazil has several wheat production regions. The most important region is located in the northwestern area of the State of Rio Grande do Sul, between parallels 28° and 29°S and meridians 51° and 54°W. The soils, in general, are reddish clay loam (latosols), very permeable and easy to handle, deficient in N, P and K, and acid or very acid (pH 5.4 to 4.5), with aluminum being toxic to many wheat genotypes.

The elevation ranges from 100 meters in the extreme west to 1,000 meters in the extreme eastern part of the area. The total precipitation is approximately 1,700 mm per year, with good average distribution in all the months of the year. However, the high temperatures and uneven distribution of rainfall in some years may develop droughty conditions from October to December or January (late spring and early summer). As this drought is more frequent southward, we have a situation similar to the Mediterranean type of climate.

In many years we have excess rainfall, cloudy days, and high humidity in July, August and September, which increases diseases, mainly *Septoria* and *Giberella*. The rainfall, temperature and other climatological data of two typical sites of this region (Cruz Alta and Passo Fundo) are given in Table 1.

This region produces about 65% of the nation's wheat crop. The farmers, in general, fertilize with 20-60-30 (NPK) kg/ha at planting time in May or June. Some of them use lime to correct the aluminum and increase the pH of the soil to 6.5, but this is not yet a general practice. They use early spring-type varieties, resistant to acid aluminum soils, with some tolerance to *Septoria* and susceptible to lodging when heavily fertilized. The kernels of these varieties are soft-textured but have fair to good protein content (12% or higher). The wheat heads in August-September and is harvested in October-November.

The common diseases are: Puccinia graminis tritici, Puccinia recondita, Septoria tritici, Septoria nodorum, Giberella saubinetti (Fusarium head blight), Barley Yellow Dwarf Virus and some Soilborne Virus in certain areas.

Armyworms and aphids are problems in some years.

The farmers need early varieties in order to harvest the wheat crop early and immediately plant soybeans at a good date of planting, when the soil still has adequate moisture for germination. The economy of the region depends highly on the association of these two crops.

The main research center of this region is an important experiment station at Passo Fundo (latitude 28°16'S, longitude 52°24'W, altitude 676 m), belonging to the IPEAS (Southern Research Branch of the Ministry of Agriculture), where a special group of the FAO is cooperating with the research work. There is also an important wheat research center located at Cruz Alta (latitude 28° 38'S, longitude 53°36'W, altitude 473 m), which belongs to a semiprivate program sponsored by a farmers' special fund administered by the Wheat Cooperatives Association (FECOTRIGO), presently under the technical leadership of Dr. John Gibler. This program is also using, by special agreement with the Secretary of Agriculture of the State of Rio Grande de Sul, the Julio de Castilhos Experiment Station (latitude 29°14'S, longitude 53°43'W, altitude 500 m). The secretary of Agriculture has another wheat experiment station at Veranópolis (latitude 28°56'S, longitude 51°34'W, altitude 700 m), where several varieties very tolerant to Septoria have been bred C-17 (Lagoa Vermelha) is the most tolerant).

The western part of the State of Santa Catarina and the southwestern part of the State of Paraná (from latitude 27°30'S to 24°S, longitude 51° to 54°W) is an extension of the first region up north into better soils, higher temperatures, less humidity in the spring, and consequently, less disease problems. The varieties used are the same ones bred in the south. The yield trials are made at Rio Cacador Experiment Station (State of Santa Catarina), that belongs to the IPEAS (Ministry of Agriculture) and in farmers' fields. In the State of Paraná, the IPEAME (Paraná Research Branch of the Ministry of Agriculture) is in charge of the trials and a new breeding program.

A new developing agricultural region, called "North of the 24° parallel" is increasing wheat and soybean culture very rapidly. It comprises the northern part of the State of Paraná, the southwestern part of the State of São Paulo (from latitude 24° to 22°S, longitude 51° to 54°W) and the southern part of the State of Mato Grosso (latitude 24° to 22°S, longitude 54° to 56°W). It has some very fertile soils, good rains from September to April and very few rains in the other months. The farmers seed wheat in April and harvest in August. There are a very few light frosts in July. As the weather is dry during the cycle, there are almost no disease problems other than leaf and stem rusts. The true spring very early types of Mexican descendants may have their best place in this region. Dr. Ady Raul da Silva of the Ministry of Agriculture is now the coordinator of this program.

There is a very special region in the southwestern part of the State of Rio Grande de Sul (from latitude 32° to 31°S, longitude 53° to 55°W), that borders on Uruguay and has some ecological similarity with certain areas in Argentina. The main exploitation in this area is cattle grazing, but it needs some general agricultural growth to help develop the infrastructure necessary to establish better pastures, mainly in the severe winter months. This region has a very different type of soil and climate than the others mentioned. The most fertile areas of this region have black clay soils (grumosols), similar to the so-called "dinner-time soils" in Texas, with high water retention and poor drainage, impossible to enter when wet and highly resistant to plowing when dry. These soils are rich in potassium and organic matter and are acid (pH 5.2 to 5.6), but have no or very little aluminum. The altitude ranges from 200 meters to 400 meters. The annual rainfall is around 1,300 mm with some drought from late October to January (see Table 1). The temperature is lower in the winter months and early spring and there is a difference between day and night temperatures of 10°-12°C in good weather. This region has the same disease problems as the main wheat region, but with lower intensity, except for leaf rust and Helminthosporium sativum that are more severe.

Presently this region produces only about 2 or 3% of the nation's wheat crop, but has a big potential production. The best yields in Rio Grande de Sul trials are, in general, obtained in this region (Nainari 60, Mengavi and PV18 Indus outyielded the 40 q/ha level in the International Spring Wheat Yield Nursery planted in Herval in late July, 1969). The bottleneck in the development of this area into a big wheat producer depends, in our opinion, on the breeding of suitable varieties.

In this area, the association wheat-soybeans developed in the northern area is almost impossible, because the wheat harvest is too late (December) for a good establishment and development of the soybeans and very often we have severe droughts in the summer with almost total failure of the soybean crop. We are trying to introduce sorghum and sunflower for rotation with wheat, but it is too early to say if this doublecropping will be satisfactory. With wheat being the only crop and with a high cost of land preparation, the farmers very frequently have financial problems. In addition, the available varieties, early spring types developed for the main wheat region up north, are not suitable for this region, because the farmers, in order to escape damage from the September or early October frosts, must seed these varieties in July. Frequently they are not able to enter the fields with the machinery due to soil conditions. The available late spring-type varieties that could be planted earlier generally develop into very tall growth and lodge severely on these fertile soils.

As this is an important cattle-grazing region, we thought of developing winter or intermediate type varieties that could be seeded in March, April or May, when the soil conditions are excellent, would head in October and be harvested in December, with grazing possibilities in July and August when the pasture shortage is greatest. We think that with such varieties this region would be able to use this type of agriculture on more than 500,000 hectares (1,100,000 acres) and such varieties may also have a place in Uruguay and Argentina.

Table 1. Temperatures, precipitation, relative humidity and cloudiness for 3 experimental stations in the State of Rio Grande de Sul, Brazil (30-year average, 1931-1960).

Month	Average temperature °C			Average maximum temperature °C			Average minimum temperature °C			Average precipitation, mm			Average relative humidity, %			Average cloudiness, 1-10[4]		
	C.A.[1]	P.F.[2]	Bg.[3]	C.A.	P.F.	Bg.	C.A.	P.F.	Bg.	C.A.	P.F.	Bg.	C.A.	P.F.	Bg.	C.A.	P.F.	Bg.
January	23.8	22.4	24.2	30.0	28.6	30.7	18.1	17.3	18.0	148.1	143.7	107.6	69.6	72.5	64.4	5.4	5.4	4.0
February	23.1	21.8	23.5	29.2	27.9	29.9	18.0	17.1	17.8	126.3	147.1	95.8	73.6	75.7	67.4	5.8	5.6	4.0
March	21.7	20.3	21.7	27.9	26.3	28.0	16.5	15.9	16.7	123.0	120.3	97.2	73.7	76.0	71.7	5.4	4.9	4.0
April	18.1	17.0	17.8	24.2	22.6	23.8	13.1	12.5	13.1	154.0	128.8	120.3	75.4	78.1	74.8	5.3	4.9	4.0
May	15.9	14.7	14.8	21.7	20.1	20.6	11.1	10.7	10.9	153.6	140.1	119.8	76.9	79.8	77.9	5.6	5.1	4.0
June	14.2	13.2	12.9	19.5	18.5	18.0	9.8	9.3	9.0	167.8	148.8	119.1	79.7	81.6	81.6	6.4	5.7	5.0
July	13.4	13.3	12.2	19.5	19.0	17.7	8.6	8.4	8.3	124.0	131.6	103.6	75.8	77.9	79.0	5.6	4.9	4.0
August	15.0	13.8	13.3	21.2	19.8	19.2	9.7	9.3	8.8	125.8	131.6	112.1	72.4	74.3	76.0	5.8	5.1	4.0
September	16.3	15.6	14.9	22.3	21.6	20.7	11.1	10.7	10.2	157.6	160.4	124.9	74.1	75.0	76.4	6.4	5.9	5.0
October	18.8	18.1	17.5	24.1	24.1	23.4	12.6	12.5	12.4	185.6	162.4	133.7	72.3	73.4	73.2	6.0	5.8	4.0
November	20.6	19.5	20.1	26.9	25.7	26.6	14.5	14.1	14.2	119.8	110.5	74.8	67.7	68.5	66.7	5.3	5.1	4.0
December	22.8	21.8	22.8	29.3	28.3	29.5	16.7	16.1	16.4	139.5	133.1	76.7	65.2	67.5	63.6	5.1	5.1	3.0
Annual	18.6	17.6	18.0	24.6	23.5	24.0	13.3	12.8	13.0	1725.1	1658.4	1285.6	73.0	75.0	72.7	5.7	5.3	4.0

[1]C.A. - Cruz Alta; [2]P.F. - Passo Fundo; [3]Bg. - Bagé; [4]1=no cloudiness, 10=completely cloudy.

This region has one experiment station (Estacao Experimental Fi totécnica de Bagé, latitude 31°23'S, longitude 53°52'W, altitude 216 m), belonging to the Secretary of Agriculture of the State of Rio Grande de Sul, where the late Dr. Iwar Beckman created the variety Frontana. This station now has a very limited wheat breeding program, almost entirely with spring types. In this same area the senior author has a farm (latitude 31°42'S, longitude 53°40'W, altitude 200 m) where his private breeding work is being developed and where the IPEAS (Southern Research Branch of the Ministry of Agriculture) conducts various wheat trials. This is the site where the IWWPN has been planted.

The Beginnings of the IWWPN in Brazil

The beginnings of the IWWPN trials in Brazil took place when the junior author was located at Pelotas, State of Rio Grande de Sul, Brazil, working as a wheat specialist in cooperation with the Brazilian Ministry of Agriculture under the sponsorship of IRI, Inc., from 1966-1970.

In our numerous discussions pertaining to wheat production and breeding problems, the senior author suggested that, in view of the ecological similarity of certain regions of Argentina to southern Rio Grande de Sul, Brazil, intermediate and/or winter types should perform well or, if not, at least contribute valuable characteristics to the available local wheats. Naturally, the idea of producing dual-purpose types was a central idea.

Just a short time before this conversation, the junior author had received preliminary data pertaining to the First IWWPN whereupon it was suggested that this trial would be a good starting point to acquire suitable types. It was agreed and correspondence followed. When inquiry was made to Dr. Virgil Johnson he seemed somewhat surprised at our request -- winter types are not adapted to Brazil -- but admitted that his knowledge of wheat production in Brazil was somewhat limited. Fortunately, we were able to convince him and his co-workers that we were entitled to a trial and within short order the seed arrived for the second IWWPN. As the seed arrives after August, we maintain it in dry storage until the following May, the date thought best for seeding.

Results

The second IWWPN, due to problems of land preparation, some drought in May and then heavy rains, was not possible to plant until July 15, 1970, in very poor soil conditions. Then, in September, when still in the tillering stage, a tremendous attack of leaf rust gave the impression of total failure of the trial. So, it was abandoned with no attempt at weed control. Then, in a visit shortly before harvest time, we were surprised to see that even under such bad conditions many entries set seed and some produced seed of good external quality.

By reason of the late planting date, this preliminary information gave us hope of success if we succeeded in the idea. It was very impressive that some of the cold resistant varieties had very low cold requirements. Scout 66, Gage, Bezostaia, NB67730, Benhur and Arthur set good seed and a reasonable production for such conditions.

The Third IWWPN was planted under good conditions on May 22, 1971. In a year considered not good for wheat production in Rio Grande de Sul due to greenbug attack, severe late frosts (October 3, 4, 11, 12), followed by some drought in September and October, the yields were not good in general.

Of the two local checks, IAS 52, a stem rust resistant, tall spring type, lodged very badly when planted this early, but escaped the late frosts, at least from the damage at heading time, because it headed before the frosts, and gave a yield of 18.1 q/ha. This same variety, planted in a date-of-seeding trial at the same location gave its best production of 21.7 q/ha from the June 23 planting.

The other check, Buck Manantial, a widely adapted Argentinian variety, with photoperiodic response but with no cold requirement, that was introduced recently in this region by the senior author and with very good performance in commercial production (this variety is also the best in trials from May and June plantings in Uruguay), gave only 12.4 q/ha due to frost damage at heading time. This same variety also suffered in the date-of-seeding trial and gave its best yield of 21.5 q/ha from the June 23 planting.

Many of the IWWPN varieties exceeded our expectations: Strampelli (23.3 q/ha), San Pastore (21.6), Benhur (20.4), Timwin (19.6), Arthur (19.0), Lerma Rojo (18.8) and Red Star (18.5) outyielded the check IAS 52 (18.1).

The highest hectoliter weights (a measure of the weight of a liter and roughly equivalent to test weight) were produced by Benhur (80.91), Arthur (80.80) and Scout 66 (80.25). The IAS 52 had a hectoliter weight of 77.90.

Benhur, Timwin and Arthur showed high resistance to heavy attacks of leaf and stem rust. Rust readings on some other varieties were difficult to make because the leaves died prematurely, probably because of a heavy early attack of *Septoria tritici*.

Red Star and the Italian variety Strampelli were very early, heading only 7 and 9 days later than early spring type check IAS 52. Red Star gave an excellent impression because of its short stiff straw (triple dwarf), erect leaves, good tillering and good spikes, but it seemed susceptible to *Septoria tritici*. Sturdy and Timwin showed good stiff straw. Benhur showed some dark violet areas on the glumes, on the neck and on the culms below the nodes, probably due to brown necrosis. Starke, Vakka, Jyva and Felix failed to head.

TX62A4793-7 suffered a 100% attack of *Puccinia graminis tritici* (probably a biotype of race 15B). Some other varieties, including the check Buck Manantial, also suffered from a heavy attack of this disease, making readings difficult for leaf rust.

The border rows of Red Star, Strampelli, Benhur, Arthur, Heine VII and other varieties were used to make crosses with the checks, other Brazilian varieties and lines in the Milton Rocha program.

Discussion

Being aware of the value of wheat as a pasture crop in certain temperate climatic regions, principally the Southern Great Plains region of the United States, where wheat-cattle agriculture is a predominant system, it was felt that a dual-purpose type of wheat could have a place in the wheat-cattle area of southern Rio Grande de Sul, Brazil. We feel that these trials, encompassing global information as they do now and soon will be more complete, have great value because: 1) they give us a wide base of genotypes to look at, and 2) the scope of the trials will permit comparisons with areas of similar climates and problems.

Conclusions

Although limited, results already obtained convince us that the idea of the trials was well-founded and should be continued.

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WINTER WHEAT IMPROVEMENT IN CHILE AND REPORT ON THE INTERNATIONAL WINTER WHEAT PERFORMANCE NURSERY

by

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Chile

Wheat is the most important annual crop in Chile. The area planted to wheat fluctuates around 730,000 ha per year, representing more than 23% of the total surface cultivated with different crops in the country. Bread wheat (*Triticum aestivum* L. em. Tell.) covers 94% while *durum* types occupy 6% of the land devoted to this cereal. (2) (Tables 1 and 2).

Table 1. *Durum* and bread wheat: area, yield per ha and production. Chile 1965 crop year.

	Area ha	Production ton	Yield ton/ha
Bread wheat	681.859	10.287.509	1.51
Durum wheat	45.183	870.834	1.93
Total	727.078	11.158.343	1.53

Table 2. Area, average yield per ha, and production of wheat in dryland and under irrigation, Chile. 1965 crop year.

	Area ha	Average Yield kg/ha	Production metric tons
Dry Land	536.900	1.310	701.200
Irrigated Land	190.000	2.180	414.600
Total	726.000	1.540	1.115.800

The main wheat regions are found between parallels 28 and 43 South. Wheat is scarcely grown beyond these limits. Geographically, three zones can be differentiated within the country's wheat area. (Table 3). The Northern Zone has low rainfall (200-600 mm.) and most of the wheat is cultivated under irrigation. Spring types both bread and *durum*, predominate. The Central-South Zone is characterized by increased rainfall (800-1.300 mm.). Wheat is grown under dryland conditions, with supplemental irrigation at some locations. Spring, winter, and alternative cultivars are used. Bread types are grown in the largest portion of this zone with *durum* representing here a limited area along the northern border of this region. The Southern Zone has a high rainfall (1.000-2.000 mm.). Wheat is grown entirely under rainfed conditions. Bread winter cultivars predominate over spring and alternative ones, and *durum* is not cultivated in this region.

Table 3. Area, production, and average yield per ha in the 3 wheat growing regions of Chile. 1970-1971 crop year.

Region	Area (ha) (% of country)	Production (ton) (% of country)	Average Yield kg/ha
North	225.190 (28.99%)	461.707 (34.36%)	2.050
Central-South	253.320 (32.61%)	361.889 (26.93%)	1.428
South	298.130 (38.38%)	520.150 (38.71%)	1.744

Production is insufficient to meet national consumption (Table 4). The possibility of extending the area cultivated with wheat is very limited. Increased yields per unit are seen as the more efficient way to raise total production. The country's average yield per unit is low, 17.3 ton/ha in 1970. Contributing factors to low yield are: cultivation of wheat in marginal areas with inadequate rainfall and/or on poor quality soils, inefficient cultural practices and land management. Other important limiting factors are diseases such as rusts (Puccinia graminis Pers. f.sp. tritici, Ericks & Henn., P. recondita f. sp. tritici Rob. ex Desm., P. striiformis West.), foot and root rots (Linocarpum sp., Fusarium sp.). Diseases caused by Septoria and Erysiphe spp. may also affect yields but are less important than rusts. Losses due to insects like the aphid Metopolophium dirhodum W. have increased during the last three years.

Table 4. Wheat: total demand in Chile, 1965.

Demand, in 1.000 metric tons	
Human consumption	1.203,7
Per capita[a/]	137,0
Animal feeding	71,5
Seed[b/]	108,8
Other uses	37,9
Total	1.403,4
Production	1.276,0

[a/] In kgs per person

[b/] Estimated at 160 kg/ha

Winter Wheat Cultivation

Winter wheat is grown between parallels 36 to 43 South. About 55% of the area sown to wheat belongs to winter types. Rainfall increases from North to South, 800 to 2.500 mm., while annual average temperature decreases, in the same direction, from 15°C to 11°C. Highest rainfall is distributed from May to August, the winter months, when frosts with extreme temperatures of -1 to -6°C are rather frequent. The number of dry months decrease from 6 in the North to none in the southermost provinces. Snow does not fall in this agricultural area except on the slopes of the Andes range over 1.500 m. elevation. Thus, winter types adapted to this region do not need to have a high degree of tolerance to cold. Winter killing is not observed though uprooting by winter frosts is common.

On the largest portion of the winter wheat area soils originated from volcanic ash. The main deficiencies in mineral nutrients are N and P (6, 7). Fertilization practices recommended include application of 200 kg of P_2O_5 and 100 kg of N per ha.

Varietal Improvement

The majority of the winter varieties cultivated in Chile have been introduced from northern Europe, mainly from France, Belgium, the Netherlands, and Germany (1). They have shown good yield potential as data in Table 5 indicates. Today, a good farmer, using the available technology and those varieties can increase his average wheat yield up to 4.5 to 5.5 ton/ha, with a direct production cost of 2.1 to 3.1 ton/ha (3).

Table 5. Yield, stripe rust reaction, and plant height of 10 winter wheat varieties at Carillanca Exp. Sta., Chile.

Variety	Yield [a] ton/ha	Stripe rust [b] reaction	Plant height [b] cm
Vilmorin 29	5.9	10MS	135
Cappelle Desprez	4.9	70S	115
Heine IV	5.8	0	140
Hesbignon	6.8	tMR	120
Manella	6.8	0	110
Intermedio	6.4	0	135
Lilifén	5.7	70S	100
Ibis	6.6	0	120
Bezosztaja 1	5.0	50MS	110
Selection 101, C.I. 13438	5.8	30MS	100

[a] 3-year average, 1969-1971.

[b] Notes from 1971 - 1972.

Cultivars like Cappelle Desprez are an example of what has been said. Introduced from France in 1950, it is the most extensively cultivated, with a wide area of adaptation and good yields, resistant to lodging, though under high fertilization and rainfall may lodge. It was moderately susceptible to stripe rust and susceptible to leaf rust; produced low protein grain. In the last three years has become highly susceptible to stripe rust and is being replaced by resistant cultivars. Other introductions, like Vilmorin 29, were widely cultivated for the past 30 years; with similar characteristics as Cappelle Desprez, but much taller. Successful introductions have been, also, Heine IV, of excellent resistance to stripe rust; Etoile de Choisy, an earlier maturing semiwinter cultivar; Hesbignon and Manella, introduced from Belgium and the Netherlands respectively, are now being recommended to replace Cappelle Desprez.

The cultivars Lilifén, Ford Desprez x W.W.-Lee/Fn,N° 2357, and Intermedio, Heines Peko x Ministro, were derived from crosses between European winter cultivars and spring wheats (Table 5). They have alternative type of growth habit and can be sown either in fall or spring.

The varietal improvement program has been directed to overcome, among others, three major limitations observed in local and introduced germplasm, namely, susceptibility to lodging, to stripe rust, and poor quality (milling, industrial, low protein content). Secondary limiting factors also taken into consideration are: leaf and stem rust, leaf blotch (Septoria tritici Rob. ex Desm.), powdery mildew (Erysiphe graminis DC. f. sp. tritici E. Marchal) and root and foot rots caused by Fusarium spp. or Ophiobulus graminis Sacc. (2). When favorable conditions are present, shattering and sprouting may cause serious losses.

Since 1958, through an intensive crossing program, several semi-dwarfing and dwarfing genes have been employed to shorten plant height to create better, stiff-strawed material. Extremely useful for this purpose were semidwarf derivatives of the cross Norin 10/Brevor 14 x 27-15/Rex-Rio obtained from the program of Dr. O. A. Vogel at Pullman, State of Washington (denominated Vg lines in our crosses, such as Vg 8316, Vg 9144, Vg 8058, etc.). Other material, from the same origin, has been extensively used such as Gaines, Selection 101 or C.I. 13438, and Suwon derivatives. From spring type material, dwarfing genes like Tom Thumb and Olsen have been used, mainly in germplasm obtained from the Mexican program.

Today, several selections under testing at Carillanca Exp. Sta. show a semidwarf type (75-100 cm. plant height) with a very satisfactory resistance to lodging and high yield potential (Tables 6, 7). Among the advanced lines in Table 7, CAR-463 and CAR-872 are being increased for release as commercial cultivars.

Transfer of stripe rust resistance to adapted germplasm has been carried out through a hybridization program. Heines 110 has been one of the best parents in this respect, and its resistance has been incorporated to the semidwarf type material. Ibis, Riesebel 47-51 and Flevina have contributed genes for stripe rust resistance to this phase of the program. During 1970-1971, Compair, Tadorna, Manella, and Weique were entered in this type of crosses.

Until today, all commercial winter cultivars grown currently in Chile showed deficient milling and industrial characteristics as well as low grain protein content, under our environmental conditions. These facts helped support the belief that, because of climatic conditions, high quality grain could not be produced in the winter wheat area. Research by the Central Quality Laboratory of our Institute has proved the contrary. It has made possible the selection of several genotypes of excellent quality which have been used as progenitors in the hybridization program for quality breeding in the Southern zone.

Table 6. Yield, stripe rust reaction, and plant height of some outstanding winter wheat advanced lines at Carillanca Exp. Sta., 1971, Chile.

	Yield ton/ha	Stripe rust	Height cm
Cappelle Desprez (check	5.2	80MS-S	115
CAR-463, Vg 8881 x Hn IV	8.3	0	95
Hesbignon	7.6	0	125
CAR-1274, CD/Vg 8057-CD/Sk x CD	7.6	0	100
CAR-1342, Hesb-(Rn-Cmch) x Vg Sel 101	7.2	0	90
CAR-1295, Vil 53^2-Nor 10/B x Hesb	6.7	0	85
CAR-1346, Rabe x Vg Sel 101	7.1	0	95
CAR-1557, Vil 53^2-Nor 10/B x Ca C	6.5	0	85
CAR-1320, CD^2-Vg 7353 x Pch	6.7	0	95
CAR-1386, Hesb^2 x RN/Cmch	6.8	0	95

Table 7. Yield, stripe rust reaction, plant height, and lodging resistance of stiff, short-strawed parent germplasm entered in the crossing program at Carillanca Exp. Sta., Chile. Data from 1971/72 crop year.

Line	Yield ton/ha	Stripe rust reaction	Plant height cm	Lodging [a] resistance
Cappelle Desprez (check)	4.6	80S	110	3
Selección 101	6.0	30MS	100	2
CAR-12, Dj^2 x Vg 8316	4.9	30MS	90	1
CAR-245, Vil 29^2 x Nor 10/B	[illegible].4	40MS	60	1
CAR-873, Hn IV x II	[illegible].2	50S	65	1
CAR-487, Vg 8058 x IdF	4.7	0	75	1
CAR-463, Vg 8881 x Hn IV	6.6	0	95	1
CAR-872, Hn IV x II	6.3	0	100	2

[a] Lodging scale: 1 = very good
5 = very poor

Worth mentioning on this aspect are Poncheau (France) and Hilgendorf (New Zealand); other interesting wheats are Magdalena (France), Bezosztaja (U.S.S.R.), Aotea and Cross 7 (New Zealand) (Table 8). More recently, high quality spring semidwarfs from the Mexican program were widely crossed with winter germplasm.

Screening of early segregating generations is made by use of modified Pelshenke and Sedimentation tests (4, 9) which permit use of small amounts of seed --5 and 2 grams--respectively. Results have been promising and a sizable group of lines of acceptable quality and adaptation to the Southern zone were isolated.

Transfer of these quality factors into the newly developed winter semidwarfs is now under way.

Table 8. Sedimentation, Pelshenke, and grain protein characteristics of 4 winter wheat varieties used as quality parent germplasm at Carillanca Exp. Sta., Chile.

Variety	Micro-sedimentation	Micro-Pelshenke	Protein
Cappelle Desprez (check)	4.77	31.50	8.00
Vilmorin 29 (check)	2.22	21.00	9.20
Heine IV	1.40	17.45	8.40
Poncheau	6.60	89.75	10.52
Hilgendorf	12.40	56.50	15.07
Aotea	7.30	24.50	14.37
Cross No. 7	7.22	37.25	13.80

The International Winter Wheat Performance Nursery

The IWWPN has been grown for three consecutive years at Carillanca Exp. Sta. (latitude 38° 40' S, longitude 72° 25' W, elevation 332 m.). The first, second, and third IWWPN's comprised a total of 44 cultivars. Of these, only 15 were included in each of the three tests (Table 9).

Date of planting was quite late for the 1969 nursery---August 22 and June 3 for the 1970 and 1971 trials. All nurseries were grown under rainfed conditions with no supplemental irrigation. Fertilizers applied were 200 kg of P_2O_5 and 96 kg of N per ha plus 100 kg of K_2O in 1971.

Stripe rust had excellent development in the three seasons. Leaf rust appeared late and with low severity, so notes on this disease were not taken. Stem rust does not occur at this location.

The group of 15 cultivars mentioned above was used to calculate simple correlations for various traits. Within-years (Table 10) and between-years (Table 11) correlations may help to further characterize the test site and to compare, in a limited way, the consistency of the data between years for the same location.

Negative correlations existed in all cases between yield and stripe rust, which were high and significant for 1970 and 1971. Yield was positively correlated with heading date, plant height and test weight.

Stripe rust was negatively correlated with all traits considered; significantly with yield, 1969 plant height, and test weight for the 3 years.

Plant height correlation with lodging was significant and positive for all 3 seasons, and with test weight for 1969 and 1971. Lodging showed a positive, significant correlation with test weight in 1971.

Protein and lysine had small nonsignificant correlations with all traits. Protein and lysine gave a positive significant correlation for the one-year data available.

Correlation figures in Table 10 corroborate the importance of stripe rust as the main limiting factor for varietal performance at this location, and of plant height as a lodging factor.

Table 9. Summary of agronomic, disease, and quality data for 15 cultivars in the 1st, 2nd, and 3rd International Winter Wheat Performance Nursery grown at Carillanca Exp. Sta., Chile. Data from 1969, 1970, and 1971 crop years.

Variety	Yield [a/] q/ha	Stripe [b/] rust reaction	Days to heading	Plant height cm	Lodging %	Test weight kg/hl	Protein [c/] %	Lysine [c/] % of protein
Felix	49.3	10MS	190	112	12	72.9	--	
Blueboy	44.1	30S	178	108	25	71.8	12.4	3.09
Bezosztaja	38.7	40MS	170	103	40	74.5	13.0	2.87
Fertodi 293	35.0	tMR	181	133	70	75.2	11.5	3.13
Atlas 66	32.3	40S	179	135	60	75.5	14.2	3.09
Scout 66	29.9	60S	174	128	60	68.4	12.3	3.08
Sturdy	29.3	10MS	165	91	5	63.0	12.3	3.12
LR. 64	18.0	70S	156	97	35	66.6	15.2	2.91
Benhur	17.9	100VS	169	110	18	65.3	12.9	3.02
San Pastore	14.8	100VS	164	104	27	66.8	14.2	2.93
Timwin	12.8	100VS	171	91	10	63.3	13.5	3.02
Yorkstar	12.0	100VS	176	104	28	55.3	11.5	3.36
Parker	10.0	100VS	169	110	23	53.3	13.5	3.04
Triumph 64	5.3	100VS	163	114	12	--	12.3	3.15
Yung Kwang	2.5	100VS	172	105	70	--	11.2	3.34

[a/] Yield, days to heading, plant height, lodging, and test weight: average of 3 years.

[b/] Highest reading in 3 years.

[c/] Data from 1969 IWWPN.

Table 10. Simple correlation coefficients for 8 traits measured on 15 cultivars in the IWWPN grown at Carillanca Exp. Sta., Chile. Data from 1969, 1970, and 1971 crop years.

Trait	Reaction to stripe rust	Heading date	Plant height	Lodging	Test weight	Protein	Lysine
Yield	-0.423 a/	—	0.602*	0.200	0.705*	0.197	0.211
	-0.886* b/	0.513	0.282	0.188	0.763*	—	—
	-0.911* c/	0.399	0.401	0.433	0.914*	—	—
Reaction to stripe rust		—	-0.052	-0.027	-0.176	-0.401	-0.507
		-0.575*	-0.184	0.083	-0.822*	—	—
		-0.337	-0.398	-0.391	-0.908*	—	—
Heading date			—	—	—	—	—
			0.530*	0.215	0.255	—	—
			0.207	0.025	0.353	—	—
Plant height				0.571*	0.715*	0.054	0.134
				0.618*	0.133	—	—
				0.710*	0.528*	—	—
Lodging					0.288	0.141	0.042
					-0.072	—	—
					0.514*	—	—
Test weight						-0.114	-0.031
						—	—
						—	—
Protein							0.893*

a/ For 1969 data
b/ " 1970 "
c/ " 1971 "

* P less than 0.05

Table 11. Between-years simple correlations for 6 traits measured on 15 cultivars in the IWWPN grown at Carillanca Exp. Sta., Chile. Data from 1969, 1970, and 1971 crop years.

Trait	1969 vs 1970	1969 vs 1971	1970 vs 1971
Yield	0.421	0.262	0.929*
Stripe rust	0.524*	0.544*	0.939*
Heading date	--	--	0.173
Plant height	0.413	0.328	0.847*
Lodging	0.461	0.511	0.641*
Test weight	0.476	0.022	0.564*

* P less than 0.05.

Between-years correlations were all positive, indicating a relative degree of confidence when comparing data from one year with the others in this test period.

Correlations between data from 1969 with that of 1970 and 1971 were positive but not significant at P $\angle$ 0.05, evidencing that 1969 data, possibly due to a late planting date, was less reliable in relation to notes taken in 1970 and 1971. In effect, correlations for 1970 data versus 1971 were high and significant, exception made of heading date. The latter may have been influenced more than other traits by high temperatures that occurred late in the spring of 1971. Again, stripe rust shows significant correlations for all three comparisons (Table 11). This fact characterizes Carillanca as a good test site for stripe rust resistance.

Of 15 cultivars in Table 9, the top yielders were resistant or moderately resistant to stripe rust, relatively late-flowering and tall, with test weight around 70-75 kg/hl.

Within the group of 44 cultivars grown during the 3-year period, the highest yield was produced by TX 62A 4793-7 with 61.1 q/ha in the 1970 test; it had a test weight of 70.9 kg/hl and 0 stripe rust; with plant height of 125 cm and 80% lodging. The second best yielder was Heine VII with 54.3 q/ha in 1971. It had a test weight of 78.25 kg/hl, 120 cm plant height, 20% lodging, and tR for stripe rust.

Fertodi 293, Blueboy and Bezosztaja were among the top 10 yielders for all three tests. Felix, Atlas 66, and Lancer were in the same top group for two seasons. All these cultivars were superior in yield to Cappelle Desprez, the standard check for this region.

The best resistance to stripe rust was shown by Heine VII, Fertodi 293, Felix, and Odin. Sturdy had a 10R and 10MS readings in 1970 and 1971 respectively. Bezosztaja which had an immune reaction in 1969, became a 40MS and 30MS in the following years. Vakka and Jyva were highly resistant in the 1971 test.

Examination of the information obtained in the 3-year period of testing the IWWPN indicates that, at our location, it permitted an effective screening of those cultivars which possessed both good yield potential and stripe rust resistance. The same can be said about lodging. Evaluation of yield potential per se appears rather difficult since reaction to stripe rust bears such prime rank among limiting factors at Carillanca in the final determination of yield levels.

The above mentioned observations lead us to a proposal: it would be convenient to choose specific sites to test for a determined character or group of characters (yield potential, rusts, Septoria spp., foot and root rots, etc.) where a preliminary screening of candidates would be made. At these specific sites, a small preliminary nursery (no more that 50-100 entries) should be grown to help selection of candidates for next year's IWWPN.

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TRITICALE

by

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Mexico

Introduction

Triticales are derivatives of crosses between wheat and rye. Hexaploid triticales are amphiploids of crosses between tetraploid wheats and diploid ryes. Octoploids are produced from hybrids between hexaploid wheats and diploid ryes. The hybrids are treated with colchicine to double the chromosome number. Triticales have been around for at least a half a century but have made no impact agriculturally until the last few years and most of that has been through the press.

History

European scientists have done most of the early ground work on this crop. Considerable research originated from Sweden, Hungary, Russia, Spain and other European countries. Most of the work was done on the development of winter strains. Varieties produced by Dr. Kiss in Hungary are in production in central Europe and to a limited extent in the United States.

In North America the development of triticales as a cultivated crop is being done at the University of Manitoba, CIMMYT in Mexico and a few private companies. Most of this effort has been directed towards spring types. It is estimated that 200,000 acres of triticales were harvested in North America in 1971. It appears that it has found its greatest popularity as a fall and winter grazing crop in the south, centered in Texas and Oklahoma. In Canada the crop is used for grain production as livestock feed and in the malting and distilling industries.

CIMMYT Triticale Program

Triticale research at CIMMYT was initiated in 1964 and has developed into a full-fledged program during the past five years. The program was started in cooperation with the University of Manitoba using their material. In 1971 funding was obtained from the Canadian Government through the Canadian International Development Agency for a Triticale development program with the University of Manitoba cooperating.

The first triticales were very poorly-adapted to the Mexican environment. They were very tall, late, susceptible to lodging, highly sterile, and susceptible to stripe rust and other diseases. Prior to the development of the Armadillo strains, the best yields obtained were about one-half of that of the Mexican bread wheats. To overcome the problems and to improve triticales, the breeding program at CIMMYT was directed towards: 1) producing new triticales using Mexican wheats and strains of rye which were less sensitive to day length; 2) crossing the triticales directly to the Mexican wheats; 3) inter-crossing different lines of triticales and selecting for fertility and better agronomic characteristics among the segregating populations.

Armadillo

The first major break in this program came with isolation of a few fertile plants resulting from a chance outcross of triticales to Mexican bread wheats.. The progenies from these plants were referred to as Armadillo strains. Selections from Armadillo have brought the yields close to those of bread wheats at moderate levels of fertility. The strains are too susceptible to lodging to compete with wheat under high fertility production. See tables 1 and 2.

Table 1. Yields of Triticales vs. wheat checks

Location and year	Triticales Yield in kg/ha Average	Triticales Yield in kg/ha Top	Wheat checks Yield in kg/ha Average	Wheat checks Yield in kg/ha Top
	Sonora winter nursery			
Ciano 1967-68	2663	3196	4213	5207
Ciano 1969-70	4492	4990	5417	6202
Navojoa 1969-70	5066	6282	5321	6491
Navojoa 1970-71	5250	6320	5950	6600
Ciano 1971-72	5237	5388	5432	6457
Navojoa 1971-72	5152	5443	4958	5339
	Mexico summer nursery			
Toluca 1968	2691	3190	None included	
El Batan & Toluca 1969	3229	3972	3554	3645
El Batan & Toluca 1970	4117	5050	3737	4613
El Batan & Toluca 1971	3750	4590	3800	4610

Table 2. Summary of yield of Triticales and check varieties in tests at Toluca MV-71 Reps. 6, rows 2 meters in length.

Variety and crop	Expt.I	Expt.II	Expt.III	Expt.IV	Average all tests
Bread wheat					
Average	3.96	3.82	3.52	3.89	3.80
Top variety	4.40	5.10	4.38	4.55	4.61
Durum wheat					
Average	1.94	1.96	1.98	2.28	2.04
Top variety	2.16	2.02	2.16	2.48	2.20
Triticales					
Armadillo check	3.95	3.83	3.71	3.90	3.85
Top strain	4.50	4.51	4.40	4.93	4.59
Av. all Triticales	3.94	3.87	3.75	2.46	3.75

Overcoming Lodging

Since the Armadillo strains have been used throughout the program as a basis for improving yield, seed type, fertility and nutritional quality, a major limiting factor is lodging. Breeding for improved lodging resistance is being approached in two ways: by reducing plant height, that is, creating dwarf triticales; and by increasing straw strength at the semi-dwarf level. Dwarfing genes are being introduced from the Mexican bread wheats and from a dwarf rye Snoopy which was found in an outcrossing population of Gator, obtained from Dr. Darrell Morey, Tifton, Georgia. The use of dwarfing genes from bread wheat introduces several problems among which are susceptibility to wheat diseases, replacement of rye chromosomes with wheat chromosomes, and making the plant more wheat-like.

Dwarf strains of triticales originating from crosses to bread wheats were included in yield tests for the first time in 1972. The major difficulty appears to be to introduce dwarfing and maintain high fertility. One such strain, referred to as Cinnamon, appears to be able to withstand up to 120 kilos of nitrogen without lodging. Its yield at lower levels of nitrogen is equal to the best Armadillo lines.

The introduction of dwarfing from the rye strain Snoopy is developing more slowly. The original strain of dwarf rye had several undesirable features, such as susceptibility to diseases, small seed, and very low vigor. Better dwarf ryes have been obtained by crossing it to good tall types. We are also introducing self-fertility in the dwarf ryes in an attempt to overcome incompatibility and sterility problems in triticale-rye hybrids.

Endosperm Shrivelling

This occurs during the development of the seed to a greater or lesser extent in all triticales. Screening for better kernel type has been done during the past three years. The progress is slow, particularly with our emphasis on reducing plant height, we appear to be encountering the same problems as occurred when Norin 10 dwarfing genes were introduced into the Mexican wheats. I hope we are as successful as the wheat breeders in overcoming this problem. At the moment it appears that triticales will continue to have a lower test weight and more shrivelled endosperm than wheat for some years to come, but eventually I believe the problem will be overcome.

Adaptation

Current strains of triticales appear to have a narrow range of adaptation. A glance at the results obtained from the 1st ITYN is enough to convince us that we have a long way to go to compete with the range in adaptation possessed by the wheat varieties Pitic or Siete Cerros. We are sending segregating populations, from genetically diverse crosses, for screening to numerous locations all over the world. Seed samples from the best selections are sent back to CIMMYT for hybridization among material selected from other diverse areas. This material is again bulked and redistributed for a second cycle of selection. Seed from these populations is available to cooperators for the asking.

Diseases

So far in the development of triticales, diseases have not created problems which are unique to the crop. It is expected that as triticales are produced on a commercial scale, diseases will become as important as in the other cereal crops. The rusts, which attack wheats, also infest triticales but not necessarily as seriously. Stem rust was difficult to find in triticale plots until we started crossing them to bread wheats. Leaf rust attacks triticales but the disease appears to build up more slowly than on most varieties of bread wheat. Bacterial stripe, probably caused by Xanthomonas translucens, is highly destructive to many strains of triticales. The disease occurs too sporadically in Mexico to screen for resistance under natural conditions. Should this disease show signs of becoming important, adequate screening techniques will have to be developed. Ergot, caused by Claviceps purpurea, a common disease on rye also attacks triticales. Recent observations at Winnipeg indicate that infection is associated with the degree of sterility occurring in the crop. Highly fertile triticales tend to develop very little ergot. Leaf diseases are quite prevalent in some areas. In the Toluca nursery very few strains of triticales appear to ripen normally; as maturity approaches most of the strains have leaf problems. These occur as blotches, chlorotic spots or leaf firing. Numerous fungi are associated with leaf blotches. Some are as unusual as snow mold caused by Fusarium nivale, observed by Dr. M. J. Richardson at Edinburgh, Scotland.

Nutritional Quality

One of the most exciting developments in triticales relates to its usefulness as food for humans and animals. Early studies, using triticales in feeding trials with poultry and animals, were discouraging, in spite of higher levels of protein present. Reduced feed intake and slower growth rates were observed by most investigators. No attempt was made to screen for strains having better nutritional characteristics until Dr. Fred Elliott, Michigan State University demonstrated that triticale strains varied widely in increasing body weight of weanling meadow voles on diets containing a uniform level of protein. He pointed out that the efficiency of the strains in increasing body weight was affected by the quality and availability of the protein and the presence of toxic or "anti-metabolic" substances.

Strains which were classed as nutritionally suitable on the basis of voles were found to be a good source of protein for baby chicks by Dr. James McGinnis at Washington State University. Carrying this investigation one step further, an experiment was set up to determine the nutritional value of one strain of triticales for laying hens. An Armadillo strain, PM (Nut) 132, which was selected for good quality in vole bioassays and subsequently gave good results on baby chicks, was used in an experiment at Los Mochis, Sinaloa, Mexico. Dr. James McGinnis and Eduardo Rivera compared diets containing wheat, sorghum and triticales as the major source of protein and energy. Summary tables from a thesis by Dr. Buenrostro, table 3, provide the chemical compositions of the diets and production data for this study. The laying hen diet containing 85% triticale not only produced more eggs at higher efficiency than the other diets, but reduced the cost of protein supplementation by an estimated 10% of the total cost of the feed. Experiments to verify the nutritional value of triticales are being set up with other animals. Should these experiments verify the usefulness of meadow-vole bioassays in determining nutritional quality, these animals will be used in screening triticale strains for the presence of toxins and quality of the protein.

Table 3. Laying Hen Experiment in Los Mochis, Sinaloa, Mexico.

Rations	Ration composition in per cent		
	1	2	3
Ingredients			
Sorghum (8.5% P.)	36.0	38.0	-
Wheat (12% Pr.)	36.0	-	-
Triticale (16.7% Pr.)	-	38.0	85.0
Soybean Meal (48% Pr.)	10.0	9.3	1.0
Safflower Meal (21% Pr.)	2.3	-	-
Fishmeal (65% Pr.)	5.0	4.0	3.0
Alfalfa Meal (20% Pr.)	3.0	3.0	3.0
Calcium phosphate, salt minerals, and vitamins added to all diets.			
Nutritional composition of diets			
Protein	19.5	18.0	17.7
Lysine	0.83	0.75	0.67
Arginine	0.94	0.86	0.85
Meth-Cistine	0.59	0.55	0.56
Triptophan	0.23	0.21	0.21
Calcium	3.8	3.7	3.8
Phosphorus	0.71	0.57	0.68

Summary of production data

Diet	Production of Eggs: Number of eggs	Production of Eggs: Production /bird/day	Egg weight: Total g.	Egg weight: Per egg g.	Consumption of Field	Conversion: kg feed/ kg eggs	Gain in body weight g./bird
Wheat-Milo	1006	79.8	53136	52.76	124335	2.33	129.2
Milo-Tcl	990	78.5	52144	52.62	123760	2.37	134.9
Triticale	1035	83.6	54204	52.38	123870	2.28	159.2

Use and Impact on Food Production

Triticales are likely to develop importance first in fringe areas or as a crop with a specific adaptation. In the Southern U.S.A. strains particularly suited to production of plant material during cool season of the year are favored for forage and pasture crops. In Canada the unusual enzymatic activity of certain strains makes them suitable in the distillation of alcohol. Some strains have been observed to produce well in high elevation areas of the tropics such as Ethiopia and are already competitive with other cereals.

Indications from tests and observations point to triticales as a crop for sandy areas where rye outproduces wheat, in marginal wheat areas which suffer from drought, cold or certain disease. Its high protein content, and possible nutritional quality could favor its use as human food. Baking tests at El Batan and other research centers demonstrate that high quality bread with acceptable flavor can be produced from triticales. However, in the early stages it is unlikely to compete directly with wheat in areas where that crop can be grown successfully.

HYBRID WHEAT BREEDING

by

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Introduction

For a successful use of hybrid wheat two fundamental preliminary conditions must be fulfilled: a) expression of an adequate vigor of the F_1 hybrid in important economic traits, yield and quality included, and b) possibility of producing sufficient quantities of hybrid seed on an economically sound basis.

Heterosis in wheat has been proved in numerous investigations. Briggle (1963) gave a brief survey of publications dealing with wheat heterosis which had been issued up to that time. In spite of considerable shortcomings these investigations show that the fertility of F_1 hybrids can be as much as 100% higher than the most fertile parent. This was also proved by results published after 1963 (Rodriguez et al., 1967; Merkle et al., 1967; Nettevich, 1968; Rajki S. and Rajki E., 1968; Livers and Heyne, 1968; Shebeski, 1970, et al.). On the basis of all investigations to date one could conclude that the yield of grain of the best F_1 generations would be sufficiently higher than that of the best varieties to justify economically the application of hybrids in extensive production. It is supposed that the results hitherto achieved will also be achieved with restored hybrids at normal rates of seeding.

The discovery of the biologic system comprising the cytoplasmic sterility and the restoration of pollen fertility in wheat makes the commercial production of hybrid seed possible. Kihara (1951) pointed out the possibility to use male sterility by transferring the nucleus of common wheat into the cytoplasm of Aegilops caudata. From that time new sources of cytoplasmic pollen sterility were found (Fukasawa, 1958; Wilson and Ross, 1962; Oehler and Ingold, 1966). Among the cytoplasms, which in an interaction with Triticum nucleus bring about pollen sterility, it seems that T. timopheevi is the most suitable one for the commercial production of hybrid seed.

Fertility restoration in the F_1 generation is another component without which the cytoplasmic pollen sterility could not be used at wheat production. Fukasawa (1958, 1959) was the first who showed the possibility of restoring male fertility when he had substituted the nucleus from T. dicoccoides var. Kotschyanum (2n=28) from the nucleus from Ae. ovata (2n=28) in ovata cytoplasm. After that restorer genes were also found in some other Triticum species.

Numerous investigations carried out during about the twenty last years all over the world gave at least a partial reply to many questions concerning the possibility of a practical application of hybrids in wheat production. However, there are still some problems left which must be solved.

The purpose of this paper is to sum up the results that have been achieved so far and to give additional information on the most important problems of the breeding and production of hybrid wheat. In our opinion they are: 1) fertility restoration in F_1 generations, 2) cross-pollination and seed set on male sterile plants, and 3) effects of cytoplasmic male sterility on the other characteristics of plant and seeds.

Fertility Restoration

The establishment of effective fertility restoration for *T. timopheevi*-derived male sterility is the main problem on the way to the commercial use of hybrid wheat. The first report on *T. timopheevi*-derived fertility restoration in *T. aestivum* was published by Schmidt and co-workers (1962). Further investigations have shown that fertility-restoring genes for *T. timopheevi* cytoplasm can be found in different tetraploid and hexaploid wheats (Table 1). A considerable number of varieties of *T. aestivum* and *T. durum* possess genes for partial or complete male fertility restoration of *T. timopheevi*-derived cytoplasmic male sterility (Goujon and Ingold, 1967; Zeven, 1967, 1968; Johnson and Schmidt, 1968; Joppa and McNeal, 1969).

Table 1. Fertility restoration capacity (+) among known restorer and male sterility sources.

Restorer source	Male sterility source	Aegilops: ovata	Aegilops: caudata	Aegilops: ventricosa	Triticum: timopheevi	Triticum: timonovum	Triticum: zhukovskii	Authors
Aegilops	ovata	+						Fukasawa 1959, Lacadena 1966.
"	caudata	+	+					Kihara 1966, Lacadena 1966.
"	ventricosa			+				Oehler and Ingold 1966.
Triticum	dicoccoides	+						Fukasawa 1958.
"	timopheevi-derivatives	+	+	+	+			Schmidt et al. 1962, Wilson and Ross 1962, Livers 1964, Lacadena 1966, Nettevitch i Fedorova 1966.
"	timonovum					+		Nettevitch & Fedorova 1966.
"	zhukovskii						+	" " "
"	aestivum ssp. vulgare				+			Goujon & Ingold 1967, Zeven 1967.
"	compactum		+					Fukasawa 1959, Kihara 1966.
"	spelta				+			Kihara & Tsunewaki 1965.
"	macha		+		+			Zeven 1967.

All restorer lines isolated so far were put by Ingold (1968) in two groups: 1) male fertile lines derived from the same substitutions as male sterile lines and able to restore their fertility, and 2) restorer lines having another origin than the male sterile lines.

A number of studies were initiated to determine the genetic complexity of the restorer mechanism. Investigations hitherto have shown that fertility restoration can be conditioned with one, two, or more genes:

Authors	Number of genes	Mode of action
Wilson (1962)	1 + ?	dominant + minor genes
Anderson (1963)	2	dominant
Schmidt and Johnson (1963)	2 (?)	complex inheritance
Livers (1967)	2	dominant
Goujon and Ingold (1967)	1	dominant
Wilson (1968)	3 (at least)	cumulative dominants
McCuistion (1968)	more than 2	complex
Bajwa and Lecken (1968)	2 or 3	?
Ingold (1968)	3	epistatic effects

Results differ in number and effect of genes in dependence on environments under which the studies were made or the sources of restoration used. Wilson (1967) suggests that "cumulative dominance may be adequate to describe the general nature of restoration".

Monosomic analysis of the restorer lines indicated that genes for fertility restoration are located on different chromosomes:

Chromosomes carrying restorer genes	Number and action of genes	Authors
1A	1 dominant	Robertson and Curtis (1967)
2A, 6A, 1B, 6B, 3D	modifying genes	
1B	1 inhibitor	Talaat et al. (1968)
1A, 5A, 7D	?	
1A and 6B	major genes	
6D and 7D	minor genes	Yen et al. (1969)
2A, 6A, 3D	modigying genes	
1B	1 dominant	
2A, 4A, 2B, 2D, 5D, 7D	modifiers and inhibitors	Tahir and Tsunewaki (1971)

Fertility restoration genes are sensitive to environment (Schmidt and Johnson 1966; Wilson 1968). Therefore, the stability of any R-line for pollen-restoring capacity is dependent on the resistance of genotype to environmental conditions.

Wilson (1968) has classified environments into three categories: "shallow sterile", "sterile", and "deeply sterile", based on observations of pollen fertility in different experimental materials at various locations. Temperature has the strongest effect on expression of pollen fertility. A restored hybrid having complete fertility in a "shallow-sterile" environment might express tip-sterility when grown in a "deeply-sterile" environment.

Restored hybrids of the same R-line have shown distinct differences in pollen fertility within one environment. This is also confirmed by our results obtained by testing 18 R-lines on three A-lines in 1971 (Table 2). With the exception of the restorer line Bison (R_3) all other lines show a greater fertility restoration capability on the A-line Dubrava (o-44) than on the A-line Ranka (o-42). The average percentage of pollination of all F_1 hybrids was with A-line Dubrava 69.0%, Mirna 52.4% and Ranka 38.5% respectively. These differences might be attributed to genetic variability for restoration among A-lines. The A-line Dubrava is easy to restore, but A-line Ranka is difficult to restore. According to Wilson (1968) the first A-line "carries fertility which is additive or complementary to the male restorer genes", and the second A-line "carries an inhibitory effect". The differences in female restoration can be determined most easily in hybrids with R-lines having incomplete restoring ability.

Tested R-lines differ very much in their fertility restoration capability. The best one among them is Primepi (R_6) with a 95.9% average seed set of all three A-lines. Primepi was prominent as an especially good restorer also in other investigations (Ingold, 1968; Wilson, 1968). This restorer shows broad restoring capacity.

Table 2. Percentage of seed setting in the F_1 from crosses of male sterile (A-) x fertility restorer (R-) lines. Zagreb, 1971.

R-lines	A-lines (T. tpv-cms)	Dubrava (0-44)[3]	Mirna (0-53)[3]	Ranka (0-42)[3]	Average
Lot 1 (Bison)	R_1	71.1	52.3	31.0	31.4
Lot 2 (Bison)	R_2	59.1	71.5	47.7	59.4
Bison	R_3	64.3	73.5	73.0	70.3
Kansas	R_4	61.4	47.1	48.7	52.4
Nebraska	R_5	63.3	52.7	36.5	30.8
Primepi	R_6	103.3	90.3	94.1	95.9
Texas	R_7	62.1	54.0	35.3	50.5
Bezostaja 1^4S^4	R_8	54.2	35.4	21.4	37.0
Prof. Marchal	R_9	73.4	62.4	54.2	63.3
CH I x GEI[3]	R_{10}	92.9	87.9	87.7	89.5
CH 3-I-6	R_{11}	15.0	35.2	14.1	21.4
CH 4-II-2	R_{12}	68.1	38.6	14.1	40.3
Sel. from Nebraska	R_{14}	72.3	60.1	30.8	54.4
Palmares	R_{15}	77.7	50.6	11.2	46.5
IBO-1029/604	R_{16}	68.4	25.9	4.2	32.8
IBO-519/616	R_{17}	86.4	48.5	27.6	54.2
IBO-544/616	R_{18}	83.4	25.1	30.3	46.3
IBO-460/616	R_{19}	86.1	33.4	30.8	50.1
Average		69.0	52.4	38.5	

Cross-pollination and Seed Set on Male-sterile Lines

The use of hybrid wheat as a commercial crop will depend on the success of hybrid seed production. Seed set on male-sterile lines is influenced by a number of characteristics of both hybrid components as well as by environmental conditions during the flowering period.

Cross-pollination in wheat depends on the receptivity of the stigmas, the quantity of pollen in the air during the receptive period and the viability of the pollen.

Under optimal conditions of temperature and humidity stigmas remained receptive for as long as 5-13 days (Imrie, 1966; Rajki and Rajki, 1966). Too high or too low temperatures and humidity will shorten the period of stigma receptivity. Duration of stigma receptivity depends on varietal differences and environmental conditions.

Cross-pollination of male-sterile wheat is dependent on flower opening or exposure of the stigma to wind-borne pollen. If pollination is delayed the flower is more open and stigmas tend to grow beyond the lipe of the open glumes (Wilson 1967). Varieties differ in the degree of flower opening (Rajki 1962). Selection of wheat with large stigmas and lodicules might reduce some problems in seed production on male-sterile lines (Wilson 1968).

The quantity of pollen in the air at a determined time is a function of: the number of pollen grains per anther, the quantity of extruded anthers, and the number of anthers per surface unit. Therefore a good pollinator in hybrid seed production should possess high pollen productivity and ability to extrude anthers. Cahn (1925) was the first who ascertained significant variety differences in the anther length and the number of pollen grains. These differences were confirmed in later works too.

Number of tested varieties	Number of pollen grains/anther	Authors
12	1200 - 1600	Heyne and Livers (1967)
11	2687 - 3867	Joppa et al. (1968)
26	2031 - 5094	Milohnić and Jošt (1970)
22	581 - 2153	Beri and Anand (1967)

The size of an anther is positively correlated with number of grains/anther ($r = +0.87$ - Milohnić and Jost, 1970; $r = +0.734$ Beri and Anand 1971).

Varieties differ considerably also in the quantity of pollen shed from the flower (Joppa et al. 1968; Zeven 1968; Beri and Anand 1971). Semi-dwarf types shed less pollen than taller varieties (Olson 1966). Beri and Anand (1971) found out that tall varieties produce more pollen grains/anther, they have longer filaments and shed greater quantities of pollen from the flower. Varieties with a longer vegetation period produce bigger anthers ($r = +0.57$) with a larger number of pollen grains per anther (Milohnić and Jošt 1970). Wilson (1967) suggested that selection of lines with good flower characteristics would promote better cross-pollination.

Viability of pollen is prolonged by cool temperatures and high relative humidity (Watkins and Curtis 1967). Warm and dry weather hastens anther development and reduces pollen viability.

Successful seed setting on male-sterile wheat mostly depends on the time of flowering of male and female. Obviously the female should flower before the male parent, but the optimum difference for heading dates may vary with varieties being crossed and the environmental conditions under which cross-pollination takes place (Wilson 1968). The varieties differ in the speed of anther extrusion and pollen dissemination after heading (Milohnić and Jošt 1970). Rajki and Rajki (1966) and Wilson (1967) suggested that male-sterile line as female should flower 1 to 2 days before the pollen-donor line. In some cases this difference will be perhaps greater.

Experiments of Wilson and Ross (1962) indicated that male-sterile wheats could average 70% seed set. Since then, numerous investigations on the crossing potential of male-sterile wheat were carried out. Experiments have been made under different conditions, with different sources of sterility of pollen or with emasculated spikes of male-fertile varieties. The experiments also ranged in size and pollen availability. It is therefore difficult to compare the obtained results. Seed sets have ranged from less than 10 to more than 80 percent of normal (Livers 1964; Kihara and Tsunewaki 1964; Lacadena 1966; Rajki and Rajki 1966; Bitzer and Patterson 1967; Johnson et al. 1967; Kherde et al. 1967; Porter et al. 1967; Wilson 1967; Lukjanenko et al. 1970). The percentage of seed sets varied in the same range on 4 male-sterile lines in our investigations (Table 3).

Table 3. Seed set on male sterile (A-) lines and their fertile (B-) counterparts. Zagreb, 1970 and 1971.

Varieties or lines	Percent+ of seed set on:			
	A-line		B-line	
	1970	1971	1970	1971
Abbondanza (5,6)	48.5	62.5	129.4	138.2
Bezostaja 1 (4,5)	67.0	68.4	125.0	121.0
San Pastore (5,6)	35.3	35.7	102.9	112.5
Etoile de choisy (5,6)	24.6	28.9	91.1	94.7

+ Two seeds per spikelet = 100%

On the basis of these results one could conclude that lines differ in their ability of seed setting. If there is a poor seed setting on the B-line, there will also be a poorer seed setting on the corresponding A-line at the mutual dusting. To confirm these conclusions further detailed investigations are necessary. In some experiments, investigations have tried to determine the most favorable ratio of female to male component or the distance of the male-sterile from its pollinator (Wilson.1967; Rajki and Rajki 1968; Zeven 1968). Wilson (1967) considers that "although a 1:1 ratio of female to male in crossing blocks" appears successful, some types may be broadened to a 2:1 ratio.

It can be concluded that the variability in the total gene pool for many characteristics of the flower which promote cross-pollination has not to date been exploited. As more knowledge is gained the percentage of seed sets should be increased beyond the levels reported thus far.

Cytoplasmic Side Effects

The various cytoplasms exert different influences on the substituted genomes. Differences between male-sterile and normally fertile plants in meiosis and pollen grain development are known. In the production of hybrid seeds these differences are desirable. However, cytoplasm can have also undesirable effects on important economic properties. Kihara and Tsunewaki (1964) stated that alien male-sterile cytoplasms reduce plant vigor and cause some delay in heading. Aegilops ovata and caudata cytoplasms produce serious side effects (delayed development, lower vigor, pistillody, haploid and twin seedlings). Therefore these sources of cytoplasmic pollen sterility are considered to be unfavorable for the production of hybrid seed.

On male-sterile lines carrying T. timopheevi cytoplasm no adverse side effects on maturity or plant vigor have been visually detected. Porter et al. (1967) ascertained that T. timopheevi cytoplasm has no adverse effects on the height of the plant, the date of formation of ears, and resistance to cold. According to investigations carried out so far T. timopheevi cytoplasm has no negative influence on the properties of dough (Wilson and Villegas 1966; Rooney et al. 1967). Restored hybrids have shown up to 2% higher protein content than varieties with equivalent yield.

However, the seed produced on male-sterile plant from cross-pollination tends to be wrinkled or shrivelled (Johnson et al. 1967); Nettevich and Sanduhadze 1968). The results of our investigations confirm these observations (Milohnić 1967). The seeds produced on A-lines are larger and heavier than those on fertile analogous ones (Table 4). However, the germination capacity of A-lines seed is significantly lower than that of seed produced on B-lines. The mean difference was 6.9%. Coleoptile, seminal roots and 21-days-old seedlings of A-lines were shorter than those of B-lines. The differences in specific weight of seed and in the number of seminal roots were not significant.

In 1971 we carried out preliminary investigations of the content of chlorophyll in the flag leaf and head of 4 male-sterile (A-lines) and their fertile counterparts (B-lines) in the heading and milk stage (Table 5). In both stages the content of chlorophyll was significantly lower in A-lines. This might be one of the reasons for the incomplete fullness and grain shrivelling in the A-lines. The obtained results support Wilson's opinion (1968) "that physiological differences of some magnitude may exist" between male-sterile lines and normal fertile counterparts. For the time being it cannot be foreseen to what degree such differences could have an influence on the yield and quality of restored hybrids.

Table 4. Mean values of studied characters of seed and seedlings A(ms)- and B(mf)-lines of 8 wheat varieties. Averages for 3 years.

Character	Mean value A(ms)-line	Mean value B(mf)-line	D (ms-mf)
Length of grain (mm)	6.59	6.29	0.30++
Width of grain (mm)	2.93	2.75	0.18++
Weight of 1000 kernels (gr)	38.19	33.45	4.70++
Specific gravity	1.366	1.369	-0.003
Germination (%)	91.5	98.4	-6.9++
Length of coleoptile (cm)	3.18	3.36	-0.18++
Height of plant with I. leaf (cm)	14.97	15.75	-0.78++
Number of seminal roots	3.79	3.82	-0.03
Length of root (cm)	25.37	26.67	-1.30++
Weight of dry matter/plant (mg)	24.52	26.18	-1.66+

+ significant at 5%
++ significant at 1%

Table 5. Chlorophyll content (mg/g dry matter) in flag leaf and head of male-sterile (A-) lines and fertile counterpart (B-lines) at the heading and milk stages. Average for 4 lines in 2 years.

Line	Flag leaf Heading stage	Flag leaf Milk stage	Head Heading stage	Head Milk stage
A-lines (ms)	7.245	3.884	1.198	0.851
B-lines (mf)	7.979	4.155	1.335	1.032
LSD 0.05	0.218	0.157	0.032	0.040
0.01	0.300	0.216	0.044	0.055

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RESEARCH WORK ON HYBRID WHEAT USING T. TIMOPHEEVI MALE STERILITY-RESTORATION OF FERTILITY SYSTEM AT NOVI SAD

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The discovery of a cytoplasmic male sterility (cms)-restoration of fertility (Rf) system in wheat (Kihara, 1951 and Fukasawa, 1953) and the attempt to utilize it in hybrid seed production (Schmidt et al. 1962; Wilson and Ross 1962), provided impetus for initiation of work on hybrid wheat in Novi Sad in 1965.

The main task of our research was to introduce the cms-Rf system in high-yielding wheat varieties and to examine the effectiveness of this system under climatic conditions of Yugoslavia in order to create and utilize hybrid wheat.

Materials and Methods

The American varieties cms-Gaines and cms-Bison were used as the donors of the cms character, both containing cytoplasm of T. timopheevi.

Among the varieties for restoration of fertility Nebraska lot-1 and Nebraska lot-2 were examined (both with Rf genes from T. timopheevi) as were Primepi and Palmaress (both belonging to the species T. aestivum ssp. vulgare) and some others.

Aiming to identify new sources of Rf genes, over 200 varieties from the species T. aestivum ssp. vulgare were tested from about 20 countries. Wide genetic variability was exhibited by the varieties.

All experiments were conducted under field conditions with optimum cultural practices and with spacing between rows of 20 cm and between plants in a row of 10 cm. Isolation of ears was accomplished with parchment bags which were not removed until harvest time, so that the possibility of uncontrolled cross-pollination was excluded.

Results and Discussion

Male sterility.—The character of cms was introduced by the method of back-crossing in several high-yielding wheat varieties adapted to Yugoslav conditions (Table 1).

The differences in percentage of male sterility in the individual cms-lines were slight. On the average, male sterility was high in all cms-lines and ranged from 96 to 100% (Table 1). In this respect, there were no differences between cms-Gaines and cms-Bison. This shows that the character of cms can be successfully introduced into most varieties if they do not possess Rf genes and that it can be maintained at a satisfactory level.

In the individual years which were characterized by different climatic conditions, the percentage of male sterility varied slightly but it was not lower than 96 and 91% respectively in the two groups of cms-lines (Table 1). This proves that male sterility is rather stable and that climatic factors have no great effect on its expression.

Restoration of fertility.--The potential for restoration of fertility of the American Rf-lines Lot-1 and Lot-2 was investigated. The percentage of restoration of fertility in the individual years was different (Table 2). It was highest in 1967 and as an average for all hybrids it amounted to 76%. It was lowest in 1968 and its average was 24%. Lot-1 (average 43%) exhibited somewhat better ability for restoration of fertility than did Lot-2 (average 38%).

An Rf-line restored differently depending on the cms-line used. The easiest for restoration of fertility proved to be cms-Bezostaja-1-G, which in combination with both Rf-lines gave 58% fertility in F_1 generation. Wilson (1968) also found this phenomenon and he considered that the number of genes possessed by the individual cms-lines may be involved because an excess of these genes can cause a reduction of restoration effect.

Different percentages of restoration of fertility in the individual years indicated strong dependence of this phenomenon upon climatic factors. It is clearly seen from graph 1 that temperature and relative air humidity are of decisive importance. In 1967, when the percentage of restoration of fertility was the highest, air temperature at the time of wheat fertilization was about 16°C and relative air humidity between 70 and 80%. In 1968, when the percentage of restoration of fertility was the lowest, there was a combined effect of high air temperatures (about 19°C) and low relative air humidity (below 60%). The effect of precipitations on the restoration of fertility is certainly indirectly involved through its effect on relative humidity and air temperature. With greater amounts of precipitations, when the percentage of restoration of fertility was higher, there was an increase in relative humidity and some decrease of temperature.

It can be seen from the results obtained that the potential for restoration of fertility of Lot-1 and Lot-2 is not satisfactory under our conditions (it amounts to about 40%). In order that hybrid wheat would be economically justified and not lose the effect of heterosis, it would be necessary that the level of restoration of fertility be a minimum 80%. Numerous investigators agree on this point (Mustafeeva et al., 1968; Wilson, 1968; Nettevic, 1969, etc.).

Among over 200 wheat varieties from the species *T. aestivum* ssp. vulgare which we tested for ability of restoration of fertility, only some of them showed this ability. The following varieties deserve special attention as new sources of Rf-genes: VK-64-28 (Netherlands) which restored fertility by 39% in 1969 and 92% in 1970 in combination with cms-Gaines and 34% in 1971 in combination with cms-Panonija-G, IBO-460/616 (Italy) which restored fertility 28% in 1969 and 19% in 1971 in combination with cms-Bezostaja-1-G and 32% in 1969 in combination with cms-Lutescens-32-G. Other varieties tested showed considerably lower potential for restoration of fertility (Table 3).

Rf-lines from India whose F_1 test hybrids were examined in 1971, showed fairly high potential for restoration of fertility under our conditions. The best was R-1051 which, in combination with cms-Bezostaja-1-G, restored fertility to 102% (Table 3). Likewise, the French Rf-varieties Primepi and Palmaress showed high potential for restoration of fertility which ranged over 80% (Table 3).

The same variety restored fertility differently in the individual cms-lines (see in Table 3 hybrids with varieties IBO-460/616, MV-C-52, Primepi and Palmaress). Therefore, it seems necessary to establish the ability of restoration of fertility of individual varieties in definite combinations with individual cms-lines, because only in this way can useful information be obtained.

The fertility of the same hybrid in the individual years was different (see in Table 3 hybrids with varieties VK-64-28, Schermans-9, Veselopodolianska, etc.) which indicates that the expression of restoration ability depends upon climatic factors. Therefore, in order to consider properly the potential for restoration of fertility of a variety, it will be necessary to perform several years of investigations of F_1 test hybrids.

These investigations, as well as many earlier ones (Schmidt et al. 1962, Rajki, E. and Rajki, S., 1966, Wilson 1968, etc.) showed that the basic problem which limited the creation of hybrid wheat is the absence of good Rf-lines and great dependence of restoration of fertility upon climatic factors.

Seed set in cms-lines under conditions of open-pollination.--The percentage of seed set in different cms-lines of wheat open-pollinated by their fertile analogues and Rf-varieties at a female to male row ratio of 2:1 was investigated.

During six years of investigations the highest average percentage of seed set at pollination by fertile analogues (Table 4) occurred on cms-Bezostaja-1-G (36%) and cms-NS-439-G (35%) and the lowest on cms-Backa-B (13), cms-Dunav-B (14%) and cms-Panonija-B (14%). There are differences in seed set within the same cms-line in connection with the origin of cms character. If cms character originates from cms-Gaines, the percentage of seed set is higher, and if it originated from cms-Bison (Table 4) then the percentage is lower. The average seed set in all cms-lines open-pollinated by fertile analogues varied from 7% in 1968 to 51% in 1967 (Table 4). It indicates clearly the existence of the effect of climatic factors on seed set.

It can be said that, in this experiment, low seed set in cms-lines open-pollinated by fertile analogues was obtained. However, similar results were also obtained by other investigators. In the experiments of Johnson et al. (1967), it varied from 41.1-66.8% and of Sanchez-Monge (1968) from 0.4-51.2%. Low seed set in this experiment was the result of difference in stalk height because the cms-lines were somewhat taller than their fertile analogues and therefore pollination was difficult. Additionally, the cms-lines were also later in heading than their fertile analogues and this contributed to poor pollination. The smaller the difference in the time of heading between cms-line and pollinator (fertile analogue), the greater the percentage of seed set (graph 2). Porter et al. (1965) concluded also that later flowering of cms-components in relation to pollinators caused a decrease of seed set.

As regards seed set on cms-lines pollinated by Rf-varieties (Table 5), there were differences. The highest seed set was in cms-Bezostaja-1-G (48 and 49%) which indicated that this variety is adapted better to cross-pollination than other varieties. Considering average seed set independently of pollinator it can be seen that there are no differences. Both pollinators, Lot-1 and Lot-2, gave in average 35% seed set in cms-lines.

Seed set in individual years varied much and as an average for all cms-lines and both pollinators it ranged from 14% in 1969 to 63% in 1970 (Table 5), which can be also connected with the specific climatic factors in the individual years.

Seed set in cms-lines of wheat pollinated by different pollinators, depends, first of all, upon temperature and relative air humidity at the time of flowering and fertilization of wheat (May - third decade of May). The highest seed set was in 1967 and 1970 when air temperature was from 14-16°C and relative air humidity between 70-80%, and the lowest in 1968 when air temperatures were high, about 19°C, and low relative air humidity, below 60% (graph 3). The results of numerous investigators (Wilson, 1968; Johnson et al., 1967; Rajki, E. and Rajki, S., 1966 etc.) showed also that for seed set in cms-lines, temperature and relative air humidity were of decisive importance at the time of pollination and fertilization of wheat. Somewhat higher seed set on cms-lines pollinated by Rf-varieties than by fertile analogues can be explained by the fact that Rf-varieties headed and flowered later than cms-lines and that their stems were taller than the cms-lines, all of which made pollination easier. On the contrary, fertile analogues were earlier with regard to heading and flowering and their stems were shorter than the cms-lines, which made cross-pollination difficult. This was especially expressed in 1970 and 1971 when low average speed of wind (below 2m/sec) acted as an additional limiting factor, making pollination even more difficult and reducing seed set in cms-lines pollinated by fertile analogues (graph 3).

Conclusion

On the basis of the results obtained in these investigations, the following conclusions can be drawn:

- The percentage of male sterility in cms-lines of wheat is satisfactory and stable in different years, i.e. it depends little upon climatic factors. Therefore male sterility does not represent a problem for creation of hybrid wheat using the *T. timopheevi* system.

- The American Rf-varieties Nebraska Lot-1 and Nebraska Lot-2, under our conditions show low potential for restoration of fertility which is not sufficient for success in production of hybrid wheat. The French Rf-varieties, Primepi and Palmaress, as well as the Indian Rf-variety R-1051 showed under our conditions, a potential for restoration of fertility even higher than 80%, which was considered to be good.

- Among the varieties within the *T. aestivum* ssp. vulgare can be found some which possess Rf-genes, but their number is small and the potential for restoration of fertility is low. Among the varieties tested, the best potential for restoration of fertility was shown by the varieties VK-64-28 (Netherlands) and IBO-460/616 (Italy).

- Restoration of fertility in F_1 hybrids depends both upon climatic factors and cms-lines used. As regards the climatic factors, an unfavorable effect proved to be high air temperature (over 19°C) and low relative air humidity (below 60%) at the time of flowering and fertilization of wheat, particularly if they act simultaneously. For these reasons, we consider that restoration of fertility is the basic problem which limits the creation of hybrid wheat.

- The percentage of seed set in cms-lines of wheat at open-pollination by fertile analogues and Rf-varieties is low and depends very much upon climatic factors (temperature and relative air humidity), coincidence in heading between the cms-line and pollinator which is different in the individual cms-lines. This is also one of the problems which could limit the utilization of hybrid wheat.

- If the above-mentioned problems of the T. timopheevi cms-Rf system can be solved then it could be successfully used for creating hybrid wheat. However, this requires further and broader investigations and explanation of the mechanism which acts in this system.

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Table 1. Percentage of male sterility of wheat cms-lines[1].

cms-line[2]	% of male sterility						
	1966	1967	1968	1969	1970	1971	Average
vms-Panonija-G	100	100	98	100	100	100	100
cms-Dunav-G	100	100	98	100	99	100	100
cms-Backa-G	100	100	95	100	100	100	99
cms-Bezostaja-1-G	100	100	93	100	98	100	97
cms-Crvena Zvezda-G	-	100	95	100	95	100	98
cms-NS-439-G	-	100	96	99	92	97	97
cms-Libelula-G	-	100	97	98	95	100	98
cms-Sava-G	-	-	99	98	96	100	98
cms-Leonardo-G	-	-	93	96	96	100	96
cms-Ranaja-12-G	-	-	98	100	98	100	99
cms-Lutescens-32-G	-	-	91	100	92	100	96
Average	100	100	96	99	96	100	
cms-Panonija-B	-	100	100	100	89	100	98
cms-Dunav-B	-	100	99	100	94	100	99
cms-Backa-B	-	100	100	100	100	93	99
cms-Bezostaja-1-B	-	100	100	100	90	93	97
cms-Crvena Zvesda-B	-	100	97	100	98	96	98
cms-NS-439-B	-	100	99	100	86	100	97
cms-Libelula-B	-	100	98	99	90	100	97
Average	-	100	99	100	91	97	

[1] % of m.s. = $100 - \frac{X \cdot 100}{Y}$

Where: X is $\bar{X}$ kernels per spike in cms-line (only isolated spikes)
Y is $\bar{X}$ kernels per spike in fertile analogue of cms-line

[2] G = Donor of cms is cms-Gaines
B = Donor of cms is cms-Bison

Table 2. Percentage of restoration of fertility in the F_1 generation of hybrids obtained by crossing Rf-lines to cms-lines of wheat[1].

Pedigree of hybrid			1967	1968	1969	1970	1971	Average
cms-Panonija-G	x	N.lot-1	55	9	23	40	-	32
cms-Dunav-G	x	"	74	16	28	42	39	40
cms-Backa-G	x	"	69	33	23	39	-	41
cms-Bez.1-G	x	"	105	41	35	45	64	58
		Average	76	25	27	41	51	43
cms-Panonija-G	x	N.lot-2	57	17	13	8	-	24
cms-Dunav-G	x	"	50	35	28	14	17	35
cms-Backa-G	x	"	80	17	21	-	-	39
cms-Bez.1-G	x	"	118	26	49	62	36	58
		Average	76	24	28	28	27	38
Average for all hybrids			76	24	28	36	39	40

[1] $\%$ of fert. rest. $= \frac{X \cdot 100}{Y}$

where: X is $\bar{X}$ kernels per spike in F_1 hybrids/only isolated spike
Y is $\bar{X}$ kernels per spike in fertile analogue of cms-line

Table 3. Percentage of restoration of fertility in some F_1 test hybrids as compared with fertile analogues of cms-lines.

Pedigree of hybrid			Origin of tested variety	1969	1970	1971
cms-Dunav-G	x	IBO-544/616	Italy	10	-	0
cms-Bezostaja-1-G	x	IBO-519/616	"	15	-	21
"	x	IBO-460/616	"	28	-	19
cms-Lutes. 32-G	x	"	"	32	-	-
cms-Gaines	x	VK-64-28	Netherlands	39	92	-
cms-Panonija-G	x	"	"	-	-	34
cms-Bezostaja-1-G	x	Schermans-9	W. Germany	0	35	-
"	x	Veselopodol	USSR	0	31	-
"	x	Harah Weizen	Austria	1	21	-
cms-NS-439-G	x	MV-C-52	Hungary	0	20	-
cms-Libelula-G	x	"	"	0	0	0
cms-Gaines	x	Srelejevska	Poland	0	24	-
cms-NS439-G	x	Krasnodarska	USSR	0	11	-
cms-Dunav-G	x	R-1053	India	-	-	40
cms-Bezostaja-1-G	x	"	"	-	-	49
"	x	R-1051	"	-	-	102
"	x	R-1052	"	-	-	49
cms-Dunav-G	x	Primepi	France	-	-	50
cms-Bezostaja-1-G	x	"	"	-	-	84
cms-Dunav-G	x	Palmaress	"	-	-	62
cms-Bezostaja-1-G	x	"	"	-	-	73

Table 4. Percentage of seed set in cms-lines open pollinated by their fertile analogues (female to male ratio was 2:1).

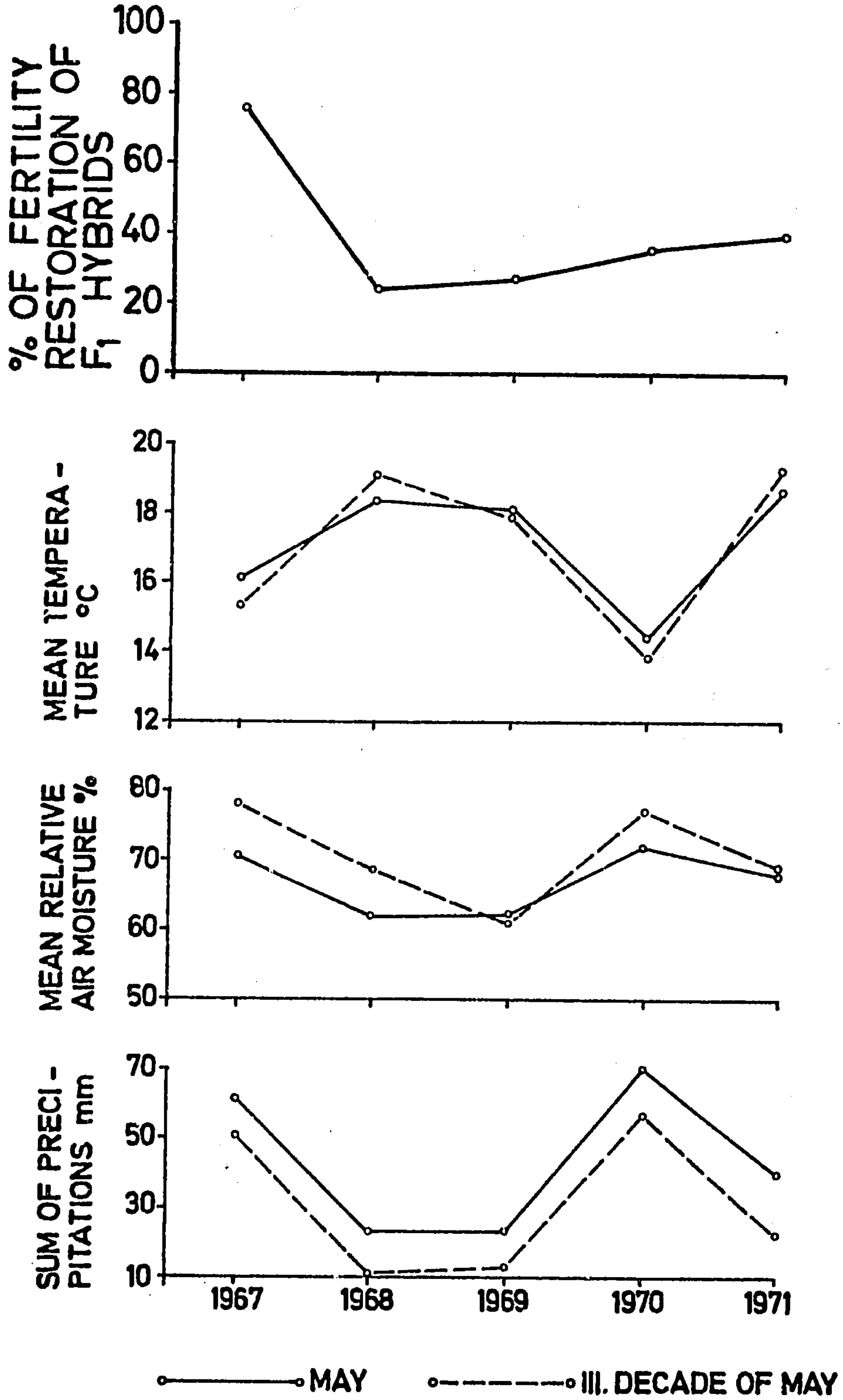
cms-line	1966	1967	1968	1969	1970	1971	Average
cms-Panonija-G[1]	14	59	3	19	10	4	18
cms-Panonija-B[2]	-	35	5	5	14	10	14
cms-Dunav-G	12	57	5	8	8	13	17
cms-Dunav-B	-	31	5	10	10	15	14
cms-Backa-G	13	40	5	9	8	8	14
cms-Backa-B	-	35	-	2	6	11	13
cms-Bezostaja-1-G	25	79	19	32	21	43	36
cms-Bezostaja-1-B	-	53	14	18	34	31	30
cms-Crvena zvezda-G	-	47	4	24	19	25	24
cms-Crvena zvezda-B	-	34	6	19	18	22	20
cms-NS-439-G	-	76	7	39	25	27	35
cms-NS-439-B	-	50	11	22	24	48	31
cms-Libelula-G	-	61	9	35	21	24	30
cms-Libelula-B	-	51	11	28	17	14	24
Average for all cms-lines	16	51	7	19	17	21	22

[1] donor of cms is cms-Gaines
[2] donor of cms is cms-Bison

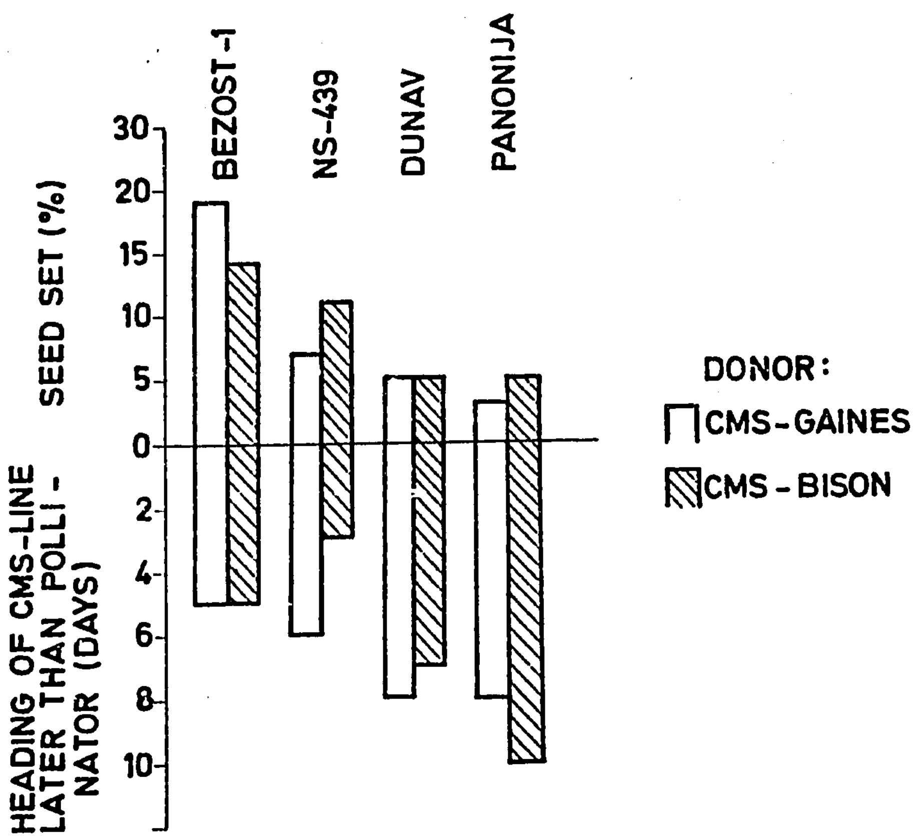
Table 5. Percentage of seed set in cms-lines open pollinated by Rf-varieties (female to male ratio was 2:1).

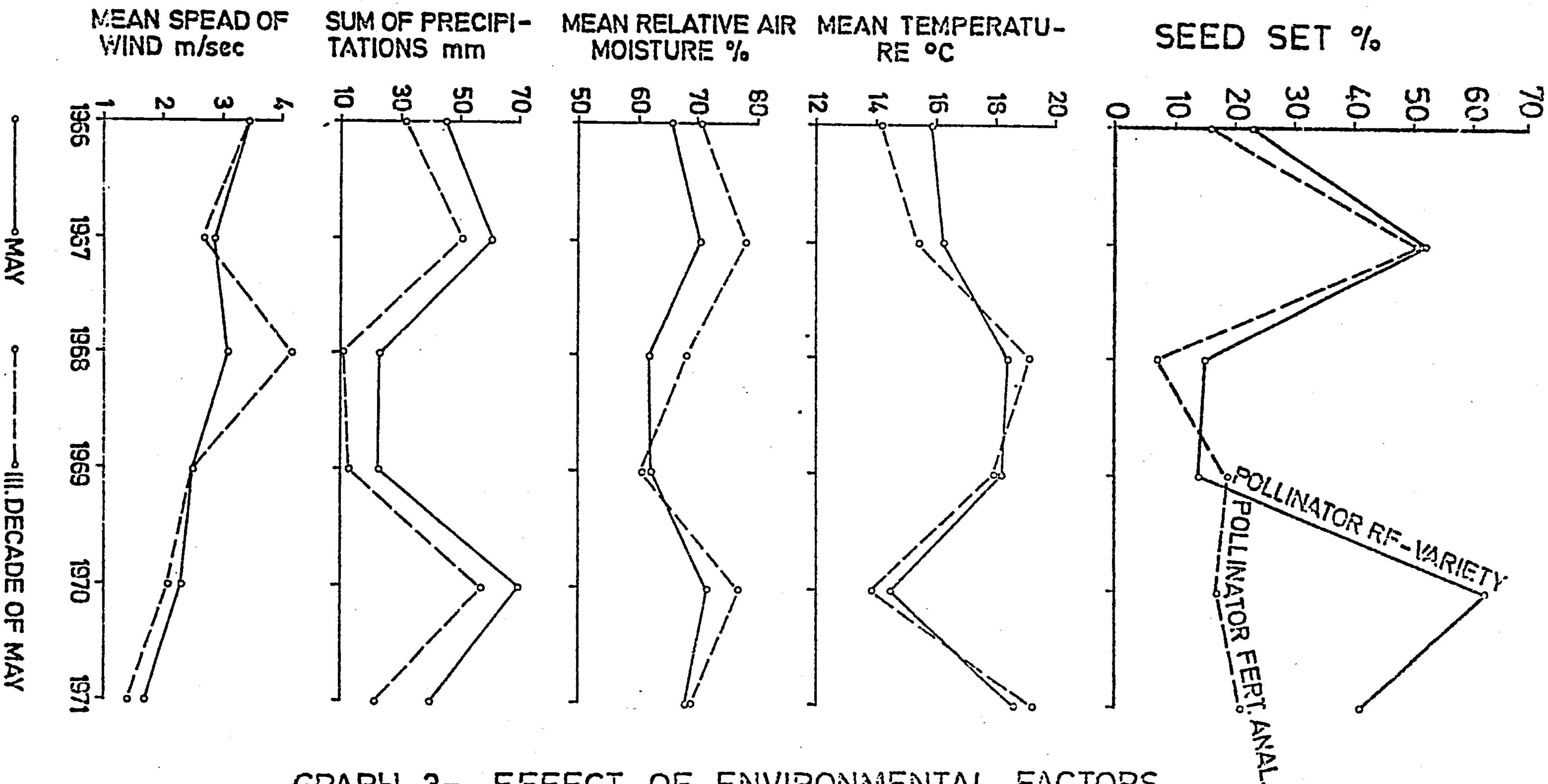
cms-line	Pollinator	1966	1967	1968	1969	1970	1971	Average
cms-Panonija-G	N. lot-1	23	55	8	7	-	-	23
cms-Dunav-G	"	19	33	9	10	48	30	25
cms-Backa-G	"	23	47	7	11	-	-	22
cms-Bezostaja-1-G	"	40	77	31	17	80	46	48
	Average	20	53	16	11	64	38	35
cms-Panonija-G	N. lot-2	20	53	5	9	-	-	22
cms-Dunav-G	"	12	37	6	11	48	35	25
cms-Backa-G	"	18	46	7	11	-	-	20
cms-Bezostaja-1-G	"	35	74	37	40	77	56	53
	Average	21	52	14	18	62	45	35
Average for both pollinators		23	52	15	14	63	41	35

GRAPH. 1- EFFECT OF INDIVIDUAL CLIMATIC FACTORS ON FERTILITY RESTORATION IN F_1 HYBRIDS



GRAPH. 2– EFFECT OF COINCIDENCE OF HEADING BETWEEN POLLINATOR AND CMS - LINES ON THE SEED SET (1968)





GRAPH. 3- EFFECT OF ENVIRONMENTAL FACTORS ON SEED SET AT CMS-WHEAT LINES (FEMALE TO MALE RATIO 2:1)

EVOLUTION IN THE MILDEW POPULATION IN ITALY AND BREEDING FOR MILDEW RESISTANCE IN BREAD WHEAT

by

G. Zitelli
Italy

The problem of obtaining mildew resistant bread wheat varieties is more and more urgent in many regions of the world, and Italy is one of them. This is mainly due to the introduction of large scale cultivation of semi-dwarf varieties with high tillering capacity. This condition associated with the use of high doses of fertilizers promotes the development of mildew pathogen in susceptible varieties. Also, as has been demonstrated in earlier works (Grasso, 1964, Vallega, 1967, Zitelli, 1968), all Italian bread wheat varieties, at least those extensively cultivated, are susceptible to this parasite.

For more than a decade, intensive studies have been carried out to analyse the evolution of the different genes for virulence present in parasite populations, in order to determine the potential durability of resistant sources and to find out which among them remain stable, regardless of certain pathogenicity fluctuations in the parasite itself. This appears of some use in breeding resistant varieties. In effect, in this regard, the resistance to a given race or to a single culture is not always so important as are large populations representing a complex of the genes for virulence in a certain region. Consequently, there is the necessity to study in space and time, the variability which takes place in the parasite with respect to the behavior of varieties or lines carrying resistant factors already known or not known.

Studies of the Pathogen Evolution and Resistance Sources

From 1962, in greenhouse environments, a group of varieties or selections has been examined continuously with respect to mildew populations collected in different Italian localities. This study (Table 1) has indicated the variable behavior of some varieties in different years, which reflect large variation in the aggressiveness of wheat powdery mildew populations present in Italy, as well as the presence of varieties carrying highly effective resistance genes. It is interesting to note that Asosan, Chul, and Sonora respectively, carry the resistant factors Mla according to Pugsley (1961), Mlc and Mls according to Carter, while according to Briggle (1966) they carry only Pm_3 but behave differently in agreement with the results of Vallega (1967) and Zitelli (1968). Later Briggle, in 1969, on the basis of the infections with eight different cultures of *Erysiphe graminis* also demonstrated the same and distinguished between Pm_3:Pm_{3a} carried by Asosan, Pm_{3b} carried by Chul, and Pm_{3c} carried by Sonora. Chul was resistant in 1962, 1970, and 1971, moderately susceptible in 1972, and susceptible in the remaining years, while Sonora was susceptible during all of the 11-year period.

Ulka, Normandie, Wisconsin Sel. C.I. 12632, and Wisconsin Sel. C.Y. 12632 x Cc^8, all carrying the Pm_2 gene, behave differently one from the other, due to the presence of other undetermined factors. Finally, the Normandie behavior, with resistance in 1971 and 1972, suggests that another factor is present in this wheat besides Pm_2 and Pm_1. This can be deduced from the fact that Ulka carrying Pm_2, in 1971 and 1972 was moderately susceptible and Axminster, carrying Pm_1, has been susceptible during all of the years under analysis.

Table 1. Reactions of some wheats to different Italian populations of *Erysiphe graminis tritici* in the greenhouse during 11 years (1962-1972).

Wheats	Designations of genetic factors		1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
			YEARS										
Asosan Asosan x Cc^8	Mla=	$Pm_3 = Pm_{3a}$	R	S	S	S	R	R	R	R	R	R	MS
Chul Chul x Cc^8	Mlc=	$Pm_3 = Pm_{3b}$	R	S	S	S	S	S	S	S	R	R	MS
Ml	Mle		S	Seg	Seg	Seg	Seg	Seg	Seg	Seg	Seg	Seg	Seg
Sonora Sonora x Cc^8	Mls=	$Pm_3 = Pm_{3c}$	S	S	S	S	S	S	S	S	S	S	S
Axminster Norka x Cc^8	Mlt=	Pm_1	S	S	S	S	S	S	S	S	S	S	S
Ulka Ulka x Cc^8	Mlu=	Pm_2	S	S	R	R	R	R	R	R	R	MR	MR
Normandie	Mlu+Mlt	Pm_2+(Mlt)	S	S	R	R	R	R	R	R	R	R	R
Wisc.Sel.12632 Wisc.Sel.12632xCc^8		Pm_2 Pm_2	R	R	R	R	R	R	R	R	R MR	R MR	R MR
Timopheevi D357			R	R	R	R	R	R	R	R	R	R	R
Khapli Khapli x Cc^8		Pm_4	R	R	R	R	R	R	R	R	R	R	R
Yuma Yuma x Cc^8		Pm_4	R	R	R	R	R	R	R	R	R	R	R

Table 1. (continued)

Wheats	Designations of genetic factors	YEARS 1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
Vernal		R	R	R	R	R	MS	MS	MS	MS	MS	MS
Einkorn		S	S	S	S	S	S	S	S	S	S	S
Hope		S	S	S	MR	MR	MR	MR	MS	MS	MS	MR
Redcoat		R	R	R	R	R	R	MR	MR	MR	R	R

R = Resistant
MR = Moderately resistant
MS = Moderately susceptible
S = Susceptible
Seg = Segregating resistant and susceptible plant

At the same time, it is evident that Wisconsin Sel. 12632, resistant during all of the 11 years, carries another or many other factors besides Pm_2. Also, it is evident that not all the factors of Wisconsin Sel. 12632 have been transferred to Wisconsin Sel. 12632 x Cc^8, as in 1970, 1971, and 1972 it was moderately resistant.

Hope behaves as susceptible, moderately susceptible, and moderately resistant according to the year. It is interesting that Einkorn was susceptible during all the years and Vernal since 1967 was moderately susceptible. Redcoat was moderately resistant in 1968, 1969, and 1970, but resistant in all the other years. Nevertheless, Grasso and his co-workers (1967) considered this wheat to be variable in its reactions from resistant to moderately resistant and moderately susceptible.

Khapli, Khapli x Cc^8, Yuma, Yuma x Cc^8, all carrying Pm_4, have been resistant during all the years under study. The same happened for T. Timopheevi D.357 and the already mentioned Wisconsin Sel. C.I. 12632.

Analysis of the varieties under examination during the 11 years, allowed us to ascertain that Wisconsin Sel. 12632, Khapli x Cc^8, and Redcoat, can be considered for their stability of reaction as important sources of resistance factors to be used for breeding purposes.

In a further search for new resistance factors, many varieties or lines of T. Aestivum or other species have been examined. Among the varieties under study (Table 2), were included those that in the last two years appeared in the "International Winter Wheat Nursery" and in the "Regional Micro-plot Yield Trial".

Table 2. Varieties or selections resistant to all Italian populations or Erysiphe graminis tritici tested in 1971 and 1972.

Varieties	Resistance to rusts	From
Arthur	P. graminis	U.S.A.
Benhur	----	U.S.A.
Lancer		U.S.A.
Purdue 4930A	P. recondita	U.S.A.
Riley 67	----	U.S.A.
Timwin	P. recondita	U.S.A.
Centurk	P. graminis	U.S.A.
NB 68513	P. recondita	U.S.A.
Super X	P. graminis	Mexico
Mexipak 69	P. graminis P. recondita	Pakistan
Winter triticale	----	U.S.A.

Among the varieties in the "International Winter Wheat Nursery" one Triticale and eight T. Aestivum varieties from the United States (Arthur, Benhur, Lancer, Purdue 4930A, Riley 67, Timwin, Centurk and NB 68513) turned out to be immune to mildew in the greenhouse. Among those coming from the "Regional Micro-plot Yield Trial" two semi-dwarf T. Aestivum varieties were immune: Super X and Mexipak 69. Infections have been carried out in the greenhouse on these varieties with individual cultures of P. graminis and P. recondita, taking into consideration those being more frequent and those carrying more particular and interesting virulence factors. Therefore, Arther, Centurk, and Super X turned out to be resistant to a wide gene spectrum for virulence of P. graminis present in Italy; Purdue 4930A, Timwin, NB 68513 behaved so to P. recondita; and Mexipak 69 to P. graminis and to P. recondita.

Other Triticum species (more than 200 forms) have been examined in the greenhouse with regard to mildew populations present in 1971 and 1972. In Table 3, it can be observed that four Triticum, referring to timopheevi species, and five to monococcum coming from Turkey are resistant. Some of them are resistant to the complete spectrum of P. graminis and P. recondita or only to P. recondita.

Among the 11 forms of Triticum immune to mildew coming from the U.S.S.R. we note K.32510 T. carthlicum, K.054395 T. militinae, K.29548 T. timopheevi Zhuk Var. Typicum Zhuk and K.43063 T. zhukovskyi to be resistant to P. recondita.

Studies on the Inheritance Mechanism which Confers Mildew Resistance in some Sources used in Breeding

Considering the stability of resistance to different mildew populations of Wisconsin Sel. C.I. 12632, Redcoat, Khapli x Cc^8, these varieties have been selected for use in breeding. In this regard, they have been crossed with bread wheat varieties, particularly with the new ones Victor and Oscar, which are resistant to stem rust (Zitelli and Vallega, 1971), in order to accumulate in the same line mildew resistance and stem rust resistance.

Genetic analyses to establish the behavior of factors conditioning mildew resistance in Wisconsin Sel. C.I. 12632, Redcoat, Khapli x Cc^8 have been carried on. A culture of Erysiphe graminis, virulent on Vernal was used in a previous study (Zitelli, 1968) with Wisconsin Sel. C.I. 12632. The hypothesis was formulated that more than one factor was acting; at least two, one dominant and the other recessive.

Further studies on populations of F_2 and F_3 families confirmed that, in effect, more than one genetic factor is present. From the segregation for the type of infection in F_2 plants (Table 4) from the cross between Wisconsin Sel. C.I. 12632 and Victor with respect to the virulent culture on Vernal, it is possible to obtain plants (0) as immune as Wisconsin and other individuals with intermediate resistance ranging from R (0;1=) to MR (1/1+). This indicates the presence of one or more genes, which do not confer the absolute parental resistance. Nevertheless, if we consider together Immune, Resistant, and Moderately Resistant plants, we have a 3:1 ratio, which would indicate the presence of a main effective factor.

F_3 behavior (Tables 5 and 6) indicates homozygous families as immune (0) as the resistant parent, other progenies homozygous resistant (1n), and still others with different degrees of segregation: Immune/Resistant, Immune/Susceptible, Immune/Resistant/Susceptible and Resistant/Susceptible, and finally homozygous susceptible which would confirm the hypothesis that more than one factor is present.

It is interesting that from Immune F_2 plants (0) only homozygous immune families can be obtained; from Resistant plants (0;1=) homozygous resistant and segregating F_3 families can be obtained; while from Moderately Resistant plants (1/1+) only segregating families can be obtained. These last results would indicate the

Table 3. Forms of different species showing resistance to mildew populations present in Italy

Denomination	Resistance to rusts	From
N° F.A.O. 25886 *Triticum* sp. (1) HTRI 3810/62	*P. graminis*, *P. recondita*	Turkey
" " 25576 *Triticum* sp. HTRI 1759/63	*P. recondita*	Turkey
" " 25582 *Triticum* sp. HTRI 1760/63	*P. recondita*	Turkey
" " 25584 *Triticum* sp. HTRI 1775/63	*P. recondita*	Turkey
" " 25578 *Triticum* sp. (2) HTRI 2381/63	*P. graminis*, *P. recondita*	Turkey
" " 25580 *Triticum* sp. HTRI 4351/63	*P. recondita*	Turkey
" " 25577 *Triticum* sp. HTRI 656/64	*P. recondita*	Turkey
" " 25581 *Triticum* sp. HTRI 2399/64	----	Turkey
" " 25583 *Triticum* sp. HTRI 4275/64	----	Turkey
K.32510 *T. carthlicum* Nevski var. fuliginosum Zhuk.	*P. recondita*	U.S.S.R.
K.054395 *T. militinae* Zhuk et Nigusch	*P. recondita*	U.S.S.R.
K.054397 *T. timonovum* Heslot	----	U.S.S.R.
K.43065 *T. timonovum* Heslot	----	U.S.S.R.
K.29548 *T. timopheevi* Zuk. var. typicum Zhuk.	*P. recondita*	U.S.S.R.
K.43063 *T. Zhukovskyi* Men. et Er	*P. recondita*	U.S.S.R.
K.46007 *T. militinum* Zhuket Nigusch	----	U.S.S.R.
K.46956 *T. timopheevi* Zhuk. var. *viticulosum* Zhuk	----	U.S.S.R.
K.43063 *T. Zhukovsky*	----	U.S.S.R.
K. 7887 *T. persicum* vav. var. *fuliginosum* Zhuk.	----	U.S.S.R.
K.38265 *T. durum* Desf. var. *leucurum*	----	U.S.S.R.

(1) *Timopheevi* types
(2) *Monococcum* types

Table 4. Segregation of F_2 plants to a culture (virulent on Vernal) of *Erysiphe graminis tritici*.

Hybrid	Plants with indicated infection type (n°)							
	I 0	R 0;1=	MR 1/1+	MS 3-	S 4	Ratio	X^2	P value (1 d.f.)
Wisconsin Sel. 12632 x Victor I	213	119	77		134	3:1	0.0302	0.95-0.90
Redcoat x Victor I	39			33	38	13:3	3.804	0.50-0.25 1.00
Khapli x Cc^8 x Oscar I	237				72	3:1	0.483	0.70-0.50

Table 5. Classification of F_3 families from the cross Wisconsin Sel. C.I. 12632 and Victor I with respect to a culture (virulent on Vernal) of *Erysiphe graminis tritici*.

Types of families	Number of families
Homozygous Immune (o)	46
Homozygous Resistant (1n)	30
Segregating Immune/Resistant (o/1n)	35
Segregating Immune/Susceptible (0/4)	102
Segregating Im./Res./Susc./(o/1n/4)	72
Segregating Res./Susc. (1n/4)	28
Homozygous Susceptible (4)	86
Total	494

Table 6. Classification of F_3 families from the cross Wisconsin Sel. C.I. 12632 and Mara with respect to a culture (virulent on Vernal) of Erysiphe graminis tritici.

Types of families	Number of families
Homozygous Immune (o)	10
Homozygous Resistant (1n)	10
Segregating Immune/Resistant (o/1n)	22
Segregating Immune/Susceptible (0/4)	25
Segregating Im./Res./Susc. (o/1n/4)	12
Segregating Res./Susc. (1n/4)	15
Homozygous Susceptible (4)	20
Total	114

probable presence of at least two factors in Wisconsin C.I. 12632: one which gives immunity and the other resistance and that one or both, when present in F_2 plants in the heterozygous condition, do not show complete dominance, giving an intermediate resistance type. It is evident that in order to confirm these results, further studies are necesaar: either examining single family behavior or making appropriate crosses.

On the other hand, we must take into consideration that when the Wisconsin C.I. 12632 behavior has been examined with regard to the different populations in many years, the presence of more than one resistant factor, besides Pm_2, was evident.

The nature of genetic factors which confer resistance in Redcoat, appears similar to that of Wisconsin C.I. 12632. In the segregation for type of infection in F_2 from the cross between Redcoat and Victor I using a culture virulent on Vernal (Table 4), Immune plants (0) of the parental type appear along with Resistant (0;1=), and Moderately Susceptible plants. This would indicate the presence of two factors: one dominant and the second recessive. If we consider together, Immune, Resistant, and Moderately Susceptible plants, we get a 3:1 ratio for one dominant factor or a 13:3 ratio for two factors, one dominant and the second recessive.

Examining F_3 families (Table 7), we can observe homozygous resistant families, segregating families with different resistance and susceptibility degrees, and susceptible homozygous families. The genetic analysis carried out in F_2 plants and F_3 families of the Khapli x Cc^8 and Oscar crosses (Table 4 and Table 8), indicate clearly the presence of only one dominant resistance factor. Probably this resistance factor of Khapli, transferred to Chancellor, is the same to the one transferred to Yuma. On the other hand, it must not be forgotten that Khapli has two resistance factors, at least according to Leijerstam and some unpublished data of ours.

Table 7. Classification of F_3 families from the cross Redcoat and Victor I with respect to a culture (virulent on Vernal) of Erysiphe graminis tritici.

Types of families	Number of families
Homozygous Resistant (0/0;)	74
Segregating M. Resist./M. Susc. (1+n/1+3-/4)	18
Segregating	156
Segregating M. Resist./Susc. (1+n/4)	48
Homozygous Susceptible (4)	86
Total	382

Table 8. Classification of F_3 families from the cross Khapli x Cc^8 and Oscar I with respect to a culture (virulent on Vernal) of Erysiphe graminis tritici.

Types of families	Number of families
Homozygous Immune (0)	31
Segregating Im./Susc. (0/4)	74
Homozygous Susc. (4)	38
Total	143

X^2 (for 1:2:1) = 0,843 P (d.f.2) = 0,98 - 0,95

The new lines obtained as a result of breeding, even if they are mildew and stem rust resistant, do not compare with the widely cultivated varieties for their agronomic characters. In effect, their productivity is not superior to that of varieties normally cultivated. They are rather tall, they have a low thousand-seed weight, and a certain lateness in the biological cycle which limits the immediate use of such new selections. In order to incorporate these requirements it has been necessary to make two or three backcrosses using as recurrent parents the traditional Italian varieties and our selections Victor and Oscar which are resistant to stem rust. Promising results have been observed since the early tests with this newly obtained material.

Summary

A comprehensive study to ascertain the evolution of mildew populations in Italy has been carried on.

The reactions of some wheat varieties carrying resistance factors were examined continuously, during eleven years, in greenhouse environments, with regard to different mildew populations. The analysis of the behavior of such wheats, during the years under examination, allowed us to ascertain that some varieties present a variable reaction, while others present a stable one. Khapli, Khapli x Cc^8, Yuma, Yuma x Cc^8, Redcoat, Wisconsin Sel. C.I. 12632, Wisconsin Sel. 12632 x Cc^8, and T. timopheevi D 357 showed complete resistance during all the years.

Therefore, Wisconsin Sel. C.I. 12632, Redcoat and Khapli x Cc^8, because of their stability to resistance, have been used for breeding purposes. These varieties were crossed and backcrossed with the new bread wheat varieties Victor and Oscar which are resistant to stem rust, or with the traditional Italian varieties.

Genetic analysis of F_2 populations and F_3 families from crosses of Wisconsin Sel. C.I. 12632, Redcoat, Khapli x Cc^8 with susceptible varieties, using a mildew culture virulent on Vernal, indicated that resistance in Wisconsin Sel. C.I. 12632 and Redcoat is conditioned by more than one factor; among these factors, at least one of them shows uncomplete dominance, while in Khapli x Cc^8 resistance is conditioned only by one dominant factor.

During further studies to identify new factors of resistance, several varieties or lines of T. aestivum or of other species have been examined in greenhouse environments using mildew populations present in Italy during 1971 and 1972.

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AUTUMNIZED MEXICAN SPRING WHEAT AT MARTONVÁSÁR

by

E. Rajki and S. Rajki
Hungary

Autumnization experiments have been conducted for the third year at Martonvásár on several Mexican spring wheats bred by Dr. Borlaug, resulting in a hardy winter Penjamo 62.

By using a method of autumnization elaborated at Martonvásár in field and growth chamber experiments as well as during investigations conducted in our cytological and physiological laboratories (Rajki 1967, Rajki, E.-Rajki 1969, Rajki-Devay, M.-Rajki, E. 1970, 1972) experiments were launched in the autumn of 1969 in order to autumnize several Mexican spring wheats bred by Dr. Borlaug.

The Mexican spring wheats were selected, on the basis of first-year results of their performance test (Rajki, E.-Pal 1972), from those cultivars which seemed to have the best prospects in spring sowing under local conditions.

This autumnization experiment was carried out in order to obtain winter-hardy semi-dwarf basic material for wheat breeding and to control the reproducibility of the autumnization research results.

The Mexican spring wheat cultivars under study are as follows: Super X, Penjamo 62, Siete Cerros 66, Nainari 60, and Azteca 67. Together with these Mexican spring wheats the standard Hungarian spring wheat cultivar Kompolti szalkas and the Russian Bezostaya 1 as a winter wheat control cultivar have been sown.

The method of sowing times employed is illustrated in Table 1. Here only the sowing time combinations of September 1971 are shown. Nevertheless, the sowing time combinations of October 1971, November 1971, and spring 1972 also correspond to these.

A hundred plants were taken from each plot in the summer of 1970 and also in 1971 and in the next year experiments were sown with a seed blend of their first spikes. This was modified in the summer of 1971 in a way that the first spikes were broken into four parts and the seed blend of these hundred quarter-spikes were sown in September, October and November, 1971 and at the beginning of April 1972.

Three hundred twenty seeds per row were sown in three rows, four meters each, at every sowing time treatment in 1969-70 and 1970-71. Owing to the great number of variants, a single four meter row with 320 seeds per combination produced one plot in 1971-72. From each treatment of the September 1971 sowings several plants were replanted into pots on November 22 and raised in a growth chamber at a temperature of 18-22°C. Growth habit was determined on the basis of the type of young shoots as well as the heading of spring and growth chamber sowings.

There was no change whatsoever in the growth habit of experimental plants indicated either by the type of young shoots or heading in the first and second years of the autumnization experiments of the Mexican spring wheats. Due to the mild winters and the fair snow-cover there was no notable winter damage in the autumn sowings.

The first signs of change in the type of young shoots appeared in mid-November 1971 in several September sowing-time treatments of certain cultivars. According to the results of examinations, autumnization took place in certain cultivars (Nainari 60, Kompolti szalkas), and was especially demonstrable in the Mexican spring wheat Penjamo 62, as well as in all test plants of the earliest autumn sowing combination. The change in growth habit completed for the third year in the earliest autumn sowing time treatment of Penjamo 62 was also indicated by the heading of plants replanted on November 22 (Table 2). Concerning the change in growth habit of Penjamo 62, the heading of plants in the earliest sowing time treatment of the fifth series sown on November 25 in growth chamber, more exactly, the lack of heading in the earliest autumn sowing-time treatment, is an even more convincing proof (Table 3). In some early autumn sowing-time combinations of Penjamo 62, autumnization was observable in approximately one-third of the test plants. At the same time no autumnization occurred in late autumn and in those autumn sowing-time treatments which were further combined with spring sowing.

Over-wintering corresponded to autumnization, i.e. in general, only autumnized plants survived. Certain temperature and snow-cover values of the 1971-72 winter are shown in Table 4. The 1971-72 winter was characterized both by the almost complete lack of a fair snow-cover and the extreme fluctuation of negative and positive temperatures, the latter even in the pre- and post-winter periods.

The morphology of the autumnized Penjamo 62 plants is similar to that of the initial spring Penjamo 62 plants.

Autumnization observed in the earliest and early autumn sowing-time combinations of the Mexican spring wheat Penjamo 62 was in full agreement with earlier conclusions reached in the course of the fundamental research in autumnization at Martonvásár.

As to the genetic interpretation of the mentioned fa ts of autumnization it should be borne in mind, that the earliest and early . utumn as well as the mid- and late autumn sowing-time treatments "saw" the same three winters so far. This, taking into account also the estimated rate of autumnization as an adequate genetic conversion, casts a priori doubts on the validity of interpretations founded on original heterogeneity and/or mutation. Certainly no comment is required to interpret these facts from either breeding methodology or practical wheat breeding points of view.

In the Phytotron under construction at Martonvásár it will most certainly be possible both to reproduce the changes of several such environmental conditions and to carry on the exact testing of their individual effects to which autumn-sown spring wheats are exposed. In the course of the autumn vegetative period they are as follows: gradually decreasing temperature and light intensity, shortening day-length, a spectrum becoming rich in red, i.e. those which are otherwise diametrically opposed to the corresponding tendencies prevailing in spring. From these and similar investigations the elaboration of an autumnization "recipe book" for cultivars to be converted as well as for planned winter type, and winter- and frost-resistance is to be expected.

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Table 1. Sowing time combinations of September 1971. Martonvasar 1971-72.

Sowing time combinations	69/70	70/71	71/72
Earliest autumn	S	S	S
Early autumn	S	O	S
	S	N	S
Mid-early autumn	O	S	S
	O	O	S
	O	N	S
Late autumn	N	S	S
	N	O	S
	N	N	S
Autumn combined with spring sowing	T	S	S
	T	O	S
	T	N	S
	S	T	S
	O	T	S
	N	T	S
	T	T	S

Legends: S = September; O = October; N = November; T = Spring.

Table 2. Heading of plants replanted from nursery into growth chamber. Martonvasar 1972.

Cultivar	Sowing time 1969-70	Sowing time 1970-71	Sowing time 1971-72	Heading
Penjamo 62	September	September	September + Phytotron*	Feb. 5
"	Spring	Spring	" "	Jan. 22
Bezostaya 1	September	September	" "	Feb. 13

*Plants replanted from nursery into growth chamber on November 22.

Table 3. Heading in growth chamber. Martonvasar 1972.

Cultivar	Sowing time			Heading
	1969-70	1970-71	1971-72	
Penjamo 62	September	September	Phytotron	-
"	Spring	Spring	"	+
Bezostaya 1	September	September	"	-

Table 4. Wintering conditions. Martonvasar 1971-72.

	October	November	December	January	February	March
Number of days with a radiation minimum temperature below -10°C	2	3	1	11	4	2
Least value of radiation minimum, °C	-13.5	-13.6	-10.2	-18.2	-12.5	-13.2
Maximum air-temperature, °C	23.0	18.3	14.5	5.0	12.0	20.7
Deviation of the monthly mean values of air-temperature from the many year averages, °C	- 0.7	0.4	3.2	- 0.5	2.9	2.5
Number of days with a fair snow-cover	0	5	0	4	0	0
Deviation of the number of days with snow-cover from the many year averages	0	4.5	- 9.7	-13.1	-10.5	- 2.9

Data of the Martonvasar Agro-Meterological Observatory of the National Meterological Institute (Pletser J.).

SOME IDEAS ON WHEAT BREEDING METHODS

by

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I should like to speak about three items of methodological problems:
(1) suggestions on local varieties of high quality,
(2) improved miniature plot method, and
(3) a new way of hybrid wheat production.

Future of quality local varieties

After the hybrid corn had replaced corn varieties, the majority of these disappeared step by step from the farms and from nurseries too. The situation, at least in some respects, is now similar to that of the local wheat varieties too, such as the "old fashioned" South-East-European varieties, although they have a lot of desirable characters ranging from quality to adaptability. Their weakness, such as tallness, severe lodging, disease sensitivity, etc. have retarded their utilization in modern breeding nurseries.

Two years ago a program aimed at saving the local wheats of the East-European, and first of all, the Hungarian quality wheats such as Bánkuti, Bánáti etc. was initiated, with the purpose of a rough screening, selecting and transforming them into up-to-date types according to the requirements of the wheat breeders of today. This work involves three or four steps:

(1) A great many (cca. 1000 per year) local varieties are tested in pathological nurseries. All varieties are grown on two agronomic levels, optimal and stressed (under-nourished). Both are infected heavily with leaf- and stem-rust and mildew race populations respectively. It is suitable for determining the horizontal resistance of the adult plants.

(2) If any variety has noteworthy resistance to one of these diseases, it is tested in the greenhouse for seedling resistance too.

(3) The best of the local wheats, (3-5% only) will go over to the breeding nursery, for transforming them into dwarf types. The method is back-crossing. During the BC-procedure, care must be taken for (a) quality, (b) disease resistance level, (c) morphological characters of the original wheat.

Obviously, the dominantly inherited dwarfness,(e.g. Blé Tome Pouce, Minister, Oleson etc. varieties) is more comfortable for a BC program than the recessive ones. To keep the variability of the genetical background, recessive lines must be used too.

(4) Parallel to this work we are going to start a genetical program to obtain more useful information about the inheritance of dwarfness, (a) with diallel crosses between the dwarfs, (b) by producing monosomics and nullisomics in a dominant (Blé Tome Pouce) and in a recessive (Norin 10) variety, as well as in one of the dwarf Hungarian Triticales of Dr. A. Kiss, (c) we need to transform one variety (Bánkuti 1201) with isogenic background into all different recognized dwarf forms.

It is hoped many of the wheat research workers will be able to use the products of this program. At present, the co-workers of this group are the collaborators of Cereal Research Institute and Biological Research Centre, Szeged, Hungary: Barabás Z., Beke F., Belea A., Dudits D., Kertész Z., Nemeth G., Parádi L., as well as Mesch J., from Agrobotanical Institute, Tápioszele. I would like to express our desire to work together with many other colleagues to transform and to save many old quality local wheats.

Miniplot method for dimensional wheat testing

The ingenious method of "miniature plots" developed by Jensen and Robson (1969) unites many advantages of wheat testing: (1) near to optimal population density, and (2) minimal requirement of seed, space and operating cost. I had an opportunity to observe the method when I paid a visit to Dr. Jensen's nursery at Ithaca, New York, in 1970.

According to the article, mentioned above, linear hill plots were adapted to fit into the prevailing rod row field scheme. Ten linear hill plots, each 30.5 cm long, were planted in a rod row (488 cm); a 10-cm space separated plots within the row and 36-cm guard plot capped each end of rod row. Rows were 30.5 cm apart and seed used was 1 g per plot.

We have been using a similar method, but with rows 12.5 cm apart. Each of our experiments are laid out in randomized block design of 20 entries, with 10 replications of two spring wheat experiments in 1971, and with 15 replications in two experiments with winter wheat varieties. In addition, two spring wheat experiments were planted in 1972. One of the winter wheat miniplot trials was laid out parallel, according to the conventional plot method with 5 m^2, and with 4 replications.

Though our examination period was short, it seems to us that the miniature plot method is really very effective and useful tool for preliminary screening of wheat lines, varieties, hybrid combinations, etc., on the basis of their yield performance. The only disadvantage of the method is the relatively high genotypic interaction (intervariety effect) and a great deal of manual work requirement. Consequently, its use is limited in a large testing program.

We can adapt the miniplot method to mechanization. The Wintersteiger "Seedmatic" program seeding machine fits it. The Seedmatic can sow about 60 cm long rows, with about 40 cm spacing fast and reliably. Rows are 15 or 20 cm apart and the seed requirement is 50 seeds per 60 cm, which is equal to 25 seeds or 1 g per 30 cm. Using the mechanical miniplot method we can plant hundreds or thousands of entries without any outdoor manual work. For 1000 entries with 10 replications plus guard plots, 1/5 hectare of nursery space is required.

In addition to the mechanization we should like to suggest another modification is to plant buffer rows of a male sterile variety between the rows of all tested entries. This buffer has three kinds of favorable influences for the experimental work: (1) it reduces the genotypic interaction; (2) it decreases the intervarietal out-pollination between the varieties tested; (3) it catches a part of the pollen of the wheats tested.

If harvested, it could be used as a Stadler's "gamete selectional" net. It would be worthwhile to screen the seed yield of the ms buffer plants to obtain new forms, restorers, etc. The mechanized neo-miniplot, completed with male sterile buffer rows, should be a useful tool for large-scale wheat genotypic testing.

The use of marker genes in producing hybrid wheat

The basic tools for the hybrid wheat production are cytoplasmic male sterility, a fertility restoring system, and cross-pollination under field conditions (Wilson, 1968). In recent years considerable progress has been achieved by the utilization of male sterility and restorer genes. However, one of the great difficulties in large-scale production of hybrid wheat seed remains to be solved. The relatively poor seed setting, thus the high cost of commercial seed production has for many years retarded the development of the hybrid wheat.

The problem has many aspects, such as the width of the male sterile strip in relation to the pollinator strip in hybrid seed production (Vries, 1971). The parental strips must be planted and harvested extremely carefully to avoid any mechanical mixing. If the strip of the male sterile plants is broad, the seed setting in the central rows will be sharply reduced. When parental strips consist of a few rows only, the pollination should be better, but the sowing and harvesting will be more complicated and costly.

The contradiction can be solved in two ways: (1) Improved combining ability, which could compensate the more expensive manipulations of the seed production; (2) A basically new, economical hybrid seed-producing method, like the proposed process using the marker genes (Patented No. 4078, March 13, 1972).

Among the ordinary white, yellow, brown, red colored seed of wheat varieties, there are blue, purple colored ones too (Hurd 1959). The inheritance of a conspicuous purple color was studied by McIntosh and Baker (1967). The pericarp color is conditioned by duplicate dominant gene pairs. By backcrossing it can be transferred to any of the hexaploid wheats; thus to any of the parents of the hybrids too. Using this marker effect we have some advantage for the hybrid seed production.

(1) If the male parent is marked in this way, the parents can be mixed together because the two parents are distinguishable. The purple grain pigmentation is maternally inherited and determined by pericarp. Hence the segregating generations referred to previously apply to maternal tissue (McIntosh). Consequently, after harvesting, the hybrid (e.g. white) seed and the purple male parent can be separated. The selection can be done mechanically by color-sensitive photo-electric selectors.

(2) In this way, we do not need to plant different strips of the male and female parents.

(3) McIntosh and Baker wrote: "the F_2 pericarp phenotypes were determined from observations on lines in the F_3 embryo generations". So the F_2 seeds produced by the F_1 hybrid in the farmer's field, also would have a normal (e.g. white) seed color, instead of an unusual purple one.

(4) Owing to the mixed sowing of parents, each male sterile plant will have in its immediate neighborhood pollinators. Therefore the seed setting improves considerably which may change the quantity of the mother component in the seed production field.

Summing up: it seems that by using the marker genes method for hybrid seed production, the field manipulations will be cheaper, more reliable and easier, the yield of seed will be higher than from the "striped method". It appears to be an important step forward in producing hybrid wheat of economical value.

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SUMMARY OF BREEDING PROGRAM AT WHEAT RESEARCH CENTER - ANKARA

by

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The Wheat Research and Training Center was established in 1969 after the agreement signed between the Turkish Ministry of Agriculture and the Rockefeller Foundation. The purpose of the Center is to develop the research in the various wheat disciplines. The disciplines involved are breeding, pathology, tillage practices, fertilization, etc.

Before the establishment of the Wheat Research and Training Center, wheat research (breeding and cultural research) was conducted by the Agricultural Research Institute. This Institute was established in 1928 and has developed the varieties currently being grown in Turkey. Researchers transferred to the new organization in 1969.

At present, the Research Institute has about 300 ha of land for research and foundation seed production. This land is unsuitable for research for many reasons: proximity to the city, shallow soils, salt and drainage problems, the fact that the land is split into many small fields in separated areas, and lack of irrigation facilities.

Beginning with the 1972-73 season, all research work in Ankara will be conducted at a new 300 ha farm located 45 km south of Ankara. Facilities are being planned for this location. An additional 300 ha will be purchased at the same location within two years. Irrigation facilities are being planned at the new location.

Ankara is located in the north central part of the Anatolian Plateau. It is typical of the main winter wheat growing area of Turkey. The average rainfall in the region varies from 350-400 mm. However, the distribution and yearly totals fluctuate widely. The critical periods for rainfall are in late October and November (seeding) and in April and May.

The Anatolian Plateau typically has cold winters and hot summers. Because of this, the area grows winter wheats with cold resistance. Early varieties are also needed to escape the hot conditions in late June and July. The major disease is stripe rust and varieties must have resistance.

The main objectives of the breeding program are to develop higher-yielding varieties with shorter straw, resistance, winterhardiness, drought tolerance, responsiveness to fertilizer, and good quality. To accomplish the objectives, the germplasm variability is being expanded by introduction of new lines and by an extensive crossing program utilizing the variability present. In the past year, wheats have been collected from many different sources and currently these wheats are being intercrossed and also crossed to the Turkish varieties.

The current nursery includes the following materials:

Bread Wheats

F_1	260	
F_2	530	
$F_3 - F_6$	9000	lines
Crossing Blocks	900	lines
Observation Nurseries	3650	lines
Yield Trials	200	lines (7 trials)
IWWPN	30	varieties
RDISN	2400	
Turkish Trap Nursery	60	
Regional Trap Nursery	40	
Other Disease Nurseries	80	
Increase Plots	200	

Durum Wheats

F_1	30	
F_2	76	
$F_3 - F_6$	1600	
Crossing Blocks	320	lines
Observation Nurseries	150	lines
Yield Trials	40	lines (2 trials)
IDYN	25	lines

These nurseries were seeded in October and early November. However, due to lack of rain germination did not occur until mid-December. Shortly after germination, the weather turned very cold. As a result, the plants entered the cold period poorly established. The cold period continued until late February. Therefore, all development has been accomplished since late February. Due to these conditions, the current crop is 2-3 weeks later than normal. The precipitation from November to June 5 has been 240 mm which is 100 mm below normal. These abnormal conditions have reduced stands and affected plant development.

Plans are being made to increase the size and scope of the crossing program, especially in the durums. Early generation testing will be increased not only in numbers but also in number of locations. More extensive yield testing with many locations will begin next year. Using these methods, new and better varieties can be developed in a much shorter time.

IWWPN
PLANNING SESSION

Discussion led by
J. E. Stroike and V. A. Johnson

Seeding rate -- The discussion centered around the question of whether all varieties in the nursery should be seeded at a common rate at each nursery site or whether the rate for each variety should vary according to the recommendation of its developer. There were strong arguments on both sides. European cooperators suggested that their varieties do not generally tiller as much as USA varieties. Therefore, when seeded at rates commonly used in the USA, which are much lower than the recommended European rates, the European varieties would be penalized.

It was pointed out that the seeding rates currently used vary between sites according to the recommendation of the cooperators and that only the rate between varieties at an individual site is held constant. Increased problems of seed preparation and packaging for the many nursery sites was cited as one argument against a different seeding rate for each variety. There was some question as to whether there is sufficient evidence for effect of seeding rate on yield in all parts of the world to justify the use of variable rates within the IWWPN.

There was agreement that effort should be made to obtain information on the question. Additional plots of selected nursery entries in which the seeding rates recommended by the developers would be utilized were suggested as a means of quickly obtaining useful information. This or alternative approaches will be considered when plans for the 6th Nursery are formulated.

Check varieties -- There was general agreement that Bezostaia 1, Blueboy, Atlas 66, and a spring wheat variety (Lerma Rojo is now used) are acceptable check (standard) varieties for the IWWPN.

Period of testing -- There was sentiment among cooperators for a short testing period to permit more varieties to be evaluated in the nursery. It was agreed that nursery entries (other than check varieties) would be dropped after two years of testing unless there were special reasons for their retention for a longer period.

Candidate varieties -- The initiative for submission of candidate varieties for the IWWPN should reside with the cooperators. Seed in the amount of 1½ kg should reach Lincoln, Nebraska by October 1 to permit its inclusion in U. S. quarantine increase plantings at Yuma, Arizona. In the following year the candidate variety will be included in the Preliminary Nursery.

Preliminary nursery -- This is primarily a screening nursery to identify candidate varieties most worthy of advancement to the main IWWPN. It will be grown at Yuma, Arizona; Cambridge, England; Fundulea, Romania; Ankara, Turkey; and Temuco, Chile in 1973 as an observation nursery for disease and insect reactions and agronomic traits other than yield. Seed was also sent to McVey (Minnesota) and Saari (India) for additional disease observations. The nursery coordinator, Dr. Stroike, may not be able to visit all the Preliminary Nursery sites each year. Thus, comprehensive cooperator evaluations of the varieties are needed.

Observation Nursery -- This is not to be confused with the Preliminary Nursery. The Observation Nursery is identical to the main IWWPN in composition but involves only non-replicated single rows of each variety for observation by breeders, pathologists, etc. at sites where growing the main IWWPN cannot be justified. Fuchs (West Germany), Boskovic (Yugoslavia), Lamberts (Netherlands), G[illegible]nt (Canada), Everson (USA), Porter (USA), and Hughes (USA) have requested the nursery for 1973.

Data recording books -- These should be bound in a way that permits easy disassembly for typing of data onto pages by cooperators. The currently-used plastic binders can be removed easily. Additional unbound books can be provided to cooperators at their request.

Reports -- December 1 was agreed upon as the deadline for receipt of nursery data in Lincoln, Nebraska to be included in the mimeographed Preliminary Nursery Report each year. The December 1 deadline will permit preparation and distribution of the Preliminary Report by February 1.

Data reporting -- Cooperators were urged to provide complete information on the data they report. There should always be an explanation of the way in which data were taken and the units of measurement utilized.

Seed packaging -- Unless otherwise requested by the cooperator, he is provided seed of the IWWPN packaged by individual rows (6 packages per plot). This is laborious and time-consuming. If cooperators desire seed packaged by plots or by nursery entry instead of individual rows, they should make this known to Dr. Stroike because this greatly simplifies the packaging operation.

Seed shipments -- It is important that the nursery coordinator be informed by cooperators of receipt of nursery seed. In turn, he will acknowledge receipt of data recording books and seed samples upon their arrival in Lincoln, Nebraska.

Border rows -- Are they necessary in the IWWPN? They are needed for shattering observations and they reduce the effect of adjacent plots. It was agreed that they should be retained.

Lodging -- A single note that combines both the severity and extent of lodging was preferred by most cooperators over individual notes for each of these two lodging components. This will be acceptable in the future.

Test weight versus 1000-kernel weight -- The consensus among cooperators was that 1000-kernel weight is a much more meaningful measurement than test weight and will be the preferred measurement henceforth.

Fertilization of nursery -- Should there be a uniform rate of fertilizer used at all nursery sites? Strong sentiment against such a practice was expressed because no single rate would be realistic for all nursery sites. It was recommended that fertilizer application be made according to accepted practices at each nursery site.

Next conference -- There was unanimous agreement that a second international winter wheat conference be planned for 1975 or 1976. The suggestion was advanced that the conference be planned at a location near the maximum number of nursery sites so that these could be easily visited during the conference.

RESOLUTION

The following resolution was unanimously adopted by the conference participants:

"In consideration of the splendid facilities made available for this conference and the many cooperative efforts of various groups and individuals directed toward providing meaningful sessions for those attending this Winter Wheat Conference at Ankara, Turkey, June 5-10, 1972, be it resolved that we express our appreciation:

1. To the Ministry of Agriculture of the Government of the Republic of Turkey for inviting and hosting the participants of this Conference.

2. To the Ankara Wheat Research and Training Center and especially to Dr. Ahmet Demirliçakmak.

3. To the Personnel Training Center-Ankara: Director, Mrs. Ismet Tezel, Assistant Director, Mr. Veysi Baycan.

4. To the Agency for International Development, U. S. Department of State, for providing considerable financial support for this conference, support and leadership from the Washington office, and the assistance of the USAID group here in Turkey.

   We ask that Dr. Guy B. Baird convey our appreciation to USAID.

5. To Professor Dr. Osman Tosun for serving as general chairman and to the chairmen of the various sessions.

6. To the Nebraska group, and especially Dr. V. A. Johnson, Agricultural Research Service, US Department of Agriculture, for the coordination of the many operational details associated with this conference."

Respectfully submitted,

The Resolution Committee

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