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CIMMYT Report on Wheat Improvement

1984

The International Maize and Wheat Improvement Center (CIMMYT) is an internationally funded, nonprofit scientific research and training organization. Headquartered in Mexico, CIMMYT is engaged in a worldwide research program for maize, wheat, and triticale, with emphasis on food production in developing countries. CIMMYT is one of 13 nonprofit international agricultural research and training centers supported by the Consultative Group for International Agricultural Research (CGIAR). The CGIAR is sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank), and the United Nations Development Programme (UNDP). The CGIAR consists of 40 donor countries, international and regional organizations, and private foundations.

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Directors' Introduction

Byrd C. Curtis and Arthur Klatt

In accordance with its research mandate, CIMMYT devotes its resources to developing improved germplasm and making this material available throughout the world, primarily to crop improvement programs in developing countries. The fulfillment of this mandate makes it imperative that CIMMYT breeders concentrate not only on germplasm for more favored environments, where substantial yield improvements can and must be obtained, but also on materials for more marginal production areas, where drought, high incidence of diseases, acid soils, and extremes of heat or cold reduce yields. In these areas, where over one and a half billion people live, demand for wheat is rising rapidly while its production is hindered by numerous constraints. This situation is particularly acute in tropical countries, where about 85% of the wheat consumed in 1983 was imported.

Until production constraints are at least partially removed, it will be difficult to grow wheat with a great degree of success in these environments. CIMMYT is responding to this difficulty in two ways. First, the Center is using conventional breeding procedures to develop improved germplasm suited to less favorable production environments. Another approach likely to contribute to the resolution of production problems is research aimed at crossing wheat with related crops and wild species to obtain germplasm with characteristics desirable for marginal areas.

Dr. Byrd Curtis, Director of the Wheat Program.

Much of this breeding work is done at three locations in Mexico. Summer nurseries are grown from May through October at two high-elevation sites: El Batan (CIMMYT headquarters, 40 km northeast of Mexico City) and Toluca (also in central Mexico). During the winter cycle, from November to April, nurseries are planted at the Yaqui Valley Agricultural Experiment station, a low-elevation site in the northwest. Still other sites in Mexico are used to screen germplasm for resistance and tolerance to specific diseases and stresses.

The research done within Mexico is reinforced and complemented by CIMMYT's regional and bilateral programs. The Center's outreach staff play an increasingly vital role in developing and disseminating CIMMYT's research products. Working with personnel from national crop improvement programs, outreach staff help identify regional or national needs, expedite the exchange of germplasm, participate in an advisory capacity in crop improvement research, and assist with the training of technical personnel from national programs. The exchange of information among national program scientists and CIMMYT staff in Mexico and abroad is crucial for the rapid development of widely adapted, improved wheats suited to a range of environments.

The development of such materials is not the final step in crop improvement: the process is only complete when national program scientists have selected and refined

germplasm to suit specific local needs, and have successfully extended new varieties to producers.

The World Wheat Situation

World wheat production in 1984 reached about 520 million metric tons (MT), exceeding the previous year's record. Among developed nations, the countries of Western and Eastern Europe experienced the greatest increases; extremely favorable growing conditions helped raise production by 24 MT over 1983. Several Western European countries greatly augmented their wheat production by obtaining higher yields.

In North America, increases were limited by several factors, including agricultural land set-aside programs in the USA, drought in the Canadian prairies, and reductions in the amount of land planted to winter wheat in the USA. Nevertheless, total wheat production has been stable over the past few years.

Among developing nations, wheat production has repeatedly reached record levels, growing by almost 80 MT during the past decade. Exceptional yield increases realized by the major Asian wheat-growing nations have contributed greatly to achieving those higher levels of production. During the past four years, China improved production by more than 30 MT, to become the leading wheat-producing country in the world. India and Bangladesh have also experienced steady gains.

Unfortunately, the gains achieved by Asia's developing nations did not occur in the rest of the Third World. In East Africa, persistent drought continued to destroy wheat crops; Kenya's harvest was less than half the size of previous years' crops, and Ethiopian wheat production was reduced by 25% to 700,000 t. Production in the Middle East and North Africa has risen little in the past few years. However, Saudi Arabia harvested over 1.3 MT of wheat in 1984, compared with less than 200,000 t three years before.

As in the Middle East, wheat production in Latin America was largely unchanged. Production remained static in Argentina and the Andean region, and Brazil's harvest was nearly 1 MT lower than 1979's record level. In 1984, Chile and Uruguay were two exceptions to this situation; total production in Chile rose considerably, to nearly 1 MT, and Uruguay's harvest was above average.

In the near future, world wheat supplies should continue to rise, given favorable weather conditions and relatively stable prices for inputs. It is clear that several countries, including the USSR, have the potential to attain sizeable production increases by obtaining higher yields.

Dr. Arthur Klatt, Associate Director of the Wheat Program.

CIMMYT Crop Programs

Bread Wheat—In the last five International Spring Wheat Yield

Nurseries (ISWYN), a Veery selection was the best yielding variety across all locations. Along with breeding for higher yields and broad adaptation, breeding for better disease resistance, especially to leaf, stem, and stripe rusts, is a continuing priority of the bread wheat program. Recently, more attention has been given to overcoming susceptibility to *Fusarium* and *Helminthosporium* spp., pathogens that reduce yields in regions where wheat has not been widely grown before.

Durum wheat—In 1984, the durum wheat program continued to pursue its objective of improving disease resistance in durum materials, and has successfully developed lines with high levels of stripe rust resistance. Good sources of genetic resistance to stem rust, *Septoria* spp., and scab are being fully exploited in the crossing program. The increasing export potential of large-grained durum wheats with high test weights and acceptable protein and pigment content has led the breeding program to develop lines with satisfactory milling and quality characteristics as well as high yield potential. Materials with better tolerance to cold and drought are also being produced.

Triticale—Triticales with improved sprouting resistance, tolerance to drought and acid soils, and earliness — characters that are all important factors in the improvement process — were selected in 1984. Priority was given to introducing greater genetic variability into the germplasm base through the creation of new primary triticales (wheat x rye crosses). The program has identified a number of lines possessing more stable and acceptable test weights, which should eventually make it possible to obtain better quality grain in less favorable environments.

CIMMYT/ICARDA Cooperative Research

In 1984, a new division of responsibilities for wheat and barley research was effected by CIMMYT and ICARDA. Under the terms of this agreement, the global mandate for bread and durum wheat and triticale improvement remains with CIMMYT, and ICARDA possesses the global mandate for barley improvement. Associated changes in research priorities and staff assignments have accompanied this new arrangement. Two CIMMYT wheat scientists were sent to conduct research on bread and durum wheats at ICARDA's headquarters in Aleppo, Syria, and an ICARDA barley breeder was posted to CIMMYT headquarters to develop barley germplasm adapted to the production environments of the western hemisphere.

New Programs

Seed Health Unit—A seed health unit was established in 1984 to serve all of CIMMYT's germplasm development programs and provide more effective coordination of seed health work. The unit is responsible for performing standard tests for seed-borne pathogens in germplasm intended for international distribution. The unit's other activities include developing improved methods of testing for seed-borne pathogens, evaluating the efficacy of chemical seed treatments, and determining improved procedures for treating seed. This work is done in close collaboration with Sanidad Vegetal, the Mexican plant protection and quarantine organization.

BYDV project—In late 1984, CIMMYT initiated a research project, funded by the government of Italy, to reduce losses from barley yellow dwarf virus (BYDV) in wheat. This disease is both widespread and significant in areas where wheat is grown, and has been recognized only recently as a serious constraint to wheat production. The general objective of the project is to create an international network of collaborators familiar with BYDV and to promote the exchange of information and BYDV-resistant germplasm among national research institutions.

Staff changes—Dr. George Varughese, senior staff member of the North Africa and Iberian Peninsula regional program, was recalled to headquarters in Mexico, where he took charge of the triticale program. The triticale program also profitted from the arrival of Dr. E.E. Saari, who came to headquarters from Thailand to assume special responsibility for triticale pathology, in addition to performing more general pathology research. The international BYDV project was initiated under the leadership of Dr. P. Burnett, formerly a pathologist in the barley program.

Three scientists left Mexico to take up positions in regional or bilateral programs. Dr. P. Fox, a breeder/pathologist, was posted to Ecuador, in the Andean region. Dr. C. Mann moved to Thailand to work on developing tropical wheat in South and Southeast Asia, and Dr. Bent Skovmand joined the bilateral program in Turkey as a breeder of winter wheat.

CIMMYT/INIA Cooperation

Much of the research reported in this publication could not have been achieved without the cooperation of thousands of scientists and technical personnel throughout the world. One particular cooperative effort that has yielded impressive results over the years is the joint work of CIMMYT and INIA, the Mexican National Institute of Agricultural Research. Land as well as logistical support have been provided to CIMMYT by INIA at various national experiment stations, including the Northwestern Agricultural Research Center's (CIANO's) Yaqui Valley Agricultural Experiment Station near Ciudad Obregon, Sonora. This support, along with the contributions of INIA's scientific staff, has been especially important for the Center's wheat improvement work. CIMMYT also wishes to express its appreciation to the Patronato, the farmers' organization of Sonora, which provides considerable funding for CIMMYT's winter nurseries. These organizations have been instrumental in helping to meet more than local or national needs: the benefits of their work are appreciated internationally.

Bread Wheat

S. Rajaram, W. Nelson, R. Villareal, and R. Singh

Introduction

The bread wheat breeding program strives to maintain broadly based genetic variability in its germplasm. Such variability is promoted by the frequent introduction of parents of wide geographic origin and extensive genetic diversity in disease resistance, agronomic characters, and yield components. The program's eventual goal is to stabilize yield by reducing genetic vulnerability to pests, mutable pathogens, and environmental stresses. This objective is being attained through the judicious use of disease resistance and stress tolerance genes, and by multi-locational testing.

Although breeding for resistance to rusts, septoria leaf blotch, scab, and *Helminthosporium sativum* is a significant objective of the program, the crucial balance between disease resistance and other characteristics such as high yield, wide adaptation, and stability has not been lost. Indeed, the program has given increased emphasis to maintaining this balance by further identifying and incorporating materials tolerant to drought, heat and aluminum toxic soils.

The yield potential of bread wheats steadily increased from 7000 kg/ha in the early 1970s to 8000 kg/ha in the early 1980s. The greater yield potential of CIMMYT bread wheats has clearly made an impact on average wheat yields in Sonora, Mexico: yields rose from 4000 kg/ha in the early 1970s to 5000 kg/ha ten years later. Through shuttle breeding, multienvironmental testing, further refinement of selection criteria, and careful manipulation of genetic variability, genetic yield potential should rise to 9000 kg/ha in the near future in this environment.

Breeding for High Yield Potential and Wide Adaptation

The two principal locations, both in Mexico, used in selecting germplasm and advancing segregating generations are the Yaqui Valley Agricultural Experiment Station at the Northwestern Agricultural Research Center (CIANO) (39 m elevation, 27°N latitude) near Ciudad Obregon, Sonora, and the Toluca Experiment Station (2640 m elevation, 19°N latitude). The CIANO and Toluca stations differ greatly in rainfall, temperature, day length, soil type, and disease spectrum: the former is a high-yield environment, whereas potential yields are lower in the latter location.

Aside from these sites, CIMMYT's bread wheat program employs other locations within Mexico that offer different opportunities to select for specific characters: the El Batan Experiment Station (Mexico) (2249 m elevation, 19°N latitude); the Tarascan Mountains Agricultural Experiment Station (Patzcuaro) (2180 m elevation, 18°N latitude); Tepatitlan (Jalisco) (1700 m elevation, 20°N latitude); Tlaltizapan (Morelos) (940 m elevation, 18°N latitude); the Poza Rica Experiment Station (Veracruz) (60 m elevation, 21°N latitude); Tampico (Tampico) (4 m elevation, 22°N latitude); the Rio Bravo Agricultural Experiment Station (30 m elevation, 25°N latitude); Culiacan (Sinaloa) (53 m elevation, 24°N latitude); the Fuerte Valley Agricultural Experiment Station (Los Mochis) (40 m elevation, 22°N latitude); Mexicali (Baja California Norte) (1 m elevation, 32°N latitude); and Huamantla (Tlaxcala) (2500 m elevation, 19°N latitude).

CIMMYT breeders use these stations for different purposes and to varying degrees; in some cases, work at the stations is carried out in cooperation with the Mexican National Agricultural Research Institute (INIA). Additional genetic information for the crossing program at CIMMYT is supplied from nearly 100 other locations throughout the world by cooperators in CIMMYT's international testing program.

CIMMYT/INIA Elite Yield Trial for the Northern Zone—In 1984, INIA and CIMMYT established the

Dr. S. Rajaram (left), head of the bread wheat breeding program.

Elite Yield Trial for the Northern Zone (EEZON). The objective of this trial is to identify varieties and advanced lines for different regions of Mexico. Twenty-four wheat varieties were included. Their relative yield in kg/ha is given in Table 1. The summary mean is based on the 25 locations listed in Table 2. The varieties Seri 82 (Veery No.5), Ures 81 (Veery No.2), and Genaro 81 (Veery No.3) were the top performers, followed by the advanced lines Pfau 'S', Buc 'S'/Flk 'S', and Bjy 'S'/Jup. Although the performance of these advanced lines is promising in Mexico, their yield potential is lower than that of the "Veery" varieties.

Table 2 compares yields of Seri 82, Genaro 81, and Ures 81 to local check varieties at 25 testing locations in Mexico; the local check varieties are cultivars widely grown in each location. On the average, Seri 82 showed a 10% higher yield than the local checks, and its yield was equal to or more than the check variety at all locations except Ensenada (Baja California Norte), General Teran (Nuevo Leon), San Lorenzo (Sinaloa), and Costa de Hermosillo (Sonora). Yields of Ures 81 and Genaro 81 were an average of 8% and 7% higher, respectively, than yields of the local check varieties. In 18 locations, their performance was either equal to or better than the local check.

Close examination of these data reveals that yields of Seri 82, Genaro 81, and Ures 81 are above the local check in most locations, indicating their wide adaptation across most Mexican environments. These three varieties constituted more than 70% of the area planted to wheat by farmers in northwestern Mexico in 1984. Although many farmers planted very late, the average yield in the State of Sonora was more than 5 t/ha. Some farmers in the Yaqui Valley harvested more than 8 t/ha.

Resistance to *Puccinia recondita* (leaf rust) is still satisfactory and there are preliminary indications that slow rusting genes are present in Genaro 81 and Ures 81. These genes are sensitive to high temperatures, and may break down when temperatures are above normal. Seeded in the middle of January (late sowing), these three varieties appeared to be insensitive to high temperatures because of their relatively longer leaf retention and higher test weights. This insensitive response is very important in northern Mexico, where there is a sudden onset of high temperatures in the post-flowering stage.

International Performance of Seri 82, Genaro 81, Pavon 76, and Anza—One of the bread wheat program's most important objectives is the development of widely adapted germplasm. Wide adaptation is evaluated in international trials such as the last five International Spring Wheat Yield Nurseries (15th - 19th ISWYN), in which a Veery selection (cross CM33027) was the best yielding variety across all locations.

Figures 1-11 present a comparison of the yields of Seri 82 (Veery No.5) and Genaro 81 (Veery No.3) with those of Anza (a widely grown variety), Pavon 76 (also widely grown), and the local check for the 56 locations of the 19th ISWYN. Locations are listed in Table 3

In Figures 1-11, the yield of one variety is depicted on a vertical axis and the other variety on a horizontal axis. The yield on each axis ranges from 0 to 110qq/ha (1qq = 100 kg). When the yield of the variety represented by the vertical axis is highest, the location appears above the solid diagonal line; when the yield is highest for the variety on the horizontal axis, the location appears below the diagonal line.

In Figure 7, for example, Seri 82 and Anza are similar in yield at location 50, and thus the location appears on the diagonal line. At location 5, Seri 82 yielde 5700 kg/ha, whereas Anza yielded 3100 kg/ha; the location appears at a point 2600 kg above the diagonal line and vertical to 31 on the Anza axis.

Figures 6, 7, and 8 compare Seri 82 with Pavon 76, Anza, and the local check across 56 locations. Yields of Pavon 76 were significantly higher at only two locations, Japan and Cerrados (Brazil). Anza yielded significantly higher in Japan, Cerrados, and Minnesota (USA). The local check exceeded the yield of Seri 82 only in Ecuador. Figure 6 shows that Seri 82 and Pavon 76 are both widely adapted, yielding above 4000 kg/ha across 28 locations. Seri 82 yielded significantly higher than Pavon 76 at 10 locations, whereas Pavon 76 was not significantly higher at any of these locations at this yield level. Seri's yield superiority was more pronounced in the comparison with Anza and the local check, as shown in Figures 7 and 8.

Genaro 81 is compared with Pavon 76, Anza, and the local check in Figures 9, 10, and 11. Across the 56 locations, Pavon 76 was significantly higher yielding only in Washington and Minnesota (USA). Anza was significantly higher yielding in Minnesota and Belgium, and the local check yielded better in South Dakota and Minnesota (USA), Ecuador, Czechoslovakia, and Belgium. With the exception of Ecuador, all of these locations are above 45°N latitude, indicating that Genaro 81 needs improvement for adaptation in higher latitudes.

It is important to note that when the comparisons in Figures 1-11 were made, three varieties were discarded because of their vernalization requirement, and thus there is no yield data for many locations. Data from seven locations were discarded because of very low location yield where yield expression between varieties is limited, and for high coefficient of variation. In Table 4, the comparison of mean yield, rank, and percent of Seri 82 is given for 56 locations with 47 varieties, and for 63 locations and all 50 varieties in the 19th ISWYN. The table shows that there was very little difference in ranking or percent

of Seri 82 for both comparisons, although the mean yield was about 300 kg/ha lower in 63 environments.

Table 5 gives mean yields for Seri 82, Genaro 81, Pavon 76, Anza, and the location mean for eight regions of the 19th ISWYN. Only regions with three or more locations reporting data were included. At yield levels above 3000 kg/ha, Seri 82 was superior to all other varieties, except in the northern United States and Canada, where Pavon 76 was higher. Genaro 81 was higher yielding in the Southern Cone region of South America.

These data indicate that Seri 82 and Genaro 81 are both widely adapted, although to different degrees. Seri 82 combines the highest yield with wide adaptation, yielding more than 10,000 kg/ha at four locations, and producing a maximum yield of 10,500 kg/ha. The maximum yield of Genaro 81 was 10,000 kg/ha; that of Pavon 76 was 9600 kg/ha. Although Anza has a high yield potential, shown by yields of over 9700 kg/ha at three locations, and a maximum yield of 10,300 kg/ha, it has become more susceptible to leaf, stripe, and stem rust, thereby reducing its overall adaptability.

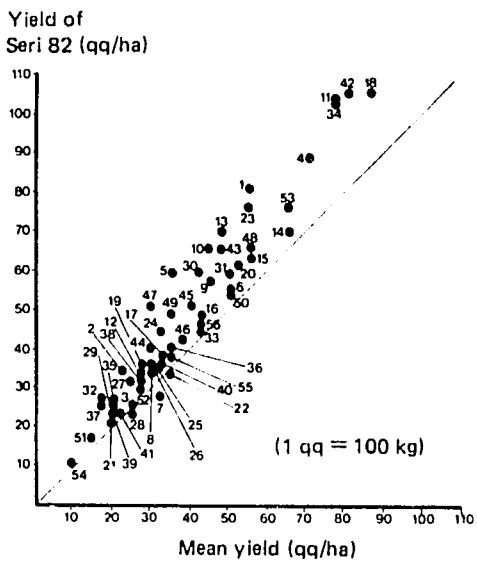


Figure 1. Yield of Seri 82 regressed over mean yield at 56 locations of the 19th ISWYN.

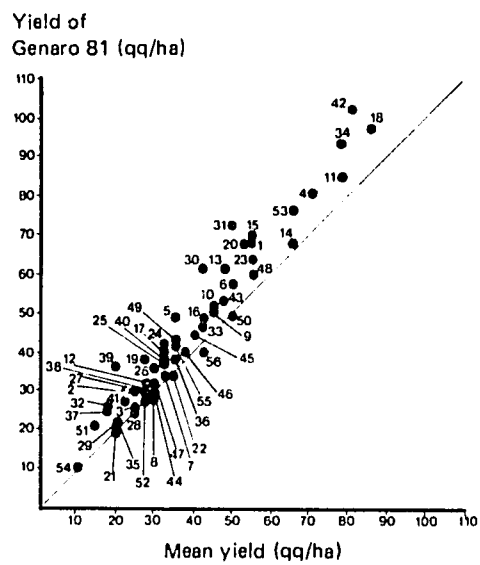


Figure 2. Yield of Genaro 81 regressed over mean yield at 56 locations of the 19th ISWYN.

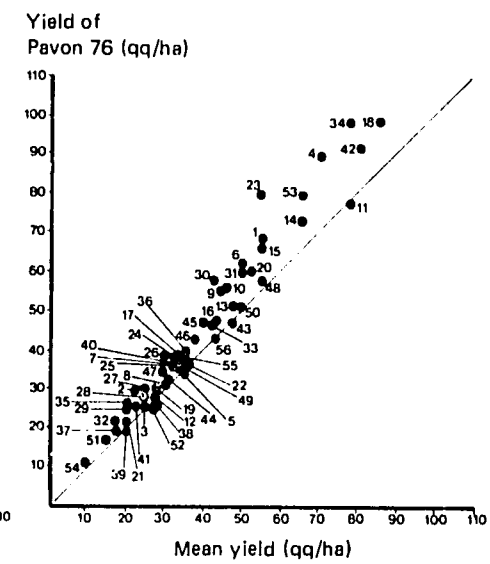


Figure 3. Yield of Pavon 76 regressed over mean yield at 56 locations of the 19th ISWYN.

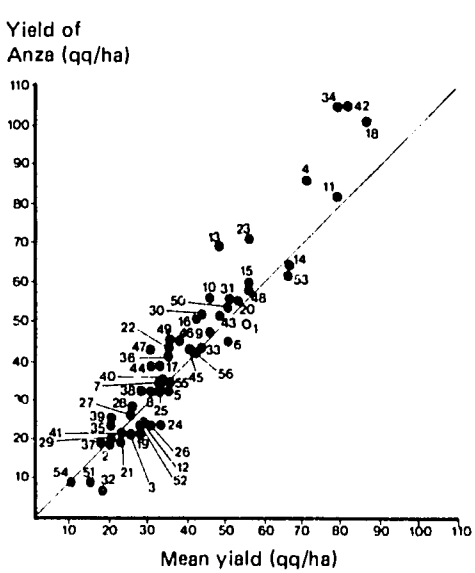


Figure 4. Mean yield of Anza regressed over mean yield at 56 locations of the 19th ISWYN.

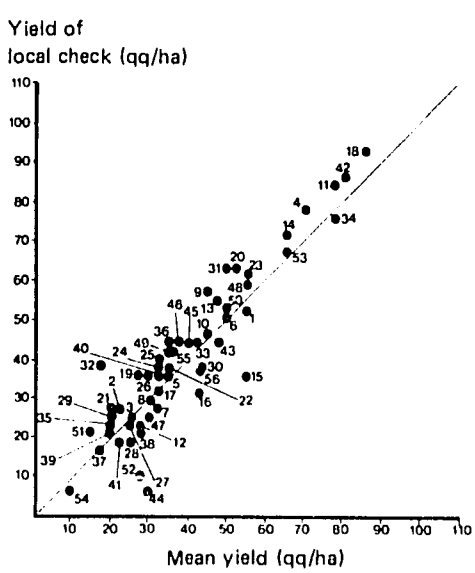


Figure 5. Yield of local check varieties regressed over mean yield at 56 locations of the 19th ISWYN.

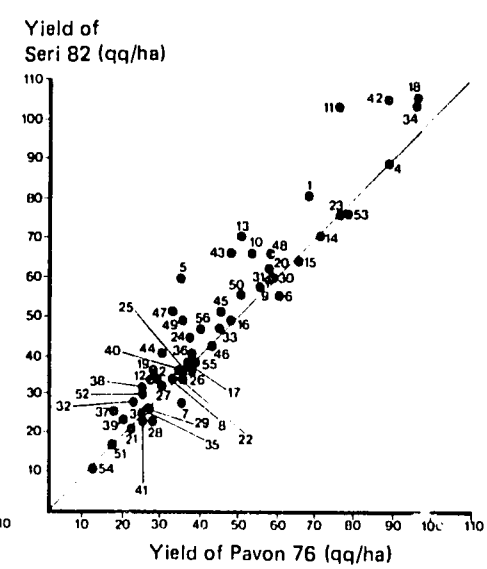


Figure 6. Yield of Seri 82 regressed over yield of Pavon 76 at 56 locations of the 19th ISWYN.

Advanced lines other than Veery in multiplication—Table 6 presents nine advanced lines whose yields varied from 96% to 114% of Ures 81 at CIANO during the 1983-84 season. Some of these lines are being multiplied for eventual release in Mexico.

Breeding for Semiarid Regions

Thirty-seven percent of the total area of the developing world consists of semiarid regions where lack of moisture is the primary constraint to wheat production. These areas lie mostly in the Middle East, North Africa, India, China, and Argentina. Drought resistance is the most important characteristic of varieties destined for these regions. This character is defined as the ability of one genotype to be more productive than other genotypes in semiarid environments. Since the pattern of moisture availability differs from one location to another, the drought resistance of a particular variety tends to be location specific. However, response may be improved by combining other such traits as high yield, yield stability, and wide adaptation together with drought resistance. Ideally, a wheat variety intended for moisture-stressed, rainfed locations should be high yielding, responding favorably whenever environmental conditions become conducive to high yields.

Although it has been maintained that drought resistance and high yield cannot be combined, and that breeding for this character should be done only in low-yielding environments, CIMMYT has attempted with great success to produce high-yielding, drought-resistant varieties. The breeding program for drought resistance employs two strategies for obtaining these results:

1) All materials are handled under environmental conditions ranging from purely rainfed environments, to conditions of reduced irrigation, to full irrigation. El Batan (rainfall 400 mm) and Huamantla (rainfall 400 mm) are used as rainfed locations; CIANO (minimal

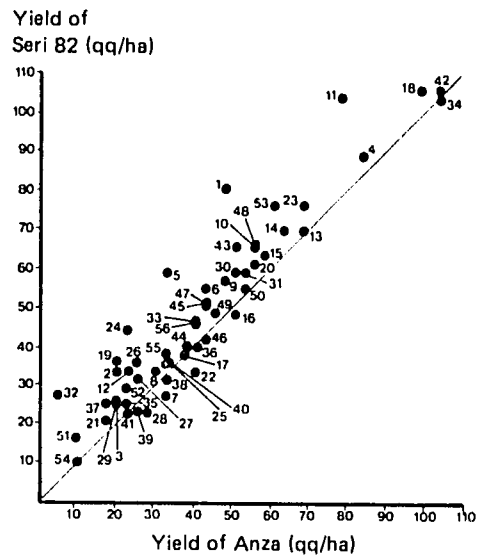


Figure 7. Yield of Seri 82 regressed over yield of Anza at 56 locations of the 19th ISWYN.

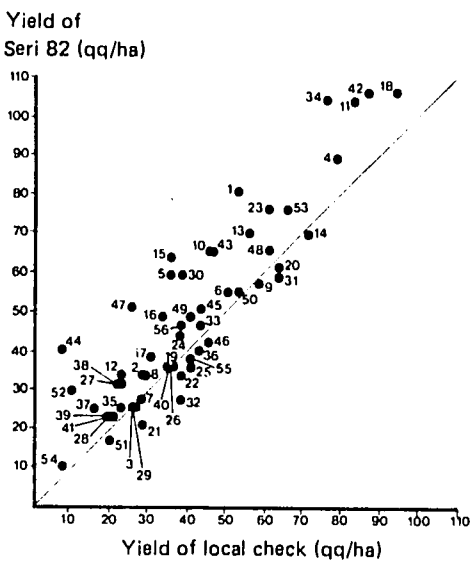


Figure 8. Yield of Seri 82 regressed over yield of local check varieties at 56 locations of the 19th ISWYN.

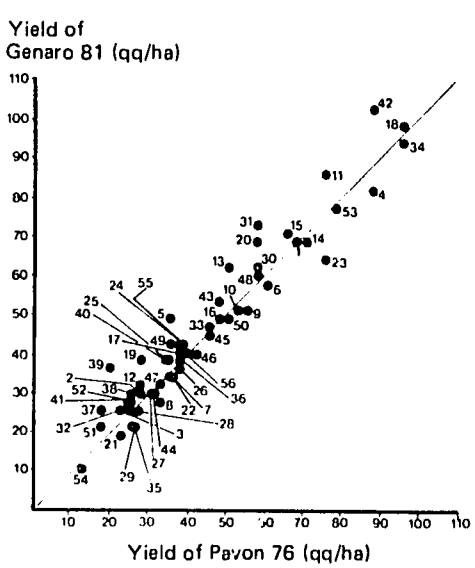


Figure 9. Yield of Genaro 81 regressed over yield of Pavon 76 at 56 locations of the 19th ISWYN.

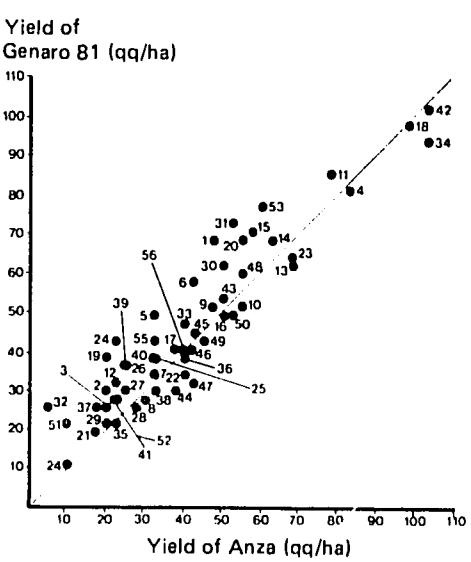


Figure 10. Yield of Genaro 81 regressed over Anza at 56 locations of the 19th ISWYN.

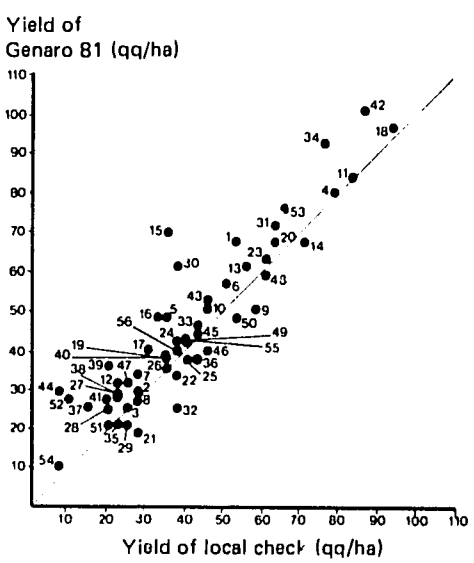


Figure 11. Yield of Genaro 81 regressed over yield of local check varieties at 56 locations of the 19th ISWYN.

rainfall of 150 mm in the wheat season) is employed as the site for full and reduced irrigation. The F_2 generation is generally evaluated under full irrigation, the F_3-F_5 generations may be evaluated either under rainfed conditions or reduced irrigation, and F_6-F_7 materials are tested under full irrigation. This system attempts to produce lines that are more stable under optimum and reduced levels of moisture.

2) All high-yielding advanced lines developed under full irrigation are retested under moisture stress either under rainfed conditions or reduced irrigation. This procedure ensures the identification of advanced lines that are high yielding at both optimum and reduced levels of moisture. A partial listing of these lines is given in Table 7, where their yield performance is compared to Seri 82 at El Batan in 1984. The moisture supply (558 mm) that year was relatively higher than normal, resulting in higher yields. However, in previous years these same lines performed well in unreplicated tests under two irrigation regimes at CIANO. Their performance was evaluated again in yield trials under two irrigation regimes at CIANO, and under rainfed conditions in El Batan. Some of these lines will be tested further in both irrigated and rainfed environments to measure their stability and adaptation.

Breeding for Highland Regions

Wheat-producing highland areas are found in the Andes, Central America (including Mexico), and East Africa. These regions are generally higher than 1500 m, and are characterized by rainfall in excess of 1000 mm/crop cycle. This level of moisture could provoke high incidences of stripe rust, leaf rust, septoria leaf blotch, septoria glume blotch, *Fusarium nivale*, *F. graminearum*, and *Xanthomonas translucens*. Stem rust is a potential threat in some areas close to the Equator. Disease is one factor preventing the yield potential of wheat from being fully expressed in highland regions. The breeding program has made noticeable progress towards improving yields by incorporating resistance to septoria leaf blotch, stripe rust, leaf rust, stem rust, and *Fusarium nivale*. Screening for disease resistance and high yields is done in Toluca, with additional testing carried out in Patzcuaro. Both locations receive rainfall in excess of 1000 mm/crop cycle. Certain advanced lines with yield potential as high as 6 t/ha have been produced. A partial list of these varieties is given in Table 8. Yields are compared to Lira 'S', the highest-yielding advanced line tested over three years in Toluca.

Table 9 lists 14 semidwarf advanced lines found to be resistant to septoria leaf blotch and compares them to Seri 82, which is known to be susceptible. These resistant lines are being used in crosses with high-yielding lines and then top crossed to scab- and rust-resistant lines to produce wheats suited for high elevations. Given the results of the breeding program to date, it should be possible to increase the yield potential of varieties for highland conditions up to 8 t/ha.

Breeding for Tropical Lowlands

In the tropical lowlands, which are situated between 23°N and 23°S latitudes and below 1500 m, high temperatures are a critical physiological stress that limits wheat yields. Yields are also reduced by such diseases as *Helminthosporium sativum*, leaf rust, and *Sclerotium rolfsii*. The program's breeding strategy has been to combine characters for heat tolerance (at both juvenile and post-flowering stages of development) with genes for resistance to leaf rust and *H. sativum*. The Poza Rica station is used to screen materials for helminthosporium resistance and heat tolerance, Tlaltizapan for heat tolerance, and CIANO for yield and leaf rust. Twelve varieties and advanced lines found to be resistant to *Helminthosporium sativum* are compared to BH1146 (resistant check) and Ciano 79 (susceptible check) in Table 10. These results indicate that in the near future it should be possible to produce tropical wheats with both good yields and disease resistance.

Aluminum Toxicity

Toxic levels of soluble aluminum and manganese are found in the highly leached, acidic oxisols and ultisols of the central African highlands and Brazil. Aluminum toxicity is an especially severe problem in Brazil when the soil pH is below 5.0. Several Brazilian wheat breeding organizations, including the Brazilian Agency for Agricultural Research (EMBRAPA), Passo Fundo; the Federation of Brazilian Wheat and Soya Cooperatives (FECOTRIGO), Cruz Alta; the Organization of Cooperatives of the State of Paraná (OCEPAR), Cascavel; the Agronomy Institute of Paraná (IAPAR), Londrina; and the Centro de Pesquisa Agropecuária do Cerrados (CPAC) EMBRAPA, Brasilia, are cooperating with CIMMYT in the development of aluminum-tolerant wheat varieties.

Crosses are made in Mexico between high-yielding materials from CIMMYT and aluminum-tolerant varieties from Brazil. Progenies are evaluated for aluminum tolerance under field conditions in Brazil. In Mexico, the same progenies are evaluated for aluminum tolerance at the seedling stage in CIMMYT's aluminum toxicity laboratory; at the CIANO and Toluca stations, varieties are evaluated for agronomic characteristics.

This collaboration has resulted in the release of two high-yielding advanced lines, Thornbird and Maringa/Aldan, in Brazil. It is anticipated that the yield potential of aluminum-tolerant materials can be increased to 6 t/ha by combining scattered genes for yield potential with tolerance to high levels of free aluminum and resistance to the most important pathogens encountered in these acid-soil environments.

Table 1. Average yield of 24 varieties and advanced lines in the Elite Yield Trial grown at 25 locations in northern Mexico, 1983-84

Rank	Variety or cross	Yield (kg/ha)	Rank	Variety or cross	Yield (kg/ha)	Rank	Variety or cross	Yield (kg/ha)
1	Seri 82	5286	9	Myna 'S'	4854	17	Ttr 'S'/Bow 'S'	4657
2	Ures 81	5175	10	Buc 'S'/Pvn 'S'	4832	18	Veery No. 10	4633
3	Genaro 81	5130	11	Ciano 79	4800	19	Lira 'S'	4579
4	Pfau 'S'	5020	12	Glennson 81	4786	20	Kea 'S'/Buc 'S'	4531
5	Buc 'S'/Flk 'S'	4975	13	Local check	4782	21	Apache 81	4526
6	Bjy 'S'/Jup	4938	14	Buc 'S'/Bjy 'S'	4761	22	Huasteca 81	4519
7	Guasave 81	4876	15	Delicias 81	4717	23	Mon 'S'/Imu	4501
8	Yavaros 79 (durum)	4857	16	Fln/Acc//Ana	4664	24	Sonoita 81	4456

Table 2. Yields of Seri 82, Genaro 81, and Ures 81 compared with local check variety at 25 locations in northern Mexico, 1983-84

Location	Yield (kg/ha)						
	Local check	Seri 82	% Local check	Genaro 81	% Local check	Ures 81	% Local check
Mexicali, B.C. Norte	7531	8544	113	7463	98	7052	94
Ensenada, B.C. Norte	1457	1260	86	1409	97	996	68
Mexicali, B.C. Norte	7530	8543	113	7462	99	7051	94
Valle Sto. Domingo, B.C. Sur	3402	5164	152	5208	153	5243	154
Delicias, Chihuahua	6109	7453	122	7094	116	7586	124
Casas Grandes, Chihuahua	3292	3777	115	3139	95	3269	99
Matamoros, Coahuila	5229	5824	111	5969	114	6898	132
Zaragoza, Coahuila	2049	2716	132	2850	139	2973	145
Anahuac, Nuevo Leon	4310	5226	121	4545	105	4849	112
General Teran, Nuevo Leon	4290	3816	89	4340	101	4369	102
Ebano, San Luis Potosi	2606	3778	145	2618	100	3619	139
Valle del Fuerte, Sinaloa	5498	6216	113	6641	121	5906	107
Valle de Culiacan, Sinaloa	6056	6111	101	6063	100	6732	111
San Lorenzo, Sinaloa	3517	3975	113	3765	107	3150	89
Valle de Culiacan, Sinaloa	6303	6504	103	6405	102	6632	105
San Lorenzo, Sinaloa	3609	3023	84	3602	100	3092	86
Valle del Yaqui, Sonora	5495	5690	103	5512	100	5746	104
Valle del Yaqui, Sonora	6054	6319	104	5900	97	6117	101
Valle del Yaqui, Sonora	7039	7053	100	6904	98	7320	104
Valle del Yaqui, Sonora	6131	6367	104	6016	98	6119	100
Caborca, Sonora	5447	5374	99	6494	119	6254	115
Valle del Mayo, Sonora	4001	4664	116	4409	110	4334	108
Costa de Hermosillo, Sonora	5991	5705	95	5814	97	6161	103
Rayon, Sonora	5099	5701	112	5513	108	4787	94
Rio Bravo, Tamaulipas	1501	3357	224	3112	207	3109	207
Mean	4781	5286	110	5130	107	5175	108

Table 3. Testing locations for the 19th ISWYN

Location no.	Continent/region	Country	Station	Latitude	Elevation (m)
1	Africa	Egypt	Sakha	030 49'N	0000
2	Africa	Kenya	Njoro	000 00	2165
3	Africa	Nigeria	Kano	012 00'N	1000
4	Africa	Zimbabwe	Harare	017 48'N	1486
5	Asia	Afghanistan	Kabul	034 33'N	1803
6	Asia	Bangladesh	Ishurdi	024 25'N	0008
7	Asia	Japan	Kitami	043 47'N	0196
8	Asia	Nepal	Bhairawa	027 30'N	0105
9	Asia	Pakistan	Lyallpur	031 30'N	0213
10	Asia	Pakistan	Sind	025 02'N	0019
11	Europe	England	Cambridge	052 10'N	0017
12	Europe	Greece	Thessaloniki	040 38'N	0010
13	Europe	Portugal	Elvas	038 54'N	0208
14	Middle East	Israel	Mivhor Farm	031 37'N	0120
15	Middle East	Jordan	Dier Alla	032 12'N	0224
16	North America	Canada	Alberta	053 34'N	0667
17	North America	Canada	Saskatoon	052 10'N	0501
18	North America	Mexico	Guanajuato	020 32'N	1765
19	North America	Mexico	Toluca	019 16'N	2640
20	North America	Mexico	Cd. Obregon	027 20'N	0038
21	North America	USA	South Dakota	044 20'N	0591
22	North America	USA	Minnesota	044 57'N	—
23	North America	USA	Washington	046 02'N	0762
24	Central America	Guatemala	Quetzaltenango	014 52'N	2407
25	South America	Argentina	La Dulce	038 20'S	0072
26	South America	Argentina	Pergamino	033 56'S	0065
27	South America	Argentina	Marcos Juárez	032 42'S	0110
28	South America	Brazil	Dos Cerrados (D.F)	015 45'S	1000
29	South America	Brazil	Passo Fundo	028 16'S	0700
30	South America	Chile	Cautin	038 41'S	0200
31	South America	Chile	Santiago	033 27'S	0629
32	South America	Ecuador	Quito	000 22'S	3058
33	South America	Uruguay	Colonia	034 20'S	0081
34	Africa	Egypt	Sids	029 04'N	—
35	Asia	Taiwan	Taipei	025 02'N	0077
36	Europe	Czechoslovakia	Czechia	049 05'N	—
37	Africa	Malawi	Ntcheu	015 18'S	1615
38	South America	Paraguay	Cacupe	025 24'S	0228
39	South America	Bolivia	Santa Cruz	018 39'S	0386
40	Middle East	Syria	Aleppo (ICARDA)	036 05'N	0282
41	Africa	Tanzania	Iringa	009 17'S	1980
42	Europe	Spain	El Encinal	038 01'N	0200
43	Asia	Pakistan	Islamabad	033 39'N	0683
44	Europe	Norway	Volle Bekk	059 40'N	0090
45	Middle East	Syria	Aleppo (ICARDA)	036 05'N	0282
46	Europe	Italy	Casaccia	043 30'N	0030
47	Oceania	New Zealand	Lincoln	043 38'S	0011
48	Middle East	Saudi Arabia	Al Gassim	026 04'N	—
49	Asia	Pakistan	Pirsbak	034 00'N	0905
50	Europe	Belgium	Gembloux	050 32'N	0170
51	South America	Brazil	Paraná	023 22'S	0585
52	North America	U.S.A.	Texas	031 23'S	0210
53	Middle East	Turkey	Izmir	038 35'N	0020
54	Asia	Thailand	Chiang Mai	018 — N	0314
55	North America	U.S.A.	North Dakota	046 54'N	0237
56	Europe	U.S.S.R.	Odessa	— —	—

Note: Location numbers used in Figures 1-11.

Table 4. Yield comparisons of seven entries in the 19th ISWYN; rankings and mean yields based first on a reduced number of nursery entries and locations, and then on the total number of entries and locations

	Reduced no. entries and locations			Total no. entries and locations		
	Mean yield (kg/ha)	Rank	Yield (% of Seri 82)	Mean yield (kg/ha)	Rank	Yield (% of Seri 82)
Seri 82	4760	1	100	4490	1	100
Ures 81	4620	2	97	4340	2	98
Glennson 81	4560	3	96	4250	3	95
Genaro 81	4480	4	94	4210	4	94
Pavon 76	4350	7	91	4110	7	92
Anza	4110	14	86	3910	12	87
Local check	4000	21	84	3800	20	85
Location mean	3890	23	82	3630	24	81
$LSD_{.05}$	251					

Note: Total number of entries: 50; total number of locations: 63. Yield data unavailable for three entries; data for seven locations discarded because of low location yield or high coefficient of variation.

Table 5. Yield performance of Seri 82, Genaro 81, Pavon 76, and Anza in regions with three or more testing locations in the 19th ISWYN

Region	Location		Mean yield (kg/ha)			
	No.	Mean (kg/ha)	Seri 82	Genaro 81	Pavon 76	Anza
Highlands Central America	3	4688	6151	5796	5360	4668
N.E. Africa-Middle East	13	4640	5737	5367	5272	4774
Indian Subcontinent	6	4111	5274	4573	4643	4473
European Region	7	3970	4762	4093	4129	4317
Northern USA and Canada	6	3560	4144	3987	4223	4105
Southern Cone	10	2988	3558	3730	3507	3058
East Africa	3	1981	2663	2637	2330	1887
Tropical Zone	4	1237	1465	1512	1420	1591
Total	52	—	—	—	—	—
Mean	—	3634	4467	4201	4124	3853

Table 6. Yield performance of advanced bread wheat lines with high yield potential under irrigation compared to Ures 81 at CIANO, 1984

Line	Yield (kg/ha)	Yield (% of Ures 81)
Veery No. 9 CM33027-F-12M-1Y-12M-1Y-2M-0Y	8403	114
PF70354-Yaco 'S' CM67911-4Y-1M-1Y-0Z-6Y-0M	8143	110
PF70354/Yaco 'S' CM67911-4Y-1M-1Y-0Z-2Y-0M	8102	109
Maya/Mon 'S'//Kvz/Trm CM44083-N-2Y-2M-1Y-1M-1Y-1M-0Y	7986	108
Veery 'S' CM33027-F-12M-1Y-1M-1Y-1M-0Y-60B-1PTZ-0Y	7830	106
Lira 'S' CM43903-H-2Y-1M-5Y-1M-1Y-1M-0Y	7234	98
R37/Ghl 121//Kal/Bb/3/Klt 'S' CM64609-6Y-3M-1Y-0M	7220	97
4777*2//FKN/Gb/3/Vee 'S'/4/ Buc 'S'/Pvn 'S' CM66684-B-1M-6Y-1M-2Y-1M-0Y	7196	97
Bow 'S'/Vee 'S' CM64693-3M-1Y-3M-2Y-0M	7113	96

Table 7. Advanced lines of bread wheat with high yield potential compared to Seri 82 under rainfed conditions at El Batan, 1984

Line	Yield (kg/ha)	Yield (% of Seri 82)
Veery 'S' CM33027-F-15M-500Y-0M-7B-0Y	7806	115
Veery 'S' CM33027-F-15M-500Y-0M-110B-0Y	7653	113
Mon 'S'/Imu CM61942-4Y-2M-2Y-2M-2Y-0M	7472	111
Veery 'S' CM33027-F-15M-500Y-0M-11B-0Y-0PTZ	7445	110
Veery 'S' CM33027-F-15M-500Y-0M-66B-0Y	7257	107
Kea 'S' CM21335-C-9Y-3M-1Y-1Y-1Y-0B	7167	106
Mrl 'S'/Buc 'S' CM61949-13Y-1M-2Y-1M-1Y-1M-0Y	7119	105
Veery 'S' CM33027-F-15M-500Y-0M-75B-0Y	7042	104
Au/UP301//Gll/SX/3/Pew 'S'/4/ Mai 'S'/Maya 'S'//Pew 'S' CM67245-C-1M-2Y-1M-7Y-1M-0Y	6987	103
Nac/Vee 'S' CM64224-5Y-1M-1Y-0M	6972	103

(continued)

Table 7. (continued)

Line	Yield (kg/ha)	Yield (% of Seri 82)
Cook/Vee 'S'//Dove 'S'/Vee 'S' CM69279-C-2Y-1M-5Y-2M-0Y	6917	102
Mor 'S'/Mon 'S' CM64736-6Y-2M-3Y-0M	6882	102
Tan 'S'/3/Ti/Tob//Ald 'S' CM64340-4M-1Y-1M-2Y-1M-0Y	6876	102
Kea 'S' CM21335-C-9Y-3M-1Y-1Y-1Y-0B-6KE-0Y	6868	102
Veery 'S' CM33027-F-15M-500Y-0M-89B-0Y	6833	101

Table 8. Advanced lines of bread wheat with high yield potential in highland environments compared to Lira 'S', Toluca, 1984

Line	Yield (kg/ha)	Yield (% of Lira'S')
Kea 'S'/Tow 'S' CM58975-2Y-3M-1Y-12M-3Y-1M-0Y	6121	119
Mon 'S'//Sis 'S'/Can 'S' CM62142-5Y-2M-1Y-1M-5Y-1M-0Y	6047	117
Kal/Bb//Tqfn 'S'/3/Bow 'S' CM68419-6Y-1M-2Y-1M-0Y	6006	117
Dove 'S'/Inia 39B-1Y-1M-0Y	5929	115
Bow 'S'//Yd 'S'/Zz 'S' CM62045-7Y-5M-2Y-1M-1Y-1M-0Y	5878	115
Mon 'S'/Vee 'S' CM64241-3M-1Y-2M-1Y-2M-0Y	5857	114
Veery 'S' CM33027-F-12M-1Y-1M-1Y-1M-0Y-60B-1PTZ-0Y	5784	112
Son64/SS2//Ald 'S'/3/Ti Resel/Coc/4/ IAS58/3/IAS20//Wtc*3/Nar CM67208-B-3M-2Y-2M-3Y-2M-0Y	5769	112
Son64/SS2//Ald 'S'/3/Ti Resel/Coc/4/ IAS58/3/IAS20//Wtc*3/Nar CM67208-B-3M-2Y-2M-1Y-2M-0Y	5722	111
Tan 'S'/3/Ti/Tob//Ald 'S' CM64340-4M-1Y-1M-4Y-3M-0Y	5686	110
Prl 'S'/Toni CM67360-2Y-3M-4Y-1M-0Y	5660	110
Vee 'S'/Buc 'S' CM61950-9Y-3M-1Y-3M-2Y-1M-0Y	5657	110
Mon 'S'//Sis 'S'/Can 'S' CM62142-5Y-3M-1Y-2M-3Y-1M-0Y	42	110
F3.71/Trm SWM5704-10Y-1M-3Y-3M-3Y-0B	5568	108
4777*2//FKN/Gb/3/Vee 'S'/4/ Buc 'S'/Pvn 'S' CM66684-B-1M-6Y-3M-3Y-2M-0Y	5532	107

(continued)

Table 8. (continued)

Line	Yield (kg/ha)	Yield (% of Lira'S')
Yaco 'S'/Jun 'S' CM68459-7Y-2M-2Y-0M	5528	107
R37/Ghl 121//Kal/Bb/3/Jup/Mus 'S' CM64611-4M-1Y-1M-3Y-2M-0Y	5519	107
Mon 'S'/Tow 'S' CM56723-2Y-1Y-4M-2Y-0M	5504	107
Tp//Cno67/No/3/Bb/Cno67/4/ Za75/5/Ttm 'S' CM55914-7Y-2M-1Y-1M-1Y-1M-0Y	5498	107
Tp//Cno67/No/3/Bb/Cno67/4/ Za75/5/Ttm 'S' CM55914-4Y-3M-1Y-2M-3Y-1M-0Y	5489	107
Vee 'S'/Buc 'S' CM61950-9Y-3M-1Y-6M-2Y-1M-0Y	5443	106
Gjo 'S'/Trm//Bda/Huac 'S' CM60767-C-1Y-1M-1Y-1M-1Y-1M-0Y	5439	106

Table 9. Advanced bread wheat lines resistant to septoria leaf blotch compared to Seri 82, Toluca, 1984

Line	Disease score[a]	Days to heading
Kea 'S' CM21335-C-9Y-3M-1Y-1Y-1Y-0B-2KE-0Y	34	83
Sunbird 'S' CM34630-D-3M-3Y-1M-1Y-0M	33	90
Gov/Az//Mus 'S' CM41257-I-8M-3Y-1M-1Y-2M-1Y-0B	43	86
Mrs//Kal/Bb/3/Az CM43429-H-1Y-1M-1Y-4M-1Y-0B	46	85
PF70354/Mus 'S' CM47091-7M-1Y-3F-1Y-0Y	42	89
IAS58/4/Kal/Bb//Cj 'S'/3/Ald 'S' CM50464-12Y-6F-1Y-1Y-8M-5Y-0M	43	86
Vee 'S'/Snb 'S' CM61981-4Y-1M-5Y-2M-0Y	35	90
Mon 'S'/Ald 'S' CM64239-1Y-1M-1Y-0M	34	88
Crt/Ald 'S' II14055-0M-19LD-25LD-1LD-0Y	35	87
RPB709.71/Coc SWM6845-9Y-1Y-1Y-1Y-0Y	33	96
Thornbird 'S' F11915-A-502M-1Y-3F-701Y-4F-700Y	34	86
PF72640/PF7326//PF7065/Ald'S' F11933-D-500M-3Y-1F-704Y-2F-0Y	34	87
Alv110/2*IAS54/6/Tp/4/Tzpp/Sn64// Napo/3/Cno67/5/PF6968 F15183-A-901F-901F-901F-3035F-0Y	43	100
NS879.4	42	102
Seri 82	75	82

[a] Each digit was taken independently on a 0-9 scale. The first digit indicates the height to which the disease had moved on the plant. The second indicates the severity of infection, and was obtained by converting the percentage figure for the area covered by lesions on diseased leaves to a 0-9 scale.

Table 10. Best advanced lines of bread wheat resistant to *Helminthosporium sativum* at Poza Rica and Tlaltizapan, 1983-84

Variety or cross and pedigree	Disease score					
	Poza Rica			Tlaltizapan		
	Leaf (0-9)	% Diseased grain	Severity diseased grain (0-5)	Leaf (0-9)	% Diseased grain	Severity diseased grain (0-5)
Pato(R)/3/Tzpp/Sn64//Nar CM21974-4R-4M-2E-4M-20-0Y-0P-0Y	5	16	1	4	15	1
CI 14227/Trm//Mad 'S' CM47943-V-5M-3Y-1M-1Y-0M	5	30	2	3	30	2
Ald 'S'/IAS58 CM53481-6Y-1Y-4M-1Y-1M-1Y-0M	5	16	1	5	31	3
IAS54/Ald 'S' CM56805-3Y-1Y-4M-1Y-1M-1Y-0M	6	22	2	3	21	2
HI 669/4/Tor 'S'/2*HD832//Tob/3/ Tor 'S'/2* HD832 CM62550-1Y-1M-2Y-1M-3Y-0M	6	28	1	2	28	1
Kea 'S'/4/Kal/Bb//Cj 'S'/3/Ald 'S' CM64617-9M-1Y-1M-1Y-0M	4	18	2	4	34	3
Rrv/WW15/3/Bj 'S'/2*On//Bon/4/Nac CM65202-3M-2Y-3M-4Y-0M	6	14	2	5	30	2
Sn64/SS2//Ald 'S'/3/Ti Resel/Coc/4/ IAS58/3/IAS20//Wte*3/Nar CM67208-B-3M-2Y-2M-1Y-0M	6	36	2	4	22	2
Au/UP301//Gll/SX/3/Pew 'S'/4/ Mai 'S'/Maya 'S'//Pew 'S' CM67245-C-1M-2Y-1M-3Y-0M	5	12	1	5	24	2
Anb 'S'-Yaco 'S' CM67618-2Y-3M-3Y-2M-0Y	6	12	1	3	34	1
PF71131	3	12	1	3	21	1
Vee 'S'-CEP7713 OC3597-4M-2Y-0Z-1Y-0M	4	16	2	3	32	2
BH1146 (resistant check)	5	20	1	4	31	3
Ciano 79 (susceptible check)	9	58	4	8	55	3

Durum Wheat

P. Brajcich, W.H. Pfeiffer, and W.A.J. de Milliano

Introduction

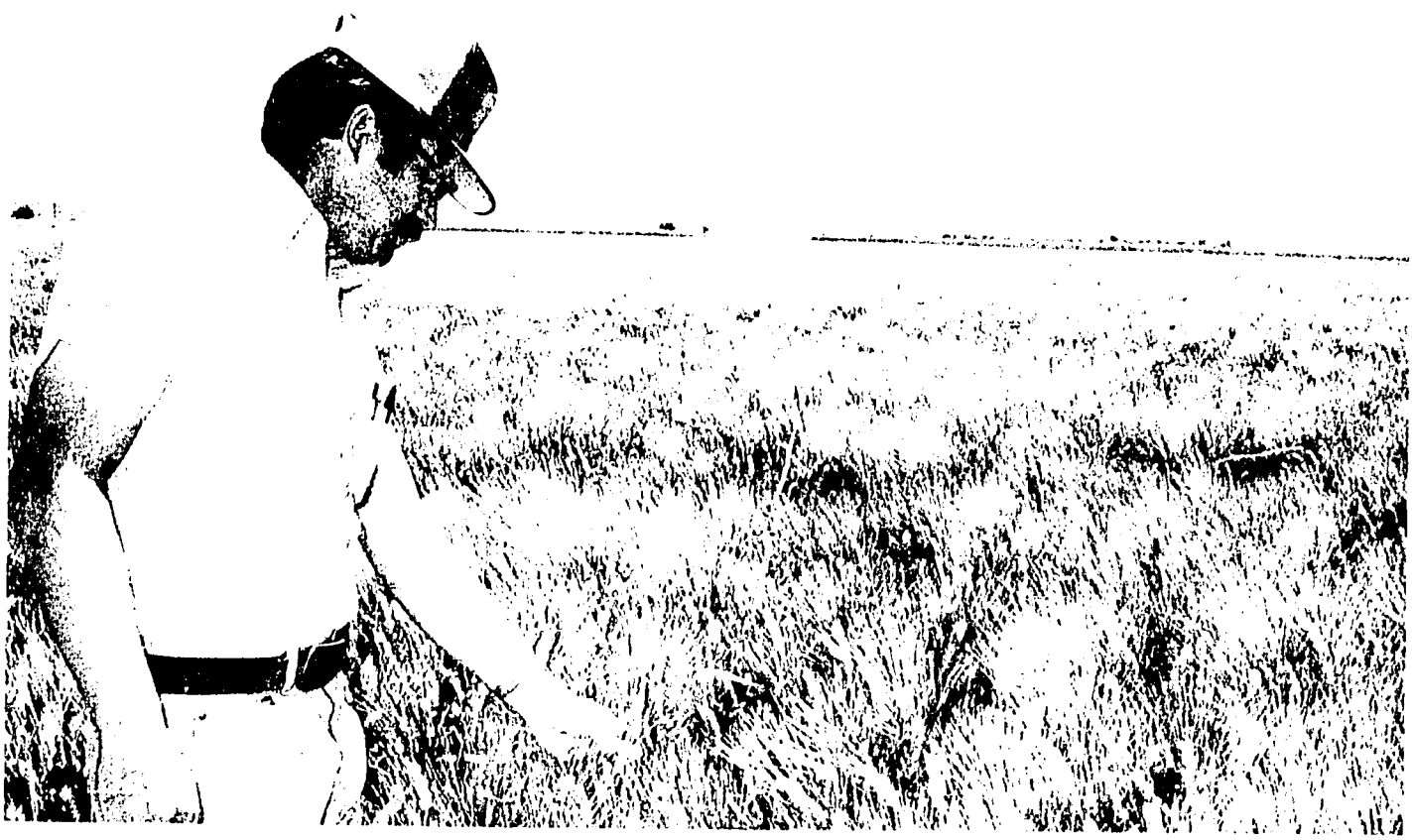
Yield potential of durum wheat has increased steadily since Tehuacan 60, the first improved durum cultivar released in Mexico, was developed. At some testing sites, yields as high as 10 t/ha have now been obtained, and approximately 50 high-yielding durum wheat varieties based on CIMMYT germplasm have been released throughout the world. Durum wheat is presently produced on about 30 million hectares worldwide, 11 million of which are in developing countries.

Since its inception in 1966, CIMMYT's durum wheat program has made considerable progress in germplasm improvement. The program's research initially focused on introducing dwarfing characteristics, overcoming day length sensitivity, reducing sterility, and improving disease resistance. Additional improvements in agronomic type and grain quality have made yields of CIMMYT's best durum materials competitive with yields of bread wheat in highly productive cereal-growing environments throughout the world. For this reason, low yields in developing nations are not attributed to low yield potential, but to poor management, the scarcity of improved technology and inputs, environmental conditions (especially moisture stress), and the use of varieties susceptible to one or more diseases — conditions that frequently prevail in developing countries.

Just as the conditions under which durum wheat is produced vary from the developing to the developed world, the crop's economic role varies as well. In Sub-Saharan and East Africa, the Middle and Near East, the Indian Subcontinent, and the Andean region of South America, durum wheat is a staple food generally used to make products for local consumption, such as chapatis, couscous, bulgur, and mote. Durum wheat is an industrial crop in Canada, the United States, Argentina, Chile, and Southern and Eastern Europe, and consequently must meet high quality standards to be acceptable for use in semolina products. It is essential that breeders' efforts to improve durum wheat should be directed toward improving the performance of the crop in a variety of environments and for a range of economic purposes.

Breeding Program Priorities and Modifications

Currently, the breeding program emphasizes improving yield potential, wide adaptation, and grain quality. Special efforts are made to obtain resistance to disease-causing organisms that attack durum wheat, especially stem rust (*Puccinia graminis*), *Septoria* spp.,



Dr. P. Brajcich, head of the durum wheat breeding program.

Helminthosporium spp., and *Fusarium* spp. Other traits receiving attention are earliness, cold tolerance, stiff straw, and head type.

Several modifications were made in the program in 1984. The first was that segregating germplasm was handled in three groups (medium-tall and tall phenotypes, semidwarf phenotypes, and early maturing phenotypes) to increase the frequency of characteristics within each group. Medium-tall and tall (100-120 cm) phenotypes were grown under reduced irrigation (just one post-seeding irrigation for germination), whereas semidwarf (60-99 cm) phenotypes were grown in the traditional manner under full irrigation (five irrigations). Early maturing (120-126 days) phenotypes were grown as a separate nursery and also received full irrigation.

The second modification, based on recommendations made by the agronomy program, was that 100 kg N/ha were applied to progenitor and segregating materials to allow more efficient selection against yellow berry. Under these same conditions, material was also selected for stiff straw.

The third modification in the program was that the same design was used in durum and bread wheat yield trials conducted at the CIANO experiment station. Each trial consisted of 24 entries, 20 advanced lines, 2 durum wheat checks, 1 bread wheat check, and 1 triticale check, with three replications in a randomized block design. All plots consisted of eight five-meter rows, with a distance of 20 cm between rows. To eliminate any border effect, only four meters of the six central rows were harvested.

Yield Potential

A total of 584 advanced lines of durum wheat with high yield potential were yield tested at CIANO in 1983. Advanced lines performing better than the check variety, Yavaros 79, were placed in international nurseries to be assessed for adaptation and disease resistance in locations around the world. Figure 1 shows the superiority of certain advanced lines over Yavaros 79. The performance of these lines varied from 110% to 133% of Yavaros 79, indicating progress in selection for yield potential in the segregating generations. Many advanced lines, six of which are presented in Table 1, have displayed high yield potential over two seasons: Gan 'S', Wulp 'S', and Mal 'S' yielded 17%-25% more than Yavaros 79.

Table 2 gives the yield, agronomic, and rust data for the last three durum wheat varieties released by INIA in Mexico. A yield trial conducted by the agronomy program indicated that the yield potential of Altar 84, the most recently released Mexican variety, is 8.20 t/ha, a gain in yield of approximately 1.0 t/ha over Mexicali 75 and Yavaros 79 (Figure 2). Furthermore, there was an annual increase of 187 kg/ha in yield potential for the seven durum wheat varieties released in Mexico between 1960 and 1984 (Figure 2), an increase which can be explained in part by greater tillering capacity and spike fertility.

Yield Stability

Although the yield potential of durum wheat is high and expected to increase, cooperators from national cereal improvement programs throughout the world have reported that durum wheat, compared to bread wheat and triticale, has shown low yield stability. Analysis of data from previous International Durum Yield Nurseries (IDYN), Elite Durum Yield Trials (EDYT), and the International Durum Screening Nursery (IDSN) confirms cooperators' reports. These results are partially caused by durum wheat's adaptive disadvantage, which leads to low yields in the humid tropical highlands, and in environments with excessive rainfall, frost, and aluminum toxic soils.

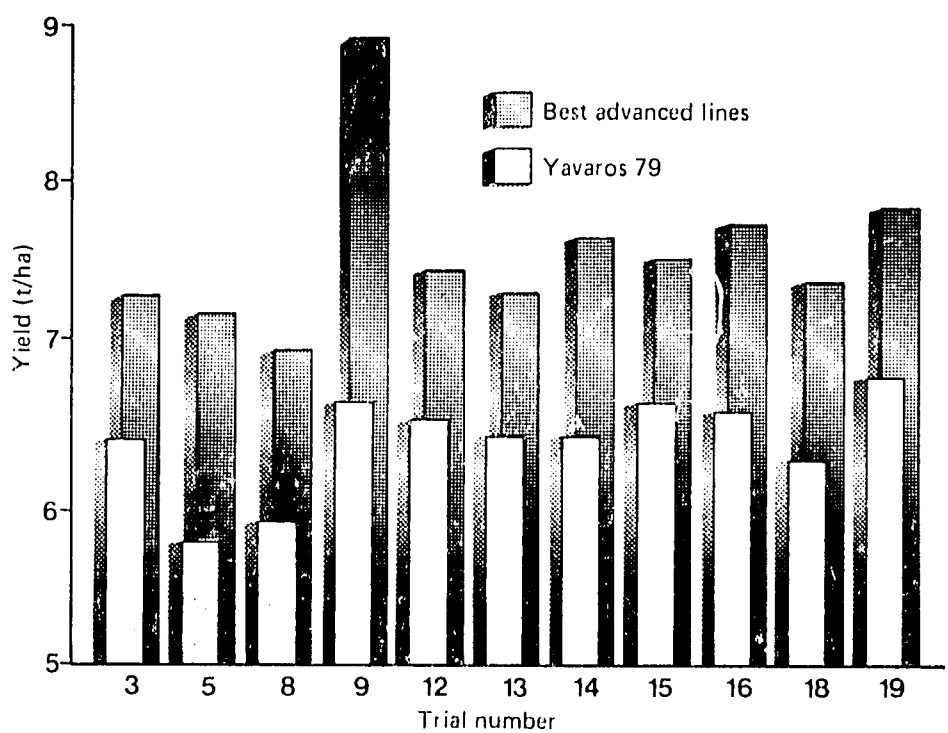


Figure 1. Yield of outstanding advanced lines compared to Yavaros 79, CIANO, 1983-84.

One means of overcoming this disadvantage is to breed for better resistance to foliar diseases and *Fusarium* spp. New durum lines should possess high levels of response to inputs under optimum growing conditions, as well as high input efficiency under such suboptimum conditions as drought or low soil fertility. Figure 3 indicates that the yield of one durum line, Carcomun (Carc 'S'), as indicated by the full circles, is above average (dotted line) in nearly all 14 environments represented in the figure. At yield levels of about 1 t/ha, not much variation between the yields of the entries can be found due to the lack of differentiating factors (i.e., drought, low fertility) in the environments, but the ability of Carc 'S' to exploit extremely fertile conditions is reflected by a high coefficient of regression (1.15). Good yield stability is indicated by the high value of the coefficient of determination (r^2) of 0.98, which is a measure of the closeness of the individual yields (full circles) around the regression line of Carc 'S' (solid line).

Though some progress in achieving better yield stability has been made, further improvements in this characteristic may be achieved through the use of greater variation, the accumulation of genes that promote yield stability, the incorporation of better resistance to foliar diseases, and multilocational selection and testing.

Yield, Test Weight, and 1000-Kernel Weight

One reason for durum wheat's high yield potential is the potential in the yield components, which are assumed to promote yield stability. Table 3 shows the 1000-kernel weight of advanced durum wheat lines having yields up to 22% better than the check, Yavaros 79. Excellent yield performance and 1000-kernel weight generally correspond with good values for test weight and indicate that high yield and high 1000-kernel weight have been achieved without reducing test weight. Average values of about 58 g for 1000-kernel weight and 83 kg/hl for test weight were achieved in the solid-seeded small multiplication plots (PCs) in CIANO. The best lines had 1000-kernel weights of 78 g and test weights of 86 kg/hl, indicating that further progress can be made.

These characteristics will be combined with high tillering capacity and incorporated into larger spikes. Spikelet fertility can also be improved: the spikelet fertility of lines like Carc 'S', with an average of 4.2 grains/spikelet, indicates that good progenitors are available in the program.

Drought Tolerance

Forty-four advanced lines, selected under conditions of full irrigation at CIANO and high rainfall at Toluca, were yield tested under reduced irrigation at CIANO, where approximately 150 mm of water was applied in one post-seeding irrigation for germination and stand establishment. This low water input resulted in serious water stress, as shown by the reduced values for days to maturity and plant height (Table 4). Several outstanding lines were identified, such as Cali 'S', which yielded 27% better than the check variety, Yavaros 79.

Advanced lines selected under reduced irrigation at CIANO were subsequently yield tested at El Batan and Huamantla under rainfed conditions. The seven advanced lines that performed best at each location are listed in Tables 5 and 6. The best advanced lines from the three Mexican locations will be evaluated in additional experiments and included in the crossing program.

Earliness

In certain regions of the world, such as the Indian Subcontinent, earliness ensures greater adaptability of durum wheat in crop rotations. Earliness is also desirable as a mechanism that permits plants to escape disease epidemics and drought stress. Table 7 presents six advanced lines with better yield performance than Yavaros 79 and the check for early maturity, Mexicali 75. Yield potential is not reduced by a decrease in days to maturity of six or seven days; for example, Gan 'S' showed a 33% higher yield than Yavaros 79.

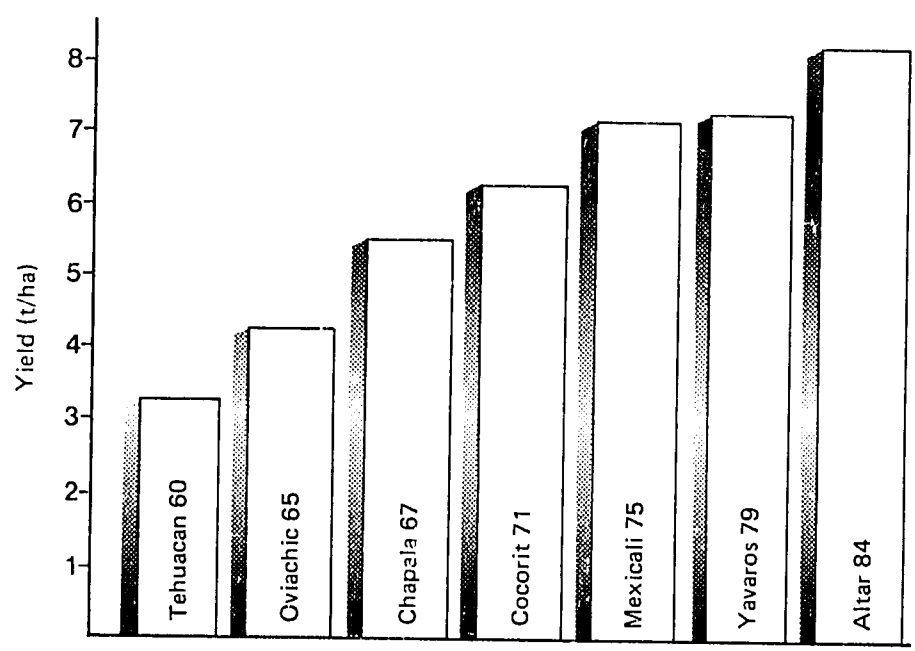


Figure 2. Yield potential of the durum wheat varieties released in Mexico from 1960 to 1984.

Disease Resistance

In 1983-84, durum wheat lines were screened for disease resistance at 10 locations in Mexico (Table 8). Screening for leaf rust (*Puccinia recondita*) resistance was done under natural infection in the tropical lowlands near Poza Rica, and after artificial inoculation in the highlands at El Batan. At CIANO, successful screening for stem rust (*Puccinia graminis* f. s.p *tritici*) resistance took place after artificial inoculation.

Stripe rust—Stripe rust (*Puccinia striiformis*) occurred at several of the screening locations, but the incidence of the disease was not high. Attempts were made to initiate a stripe rust epidemic by needle inoculation and spraying (using inoculum collected from bread wheat and suspended in water), but the effects of the artificial inoculation at Toluca and El Batan were negligible. Though conditions for the development of an epidemic were fairly favorable, only a few durum wheats were affected,

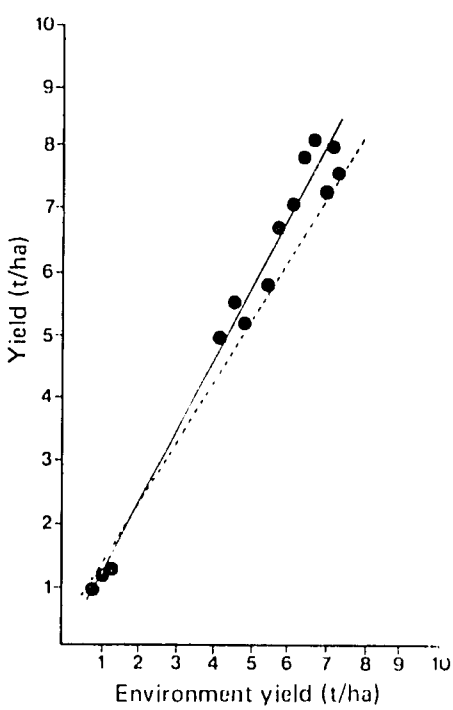


Figure 3. Yield of Carcomun 'S' across the 14 environments of the 14th IDYN (preliminary report). Broken line (- - -) indicates mean of all entries.

indicating that virulence of the local stripe rust races was low on durum wheat.

Leaf and stem rust—Leaf and stem rusts are cereal diseases of great ecomonic importance throughout the world. In Mexico, however, no rust epidemics have occurred in durum wheat in the last 45 years, and at the major Mexican screening locations, artificial epidemics are induced to identify materials resistant to these diseases. Spores are applied by needle inoculation, dusting, and spraying; in 1984, as many as 10 applications were done at CIANO and 18 applications each at El Batan and Toluca.

The leaf rust isolate (frequency 84%, 102 isolates) occurring most often on durum wheat occurred on bread wheat and triticale as well, and had the virulence/avirulence spectrum L1, 2C, 3, 10, 14a, 14b / 2a, 2b, 3ka, Genaro. After inoculation, commercial cultivars in the field at El Batan showed various degrees of adult plant susceptibility: Yavaros 79 was 10MS, Mexicali 75 50MS-S, Cocorit 71 60MS-S, Cando 100MS, and Inrat 69 60S (MS = moderately susceptible; S = susceptible). Virulence on durum wheat was found in nurseries throughout the country, and the isolate mentioned above was also found throughout Mexico. Seedling resistance to the races occurring in Mexico was common under greenhouse conditions and appeared in the field as well.

In 1984, a high incidence of stem rust occurred at CIANO after plant inoculation. Virulence for stem rust occurred on many previously resistant commercial cultivars and lines, including the most commonly grown commercial cultivars, Mexicali 75 and Yavaros 79, but this virulence was found only in nurseries and was not encountered in commercial fields. The two most common isolates, US designation QKL (frequency 46%, 78 isolates) and QTL (frequency 40%, 78 isolates), also occurred on bread wheat and triticale. Genotypes with different degrees of adult plant susceptibility in the field, such as Cocorit 71 (20MS), Mexicali 75 (20MS), Yavaros 79 (30S), and Ardea (90S), all had seedling resistance in the greenhouse. The great increase from 1983 to 1984 in the number of genotypes with adult plant susceptibility occurred in durum wheat only; for this reason, it seems possible that virulence specific to durum wheat has developed.

From Table 9 it can be derived that approximately 50% of the entries of the spring Crossing Block (CB) at CIMMYT were susceptible to stem rust and at least 30% to leaf rust. Complete resistance to stem rust occurred more frequently than complete leaf rust resistance (Table 9), which was rare among CIMMYT Crossing Block entries. In the ICARDA CB, complete resistance to leaf rust appeared to occur more frequently than complete resistance to stem rust. Incomplete resistance to stem rust occurred less often than incomplete resistance to leaf rust, particularly in spring materials. Complete and incomplete resistance to rusts, especially stem rust, can possibly be accumulated using winter-type durum wheats in combination with spring durums.

Helminthosporium screening—Effective screening for *Helminthosporium sativum* occurred at Poza Rica; other *Helminthosporium* species affecting durum wheat in Mexico were *H. giganteum* at Poza Rica and *H. teres* at Lagunilla. At Poza Rica, *H. giganteum* was found particularly on lines with some resistance to *H. sativum*, indicating that screening for resistance to *H. giganteum* under tropical conditions may become necessary, once resistance for *H. sativum* is incorporated.

Septoria and fusarium screening—Successful screening for resistance to *Septoria nodorum* and *S. tritici* was carried out in the highlands at Toluca as well as at Patzcuaro, a cool area with phosphate-deficient soils.

Durum wheat is still susceptible to *Fusarium* spp. Different species, particularly *F. graminearum* and

F. nivale, affected all durum genotypes, though incomplete resistance appeared to occur. High natural incidence of *Fusarium* spp. was found at Toluca, Lagunilla, and Patzcuaro.

Other diseases—Smuts and bunts did not reach a natural level that enabled effective screening. Durums were screened after artificial inoculation for resistance to Karnal bunt (*Tilletia indica*, syn. *Neovossia indica*) and loose smut (*Ustilago tritici*) at CIANO, and most durum wheats had a high level of resistance.

Powdery mildew (*Erysiphe graminis*) occurs in Mexico, but since incidence of the disease is too low for effective screening, CIMMYT relies on its cooperators for obtaining resistant genotypes.

Screening for barley yellow dwarf (BYD) took place at Toluca under partially controlled conditions. Incomplete resistance appeared to occur, but most of the germplasm is susceptible.

Effective screening for resistance to Orange Free State virus and to aphids cannot be done in Mexico. Although the incidence of aphids can become very high, these insects are presently chemically controlled. Screening for resistance to Hessian fly and sawfly is also done outside of Mexico.

Quality

Durum wheat is used for the household production of chapatis, couscous, bulgur, and mote, and for the industrial production of spaghetti, macaroni, and small pastas. All of these products require durum wheat with large, plump, vitreous kernels, high protein and pigment content, and strong to medium-strong gluten.

After harvest, the seed of individual plants is selected for grain type, color, plumpness, and the absence of yellow berry and black point. The F_3 and F_4 generations from CIANO are analyzed for pigment content as well. Only seed with at least 5 ppm of carotenoids is kept. Approximately 20% of the selected plants pass the rigid grain selection procedures. Progenitors and advanced lines are also evaluated for seed type, semolina production, pigment content, protein content, gluten strength, and pasta processing; some high-yielding advanced lines of satisfactory quality are compared to Mexicali 75 and Yavaros 79 in Table 10.

New Releases

During 1983 and 1984, nine durum wheat varieties were released in six countries (Table 11). Seven of these varieties were developed almost entirely by CIMMYT, and the Chilean variety Aromo has 50% CIMMYT germplasm. The varieties Karpasia, Celta, and Sham 1 are identical to or sister lines of the CIMMYT lines Frigate 'S' or Waha 'S'; the Chagual and Helvio varieties are derivates of Yavaros 'S'.

Using a backpack blower, a field assistant inoculates durum wheat for rust by spreading a mixture of rust spores and talcum powder on plants.

Table 1. Yield performance of six advanced lines at CIANO, 1982-83 and 1983-84

Cross and pedigree	Yield 1982-83 (kg/ha)	Yield 1982-83 (% of Yav79)	Yield 1983-84 (kg/ha)	Yield 1983-84 (% of Yav79)
Mal 'S' CD1894-3Y-1Y-8M-1Y-0M	7448	112	7202	122
Bta 'S' CD13557-J-3Y-3M-1Y-0M	7156	112	6995	118
Guil 'S' CM14646-C-1Y-1M-1Y-4AU-0Y	7524	110	7027	119
CH67/Jo 'S'//Tllo 'S'/3/Kif 'S' CD15413-6AL-0Y	7267	114	6987	118
Gan 'S' CD40150-14B-1Y-2M-0Y	7393	117	8882	133
Wulp 'S' CD40509-A-1M-3Y-1M-0Y	7048	118	7733	116

Table 2. Performance of three recently released durum wheat varieties, CIANO, 1983-84

Variety	Yield (t/ha)	Harvest index (%)	Test weight (kg/hl)	1000-kernel weight (g)	Days to maturity	Plant height (cm)	Rust resistance[a] Leaf	Rust resistance[a] Stem	Rust resistance[a] Stripe
Altar 84	8.20	43.7	84.5	64.0	134	95	5M	5MR	0
Yavaros 79	7.18	46.4	83.9	62.0	137	95	5MS	30S	0
Mexicali 75	7.16	49.9	83.2	67.0	130	90	60S	20MS	0

a Stripe rust data from El Batan, 1984
M = Moderate; MR = Moderately resistant; S = Susceptible; MS = Moderately susceptible

Table 3. Performance of seven advanced lines compared to Yavaros 79 at CIANO, 1983-84

Cross and pedigree	Yield (kg/ha)	Yield (% of Yav79)	Test weight (kg/hl)	1000-kernel weight (g)
Mal 'S' CD1894-3Y-1Y-8M-1Y-0M	7202	122	83.0	69.6
Carc 'S' CD24831-A-1Y-3M-1Y-4Y-0M	6954	118	84.2	60.4
Ful'S'/Goo'S'/3/7224/Ward/ /Her'S' CD37972-B-1M-2Y-1M-0Y	57.6 6997		115	84.8
Stn 'S' CD38397-B-1M-3Y-2M-1Y-0M	6699	110	83.7	58.2
Wulp 'S' CD40509-A-1M-3Y-1M-0Y	7733	116	84.2	68.8
Teho 'S' CD40553-D-3M-2Y-1M-2Y-0M	7406	111	85.1	61.4
Ruff 'S'/Fg 'S'//Yav79 CD42490-1Y-1M-2Y-2M-0Y	6906	108	85.6	63.4

Note: 150 mm water applied after seeding.

Table 4. Performance of five advanced lines observed under reduced irrigation at CIANO, 1983-84

Cross and pedigree	Yield (kg/ha)	Yield (% of Yav79)	Plant height (cm)	Days to maturity
Cali 'S' CD34934-D-3Y-4M-1Y-1M-1Y-0M	3715	127	105	110
CH67/Tern 'S'//Yav 'S' CD43837-B-1Y-1M-1Y-0M	2988	110	95	105
68111/Rgb//Ward Resel/3/Stil 'S' CD39312-8B-1Y-2M-2Y-1M-0Y	2884	107	100	110
Tern 'S' CM17835-B-2M-6Y-0M	3007	111	100	103
Qfn/Gll 'S'//Gta 'S'/3/Ibis 'S'/4/ Mal 'S'/5/USDA573/Aa 'S' CD25288-A-3Y-2M-1Y-0Y	2885	107	85	105

Table 5. Yield of seven advanced lines at El Batan, 1984

Variety or cross and pedigree	Yield (kg/ha)	Yield (% of Mexi75)	Yield (% of Yav79)
6993/Ward7463//74110/3/ LdsMut/Teal 'S' CD49030-3Y-1M-1Y-3M-0Y	6063	94	125
Altar 84	6021	107	149
Yav 'S'/Shwa 'S'//Ren 'S' CD42798-14Y-1M-1Y-0M	5930	106	148
Yav79/4/Qfn/3/61.130/Lds// Gll 'S'/5/Kol 'S' CD53151-G-1M-2Y-1M-0Y	5912	101	128
6973/Ward7463//74110/3/ LdsMut/Teal 'S' CD49030-3Y-1M-1Y-2M-0Y	5865	91	121
Qfn/Gll 'S'//Gta 'S'/3/ Ibis 'S'/4/Mal 'S'/5/ USDA573/SBA81 CD25288-A-3Y-2M-1Y-0Y	5771	103	143
Mexi75/Vic//Yav79 CD52349-3M-2Y-3M-0Y	5641	96	122

Table 6. Yield of seven advanced lines at Huamantla, 1984

Cross and pedigree	Yield (kg/ha)	Yield (% of Mexi75)	Yield (% of Yav79)
Memo 'S'/Albe 'S'//Cta 'S'/3/ Gu 'S'/Mexi 'S'//Rok 'S' CD54062-D-1M-1Y-2M-0Y	4254	189	213
Tc60/Cit 'S'//Rabi 'S'/Rok 'S'/4/ Tern 'S'/3/Ibis 'S'/PH158// Gta 'S'/Ibis 'S' CD48495-C-1M-4Y-2M-1Y-1M-0Y	4122	162	164
Cit71/MO6A58//Cit 'S' CMH78A.1108-1B-1Y-1B-1Y-3B-0Y	4071	133	202
Rok 'S' CD1895-12Y-0Y-2E-3B-0Y	3990	157	159
Frig 'S'/Ren 'S'//Ruff 'S'/Gta 'S'/3/ Ren 'S'/4/Apo 'S' CD49292-1Y-2M-1Y-1M-0Y	3859	152	153
Gediz 'S'/Cit71 CD32575-1B-1Y-1M-0Y	3744	148	149
Ward/Yav79 CD52820-5B-1Y-1M-0Y	3520	125	102

Table 7. Yield and days to maturity of six advanced lines compared to Mexicali 75 and Yavaros 79 at CIANO, 1983-84

Variety or cross and pedigree	Yield (kg/ha)	Yield (% of Yav79)	Yield (% of Mex75)	Days to maturity
Gan 'S' CD40150-14B-1Y-2M-0Y	8882	133	138	125
USDA573//Cit 'S'/Plc 'S'/3/ Gs 'S'/Tc60//Mexi 'S' CD27393-D-2M-2Y-1Y-1M-0Y	6939	106	111	125
Hui 'S' CD27137-1M-1Y-4Y-0M	7122	109	114	125
Yav 'S'/Mexi75 CD46262-7B-2Y-1M-0Y	7483	113	116	124
Mtte 'S'/Tad 'S'/4/Kif 'S'/ /Rss/BD1419/3/Mexi 'S'/CP CD48250-C-2M-2Y-1M-0Y	6262	108	110	125
Cali 'S' CD34934-I-3Y-1M-2Y-1M-1Y-2M-0Y	6826	102	109	125
Mexicali 75				126
Yavaros 79				131

Table 8. Incidence of aphids and major diseases in durum wheat at different locations in Mexico, 1983-84

Location	Cropping period	Rust			*Helminthosporium* spp.	*Septoria* spp.	*Fusarium* spp.
		Leaf	Stem	Stripe			
Cd.Obregon	Nov-May	M[a]	H	A	L	A	L
Los Mochis	Dec-May	L	A	A	L	A	A
Hermosillo	Dec-May	A	A	A	—	A	A
Rio Bravo	Jan-May	M	L	A	L	A	A
Poza Rica	Nov-Mar	H	L	A	H	A	M
Toluca	Nov-Jul	L	L	L	L	H	M
Toluca	May-Oct	L	L	L	L	H	H
El Batan	May-Oct	H	M	M	L	L	M
Lagunilla	May-Oct	L	L	L	M	A	H
Huamantla	May-Oct	L	L	M	L	L	L
Patzcuaro	Nov-Mar	A	A	L	L	H	H

Location	Cropping period	Smuts	Bunts	Mildew	Bacteria	BYDV[b]	OFSV[c]	Aphids
Cd.Obregon	Nov-May	A	L	A	L	L	A	M
Los Mochis	Dec-May	A	A	A	L	—	A	M
Hermosillo	Dec-May	A	A	A	L	—	—	L
Rio Bravo	Jan-May	L	A	L	L	L	—	L
Poza Rica	Nov-Mar	A	A	M	L	A	L	L
Toluca	Nov-Jul	A	A	A	L	H	L	L
Toluca	May-Oct	A	A	A	M	M	L	H
El Batan	May-Oct	L	A	L	M	M	M	H
Lagunilla	May-Oct	A	A	A	L	L	L	L
Huamantla	May-Oct	A	A	A	M	L	H	M
Patzcuaro	Nov-Mar	A	A	A	L	L	A	L

[a] H = High, M = Moderate, L = Low, A = Absent, — = No information

[b] BYDV = Barley yellow dwarf virus

[c] OFSV = Orange Free State virus

Table 9. Frequency of stem and leaf rust resistance in entries in durum wheat nurseries at CIANO, April, 1984

Nursery	No. of entries	Complete resistance (severity = 0%)	Incomplete resistance (severity between trace and 20%)
CB Spring CIMMYT	340		
Stem rust		.14	.36
Leaf rust		.04	.64
CB Winter CIMMYT	112		
Stem rust		.18	.53
Leaf rust		.03	.63
CB Spring ICARDA	155		
Stem rust		.07	.33
Leaf rust		.13	.69

Table 10. Quality characteristics of seven advanced lines compared to Mexicali 75 and Yavaros 79, 1984-85

Variety or cross and pedigree	Test weight (kg/hl)	Protein in semolina (%)	Pigment (ppm)	Yellow berry (%)
Auk 'S' CD25126-A-1Y-3M-1Y-1Y-0M	85.2	10.3	7.2	4.4
USDA595/Dack 'S'//Rok 'S' CD27402-D-2M-1Y-4Y-0M	83.4	11.4	5.7	1.0
Medium/Kif 'S'//Sapi 'S' CD27945-5B-1Y-2Y-0M	83.0	11.3	6.2	0.8
Aix 'S' CD31119-B-1Y-1Y-2M-2Y-0M	83.9	12.0	5.6	0.6
Stn 'S' CD38397-B-1M-4Y-4M-2Y-1M-0Y	84.3	11.5	5.4	1.6
7175.71110/3/Magh72/Fg 'S'// Cr 'S'/USA2299/4/ Mexi'S'/Gta 'S' CD44016-A-3Y-1M-1Y-1M-0Y	83.1	10.2	7.4	1.6
Cndo/4/Jo 'S'/Cr'S'//USA1679/3/ Jo 'S'/Cr 'S'/5/Mal 'S' CD47499-C-1M-1Y-1M-1Y-0M	84.1	11.2	6.6	0.8
Yavaros 79	83.9	8.8	4.4	15.0
Mexicali 75	83.2	8.8	5.4	33.8

Note: All entries have strong gluten except Yavaros 79, which has medium-strong gluten.

Table 11. New durum wheat varieties released around the world, 1983-84

Variety	Cross and pedigree	Country
Aromo INIA	Stw63/Gll 'S'//Aa 'S' A13979-3P-2P-3P	Chile
Chagual INIA	21563/Aa 'S'//Fg 'S' CM9799-126M-1M-5Y-0M	Chile
Karpasia	Plc 'S'/Ruff 'S'//Gta 'S'/Rtte CM17904-B-3M-1Y-1Y	Cyprus
Altar 84	Ruff 'S'/Fg 'S'//Mexi75/3/Shwa 'S' CD22344-A-8M-1Y-1M-1Y-2Y-1M-0Y	Mexico
Acsad 65	GdoVZ469/3/Jo 'S'//61.130/Lds CM470-1M-3Y-0M	Morocco
Marzak	BD113	Morocco
Celta	Plc 'S'/Ruff 'S'//Gta 'S'/Rtte CM7904-B-3M-1Y-0M	Portugal
Helvio	21563/Aa 'S'//Fg 'S' CM9799-126M-5Y-0Y	Portugal
Sham 1	Plc'S'/Ruff 'S'//Gta 'S'/Rtte CM17904-B-3M-1Y-1Y-OSK	Syria

Triticale

G. Varughese, E.E. Saari, and O. Abdalla

Introduction

Triticale tends to perform better than wheat in acid soils, at high elevations in the tropics, and in semiarid environments, all of which are important target areas for the varietal improvement work at CIMMYT.

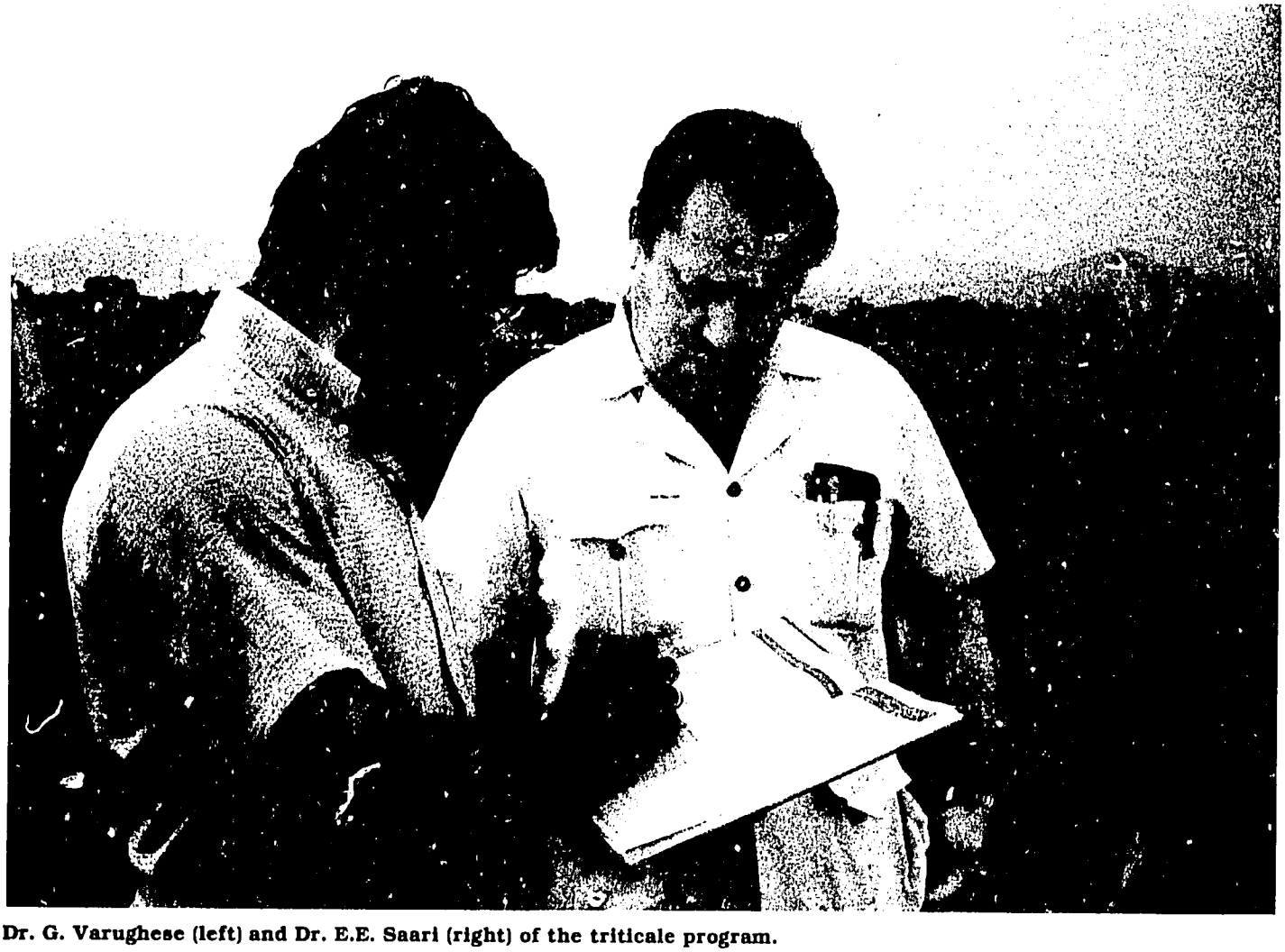
The program's primary objective is to produce widely adapted germplasm with the capacity for high yields. This objective is accomplished by making numerous crosses among various forms of primary and secondary triticales and hexaploid wheat. Intensive selection pressure is applied for yield, test weight, and resistance to diseases found in Mexico. Such characters as sprouting resistance, tolerance to drought and to acid soils, high milling and baking quality, and earliness are also considered important factors in the improvement process.

Triticale is a major small grain crop in only a few countries, but its importance is increasing (Table 1). In 1978, only three spring triticales had been released in the world. Today there are 56 spring-habit triticale varieties released in 18 different countries. Many of these are new releases still under seed multiplication, but once these varieties come into production the area devoted to the cultivation of this crop should expand rapidly. CIMMYT anticipates that with this expansion, there will be an increase in the number, incidence, and severity of diseases reported.

Expansion of the Germplasm Base

A dynamic crossing program to combine yield, test weight, adaptation, stability under environmental stresses, and resistance to diseases is essential to the success of a plant breeding program. During 1984, 6301 crosses were made (Table 2).

To develop varieties that satisfy the program's primary objectives, it is essential to expand the germplasm base through the introduction of new genetic variability. CIMMYT is working toward this goal in several ways:



Dr. G. Varughese (left) and Dr. E.E. Saari (right) of the triticale program.

- By producing new primary triticales;
- By making direct crosses between triticales and bread wheats, and then backcrossing to triticales;
- By crossing spring triticales with winter triticales, and then backcrossing to the spring types; and
- By introducing primary and secondary triticales from various programs around the world.

Production of primary triticales—Inadequate variability in resistance to the new stem rust races in Australia demonstrated the need to expand the triticale germplasm base rapidly. With this necessity in mind, an intensive effort was made to produce primary triticales using the best durum and bread wheats in combination with the ryes available in the program. A total of 412 crosses were made; of these, 209 were successful and 445 hybrid plants were obtained. These plants are presently undergoing the chromosome doubling process.

Successful hybrid plants were obtained in 56% of the crosses between durum wheats and rye. However, when two different rye varieties were used as pollen parents with each durum variety, the percentage of success increased to 87% (Table 3). The total number of crosses made with two pollen parents is rather small, but preliminary evidence suggests that to increase the number of successful new primary triticales the rye pollen source needs to be diversified. The factor(s) for incompatibility of some durums and rye parents have not been established.

Introgression of genes from bread wheat—Most of the crosses between triticale and bread wheat produce some viable seed. Although the hybrid is highly sterile on the pollen side, there is greater ovule viability. These hybrids can be successfully backcrossed to triticale, all the complements of which can be reconstituted. Crosses of this kind allow for the modification of the A and B genomes, thereby enhancing variability. During 1983-84, 226 hybrids were obtained and 92 of them were successfully backcrossed to triticale.

Variability from winter triticale—Another way to introduce variability is through the use of winter triticales. Some of the best ryes in the world are winter types. Since it is assumed that some of the good winter-habit triticales carry the desirable characteristics of these ryes, they are used in the crossing program. Such crosses are made primarily to introduce variability to the R genome and at the same time to modify the A and B genomes. A total of 127 winter x spring crosses were made during 1983-84. In triticale, as in wheat, the spring character is generally dominant over the winter habit. The most promising F_1s were backcrossed to the best available spring triticales, and the program is presently evaluating 241 crosses of this type.

Evaluation of material from collaborators—A total of 186 lines and varieties received from collaborators in various national programs and universities are under evaluation. The best of these are used in the crossing program to further expand the germplasm base.

Breeding Objectives

Yield—Data from trials carried out in Mexico, national programs, and international nurseries are used to achieve the program's principal objective of attaining high and stable yields across environments. During the 1983-84 cycle, 910 advanced lines were evaluated in yield trials. Varieties with proven potential, such as Cananea, Caborca, Alamos, and Eronga, were used as the check varieties. One hundred and twenty-one advanced lines yielded better than the check variety, and seventy-six of those lines also had better tests weights than the best check. Results of the best 25 lines are reported in Table 4. The Sixteenth International Triticale Screening Nursery (ITSN), consisting of 250 entries, was constituted on the basis of these results.

Adaptation—The 16th ITSN was planted as a yield trial during the 1984 summer cycle in Toluca, El Batan, and Huamantla. Lines showing stable productivity across these three locations and CIANO are reported in Table 5.

Test weight—Test weight influences consumer acceptance of triticale as food for human consumption, and affects flour yield as well. At present, it is not difficult to obtain acceptable test weights under good crop production conditions at CIANO. Extreme selection pressure is exercised at this location, and no advanced line with a hectoliter weight below 73 kg/hl is kept unless it has some special attributes. Obtaining good test weight under difficult growing conditions is still a problem, and CIMMYT has started applying heavy selection pressure for this character during the summer cycle at Toluca and El Batan. Table 6 lists some of the best advanced lines showing stable test weights across four different environments.

Maturity

The development and distribution of germplasm is CIMMYT's primary function. The Center collaborates with almost all the triticale programs around the world, and because these programs are located in diverse agroclimatic zones, CIMMYT selects for many maturity classes. The 910 advanced lines grown at CIANO during 1983-84 were grouped into various maturity classes (see Figure 1). The predominant group comprises a medium number of days to flowering and to maturation. The two groups with the lowest frequency were 1) late to flower and early to mature, and 2) early to flower and late to mature. Correlations between days to flowering and days to maturity in all 35 trials were highly positive, ranging from 0.491 to 0.866.

Table 7 is a comparison of days to flowering and days to maturity between bread wheat and triticale. Twenty-four early triticales were compared to two early bread wheats (Inia 66 and Sonalika). The triticales

generally flowered one week earlier than the bread wheats but matured at about the same time as the wheats. It was found that the early triticales in this study behaved more like Inia 66 than Sonalika; the two wheat varieties and the early triticale all matured in about 115 days, but Sonalika flowered about 11 days earlier than the others.

The triticale program at CIMMYT uses a modified bulk breeding method for crop improvement. Details of this methodology were discussed in previous reports. However, the pedigree method is still used when special traits are being sought. Earliness is one such trait, and selections are made from all the F_2 populations that segregate for this character. These selections are then managed all the way through the development process using the pedigree system. Fifty-six advanced lines were tested for earliness and yield during the 1983-84 cycle. The three best lines were comparable to Sonalika in maturity and are listed in Table 8.

A strong positive correlation was found between grain filling per day (antithesis to maturity) and yield. The correlations in 35 trials ranged from 0.623 to 0.897. Lines having more than 200 kg/day grain-filling capacity are reported in Table 9. In addition to excellent grain-filling capacity, almost all of these lines had excellent yield and test weight. The grain-filling period across all the trials and lines ranged from 33 to 61 days, and lines having good grain-filling capacity ranged from 34 to 47 days. It is also worth noting that these lines fall into all of the maturity classes.

Drought Tolerance

Drought tolerance is one of the performance characteristics expected of triticale, because of the presence of the rye component. Selection pressure under droughty conditions has not been practiced systematically so far, but the program hopes to give higher priority to drought tolerance in the future. This will be done in collaboration with ICARDA and by using selected sites in Mexico.

Four yield trials were planted at CIANO under reduced irrigation in 1984. One irrigation was applied at the time of planting and the second at the time of flowering. The same trials were repeated under full irrigation. The correlations for yield varied in these two sets of trials from 0.102 to 0.382. Lines that gave good performance under both conditions are listed in Table 10.

A selection from the cross Civet was included as a check variety in all these trials because of its known ability to perform well under dryland and irrigated conditions. In all trials, the check variety performed extremely well under both limited and full irrigation.

Preharvest Sprouting

Preharvest sprouting is a problem in many of the target areas for triticale. A program to select for sprouting resistance was initiated in 1982 by subjecting more than 200 segregating populations to laboratory conditions to induce sprouting. The best 25 populations were selected for planting at Toluca in January 1983, so that the crop would come to maturity during the peak of the rainy season. Based on the 1983 results, 13 populations were discarded. The remaining 12 populations were subjected to another selection cycle at Toluca in 1984. After the crop matured, it was exposed to rain in the field for one additional month. Forty spikes were selected at random from each of these populations. These spikes were individually threshed and counts were made to estimate sprouting percentages, which ranged from about 11% to 42% (Table 11). All the populations are being carried forward for one more cycle of selection under the same conditions. At the end of that cycle, individual plant selections will be made to isolate pure lines.

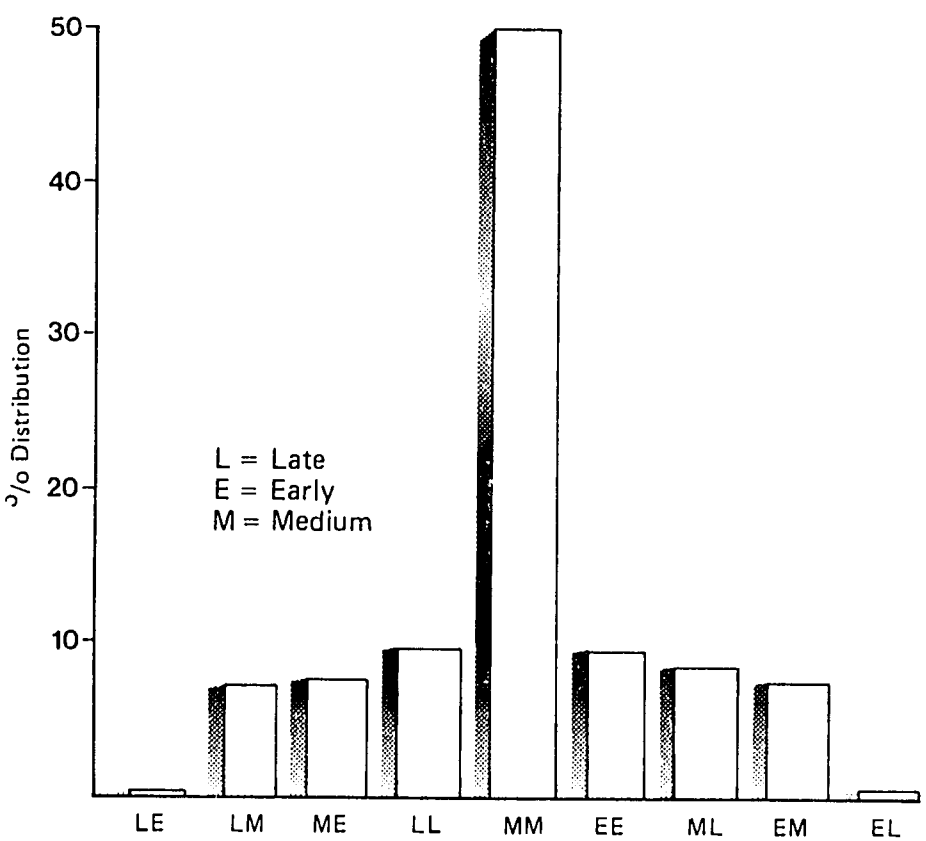


Figure 1. Percentage distribution of maturity classes of 910 triticale advanced lines, CIANO, 1983-84 (the first letter refers to flowering and the second to maturity).

A good quantity of parental material was also subjected to the same treatment. Results for 17 lines that underwent two cycles of sprouting stress are reported in Table 12. Sprouting percentage was estimated in the same manner as for the segregating populations. The lines ranged from about 1.5% to 47% sprouting. Pika 'S', showing only 1.5% sprouting, was outstanding, followed by Mula 'S' and Llama-F_3 Spy x Bgl.

A number of lines with good sprouting resistance have been identified in Brazil. Many crosses using these lines and those identified at CIMMYT will be made, and, to further improve the sprouting resistance of triticale, these crosses will be subjected to the same kind of screening described above.

Dwarf Complete Triticales

Triticale germplasm handled at CIMMYT is divided into two classes: substituted types and complete types. These two types can generally be identified in the field based on their plant and spike morphology. Complete types tend to be taller, later, and have a long lax spike, whereas substituted types are shorter with a compact spike. Until recently, the complete types were very tall, but a few years ago an effort was made to look for shorter types among the complete types. The breeding lines Beaguelita, Ram, and Giraff were the first of this group to be identified. A list of the most promising semidwarf complete triticales is provided in Table 13. These lines are 10-25 cm shorter than Beagle, a widely adapted complete triticale; they typically have a height range of 110-125 cm, which seems to be more useful than the height of Beagle or Eronga. The breeding program is making extensive use of these lines to reduce the height of the complete triticales to a more acceptable level.

Tolerance to Acid Soils

Triticale tolerates acid soil conditions much better than does wheat. Laboratory tests indicate that a much higher level of acidity can be used when screening triticale for acid soil tolerance. A number of segregating populations were subjected to laboratory screening a year ago and selections are now in the F_4 stage. Beginning this year, a set of all segregating populations will be planted at Patzcuaro, where the soils are acidic. Subjecting populations to these selection conditions should enhance triticale's inherent potential to perform well in acid soils.

Pre-harvest sprouting limits triticale yields in regions where moisture levels are high near harvest, as in East Africa and Brazil.

[1] Estimate
[2] CIMMYT survey
S = Spring type
W = Winter type

Table 1. World distribution of triticale

Country	Growth habit	Area (ha)
Argentina[1]	S	10,000
Australia[2]	S	160,000
Austria	W	--
Belgium[1]	W	400
Brazil[1]	S	1,500
Bulgaria[1]	W	10,000
Canada[2]	S + W	6,500
Chile	S	—
China[1]	W	25,000
Federal Republic of Germany[2]	W	7,000
France[2]	W + S	120,000
Greece	S	—
Hungary[1]	W	5,000
India[2]	S	500
Italy[1]	S	15,000
Kenya	S	—
Luxemburg[1]	W	400
Madagascar	S	—
Mexico[1]	S	8,000
Netherlands[2]	W	1,000
New Zealand[2]	W + S	150
Pakistan	S	—
Poland[2]	W	40,000
Portugal[2]	S	7,000
South Africa[1]	W + S	15,000
Spain[1]	S	9,000
Switzerland[2]	W	5,000
Tanzania[2]	S	380
Tunisia[2]	S	5,000
UK[2]	W	10,000
USA[1]	W + S	60,000
USSR[1]	W	250,000
Total		771,830

Table 2. Crosses realized during 1984

Type of cross	Number
Single crosses	3852
Three way crosses	1351
Winter x spring crosses	127
Winter x spring backcrossed to spring	241
Triticale x wheat crosses	226
Triticale x wheat backcrossed to triticale	92
Crosses to produce primary triticales	412
Total crosses	6301

Table 3. Summary data on production of primary triticales

	Hexaploid	Octaploid
Number of florets pollinated	14070	7801
Number of florets with seed set	4906	469
Percentage of seed set	34.87	6.01
Number of seeds with embryos developed	2943	371
Percentage of seeds with embryo	59.99	79.11
Number of plants obtained	316	129
Percentage of embryos developing into plants	10.74	34.77
Total number of hybrid crosses made (durum x rye)	258	154
Number of successful combinations	144	65
Percentage of successful combinations	55.81	42.21
Number of durum varieties crossed with two different rye pollen parents	23	
Number of durum varieties producing hybrids	20	
Percentage of successful crosses	86.96	
Number of durum varieties crossed with only one rye pollen parent	212	
Number of durum varieties producing hybrids	113	
Percentage of successful crosses	56.6	

Table 4. Triticale advanced lines with high yields and acceptable test weights, CIANO, 1983-84

Line	Yield (kg/ha)	Maturity class[a]	Grain filling (g/day)	Yield as percentage of best check	Test weight (kg/hl)
Faro 'S' B-2264-0Y-103	7677	LL	1.83	115.8	75.1
Ram 'S'-Eronga83 CT-1252-3Y-3M-0Y	8375	LM	1.99	112.7	72.0
Grizzly 'S' x Ptr 'S'-Castor 'S' X-64399-4Y-1M-4Y-0M	8063	MM	1.92	108.6	77.3
Eda 'S' x M_2A-Za75 X-61039-6M-1Y-1M-1Y-0M	8848	MM	2.11	109.1	75.0
Cml 'S' x Cno-Gallo/Bta 'S' X-60446-9M-1Y-2M-1Y-1Y-0B	8418	MM	1.87	114.9	70.5
Ptr 'S'-Castor 'S' x Bta 'S' X-60839-3M-1Y-3M-3Y-1Y-0B	7521	MM	1.79	107.1	73.7
FS381-FS477 x Toro 'S'/Tge 'S' X-61270-B-1M-2Y-1M-1Y-1Y-0B	7589	MM	1.47	108.0	76.0
Mula 'S'-Ram 'S' X-52913-60Y-2M-1Y-1M-1Y-1Y-0B	8159	LM	2.09	108.5	72.0
Gnu 'S' B-6912-078-27Y-1Y-0M	8650	MM	1.68	107.1	75.2
Stier 'S' B-6712-159-2Y-2Y-0M	8236	LM	1.87	102.0	76.5
Uron 'S' B-6811-246-4Y-2Y-0M	8381	MM	1.86	103.8	76.3
Tatu 'S' B-5644-778-2Y-3Y-0M	8489	ME	2.12	105.1	76.2
PFT 7717 x M_2A-Bn 'S'/Bok 'S'-Lmg 'S' CT-5136-H-2M-3Y-0M	8681	ME	2.02	107.5	77.3

(continued)

Table 4 (continued)

Line	Yield (kg/ha)	Maturity class[a]	Grain filling (g/day)	Yield as percentage of best check	Test weight (kg/hl)
Tapir 'S'-Bok 'S' CT-1818-5Y-1M-1Y-0M	8234	EE	1.87	105.7	75.8
Tapir 'S'-Boa 'S' CT-1830-4Y-3M-3Y-0M	9676	MM	2.06	111.5	77.2
Tapir 'S'(E3-Arm 'S' x M2A/Adx 'S') CT-1829-9Y-2M-2Y-0M	9588	LL	2.08	110.4	75.8
Ye75 x IRA-Cml 'S'/Tge 'S' X-66340-6Y-1M-2Y-0M	8209	MM	1.87	106.2	77.7
Kodiak 'S' X-63181-C-1Y-6M-15Y-5Y-0M	7989	EM	2.10	107.9	77.3
Pol 'S' x Rm 'S'-Ptr 'S' X-64675-3M-4Y-4M-2Y-0M	7730	MM	1.68	109.4	77.0
Caborca 79 x Ptr 'S'-Castor 'S' X-63844-8M-1Y-4M-2Y-0M	7562	ML	1.68	107.0	73.9
Pnd 'S'-Castor 'S' x Spd 'S' X-64422-3M-6Y-3M-1Y-0M	7530	LL	1.57	106.6	75.0
Rm 'S' x Kal-Bb/Spd 'S' X-66160-1M-3Y-2M-2Y-0M	7755	MM	1.58	104.0	75.7
Pnd 'S'-Msf 'S' x Tge 'S' X-66216-4M-2Y-2M-2Y-0M	7642	MM	1.59	107.2	77.2
Kodiak 'S' X-63181-B-1Y-2M-2Y-3Y-0M	7431	LL	1.81	107.3	73.7
Alamos 83 x F6.74-Trm CT-1352-2Y-1Y-0M	7454	LL	1.73	107.6	74.4

[a] LL = Late heading, late maturity
MM = Medium heading, medium maturity
EE = Early heading, early maturity
LM = Late heading, medium maturity
ME = Medium heading, early maturity
EM = Early heading, medium maturity
ML = Medium heading, late maturity

Table 5. Entries from the 16th ITSN that showed yield stability across four environments in Mexico, 1984

16th ITSN entry no.	Variety or cross and pedigree	CIANO[a] Yield (kg/ha)	CIANO[a] Test weight (kg/hl)	El Batan Yield (kg/ha)	El Batan Test weight (kg/hl)	Toluca Yield (kg/ha)	Toluca Test weight (kg/hl)	Huamantla Yield (kg/ha)	Huamantla Test weight (kg/hl)
5	Civet 'S'.1 B-2658	—	72.70	5583	71.45	7076	64.05	4355	65.30
10	Civet 'S'.2 B-2658	—	—	5826	72.85	6076	62.80	5261	67.70
46	Gnu 'S' B-6912-062-11Y-1Y-0M	7588	75.50	5681	71.15	6375	67.90	4950	67.10
47	Gnu 'S' B-6912-071-20Y-1Y-0M	8596	—	5667	72.75	5909	59.40	4658	66.55
49	Gnu 'S' B-6912-073-22Y-3Y-0M	8650	75.20	6215	73.65	5500	68.85	5058	66.95
59	Uron 'S' B-6811-246-4Y-2Y-0M	8381	76.30	5639	73.70	6937	67.70	4061	65.55
63	Pipit 'S'-II58.57 x UC90(Mus 'S'-MA/ Drira-IA x Bgl 'S') B-5576-447-1Y-1Y-0M	8050	76.70	6806	73.10	6666	63.05	3155	65.30

(continued)

Table 5 (continued)

16th ITSN entry no.	Variety or cross and pedigree	CIANO[a] Yield (kg/ha)	CIANO[a] Test weight (kg/hl)	El Batan Yield (kg/ha)	El Batan Test weight (kg/hl)	Toluca Yield (kg/ha)	Toluca Test weight (kg/hl)	Huamantla Yield (kg/ha)	Huamantla Test weight (kg/hl)
124	Pnd 'S'-Abn 'S' x IA(2) X-60518-1MP-1Y-1MP-2YP-1MP-2YP-0M	9004	74.60	6104	70.25	8048	68.25	3688	68.25
127	Rabi 'S'-Rye9 x Pnd 'S' X-57093-1MP-5Y-2MP-11YP-1MP-4YP-0M	6464	76.30	6118	69.75	6430	68.85	4063	70.60
150	Cananea 79	6729	—	5931	64.00	6194	57.40	4513	62.90
160	Pnd 'S'-Abn 'S' x IGA-IRA X-47171-F-4M-7Y-1Y-2M-3Y-2M-0Y	7386	76.60	6333	72.35	6284	63.70	3605	66.10
165	Eda 'S'-Cananea 79 CT-1824-4Y-4M-0Y	7817	73.50	5757	71.45	6562	61.10	4116	66.25
197	IA-M2A/Ye75 x IRA-Cml 'S' CT-591-7Y-3M-2Y-0M	7289	76.50	6222	69.80	6340	62.45	3947	67.25
201	Tapir 'S'-Bok 'S' CT-1818-5Y-1M-1Y-0M	8234	75.80	6528	72.15	6527	60.65	4336	67.40
208	Tapir 'S' x Pnd 'S'-Rm 'S' CT-1833-14Y-3M-1Y-0M	7277	77.10	5514	74.70	7562	63.95	4561	69.95
209	Tapir 'S' x Pnd 'S'-Rm 'S' CT-1833-15Y-1M-2Y-0M	7517	76.50	6264	71.70	7944	60.55	4966	66.50
212	Ye75 x IRA-Cml 'S'/Tge 'S' X-66340-5Y-5M-2Y-0M	7558	76.70	5736	69.80	6611	59.25	4252	68.10
214	Nv 'S'-Bgl 'S' x Spd 'S'-Ptr 'S' CT-2276-A-4Y-2M-2Y-0M	7572	74.50	6782	70.15	6277	56.75	3636	66.65
241	Pnd 'S'-Msf 'S' x Tge 'S' X-66216-4M-2Y-2M-2Y-0M	7462	77.20	5729	75.20	7277	59.00	4905	68.60
243	Pnd 'S'-Lnc 'S' x Tge 'S' X-66229-2M-1Y-1M-1Y-0M	6462	—	5875	72.55	7361	63.65	4144	67.05
244	Pnd 'S'-Lnc 'S' x Tge 'S' X-66229-2M-1Y-1M-2Y-0M	7132	73.70	5729	72.75	6265	62.85	4755	67.45

[a] 1983-84 cycle

Table 6. Lines showing stability in average test weight across four different environments in Mexico, 16th ITSN, 1984

16th ITSN entry no.	Variety or cross and pedigree	Average test weight (kg/hl) CIANO	El Batan	Toluca	Huamantla
43	Gnu 'S' B-6912-054-4Y-2Y-0M	—	71.75	69.40	70.65
44	Gnu 'S' B-6912-055-5Y-3Y-0M	71.40	73.80	69.75	67.50
45	Gnu 'S'	76.30	72.35	68.50	66.70
49	Gnu 'S' B-6912-073-22Y-3Y-0M	75.20	73.65	68.85	66.95
62	Uron 'S' B-6811-270-27Y-3Y-0M	76.60	74.35	69.60	66.40
75	Tapir 'S' X-36471-22M-2Y-1M-2Y-2Y-0M	—	72.40	70.70	67.70

(continued)

Table 6 (continued)

16th ITSN entry no.	Variety or cross and pedigree	Average test weight (kg/hl)			
		CIANO	El Batan	Toluca	Huamantla
78	Dingo 'S' X-41047-A-1Y-2M-1Y-2Y-0M	—	72.80	71.90	70.30
93	Mustang 'S' X-63377-E-2Y-2M-0Y	73.40	71.25	69.45	68.00
109	IRA x Bb-Cha/Inia-Tk x CMH73A.785 X-60557-1YP-2MP-2YP-2MP-0Y	76.40	70.20	70.20	68.40
114	Pnd3-Rat 'S' X-59586-4MP-1Y-1MP-1YP-1MP-0Y	75.90	72.15	70.90	69.95
116	MN72130-Rye4 x M_2A-IRA/Pol 'S' X-61595-A-1MP-1Y-1MP-4YP-2MP-0Y	76.00	70.55	70.10	69.25
117	Pnd 'S'-Kla 'S'/USA IV S.718-Spy x Gpr 'S' X-61678-D-1MP-4Y-1MP-5YP-3MP-0Y	75.50	68.75	69.55	70.00
118	FS1018-Pnd 'S' X-56733-1YP-1MP-1YP-2MP-2YP-0M	77.00	70.95	69.65	69.95
119	FS1018-Pnd 'S' X-56733-1YP-1MP-1YP-2MP-3YP-0M	76.10	71.25	70.55	70.05
122	Pnd3-Rat 'S' X-59586-4MP-1Y-1MP-1YP-2MP-4YP-0M	76.10	73.15	67.50	68.30
123	Pnd 'S'-Abn 'S' x IA(2) X-60518-1MP-1Y-1MP-2YP-1MP-1YP-0M	75.00	72.15	69.70	67.05
125	Pnd 'S'-Abn 'S' x IA(2) X-60518-1MP-1Y-1MP-2YP-5MP-1YP-CM	75.00	71.65	72.20	69.10
126	Cit 'S'-Spy/Inia-Tk x CMH73A.785 X-60529-2MP-7Y-1MP-9YP-2MP-2YP-0M	76.40	72.55	69.20	66.45
127	Rabi 'S'-Rye9 x Pnd 'S' X-57093-1MP-5Y-2MP-11YP-1MP-4YP-0M	76.30	69.75	68.85	70.60
128	Rabi 'S'-Rye9 x Pnd 'S' X-57093-1MP-5Y-2MP-11YP-3MP-1YP-0M	76.50	70.70	69.75	72.15
129	Rabi 'S'-Rye9 x Pnd 'S' X-57093-1MP-5Y-2MP-11YP-3MP-4YP-0M	76.60	68.95	70.35	71.60
130	Rabi 'S'-Rye9 x Pnd 'S' X-57093-1MP-5Y-2MP-11YP-3MP-5YP-0M	77.60	69.20	69.95	72.25
146	BvA-Pnd 'S' X-49029-8Y-3M-2Y-4M-0Y	70.30	72.80	66.30	71.75
	Genaro (bread wheat)	82.00	76.86	72.32	75.65
	Sonalika (bread wheat)	80.30	75.65	71.55	75.00
	Seri (bread wheat)	80.60	73.50	69.55	73.80

Table 7. Comparison of days to flowering and maturity in bread wheats and triticales, CIANO, 1983-84

Bread wheat or triticale	Days to flowering	Days to maturity
Average of the bread wheat check varieties Seri, Genaro, and Glennson	88.50	128.50
Average of triticales	80.96	127.35
Average of 24 early triticales	70.67	115.58
Average of bread wheat variety Inia	71.50	115.00
Average of bread wheat variety Sonalika	60.00	115.00

Table 8. Performance of three early triticale lines compared to Sonalika, CIANO, 1983-84

Line or variety	Yield (kg/ha)	Yield (% of Sonalika)	Test weight (kg/hl)	Days to flowering	Days to maturity
Cit 'S'-Spy/Inia-Tk x CMH73A.785 X-60529-2MP-7Y-1MP-9YP-2MP-0Y	8015	120.0	74.8	80	117
(IRA x Bb-Cha/Inia-Tk x CMH73A.758) M_1A-Pi62 X-63166-E-1YP-1MP-5YP-2MP-0Y	7050	105.6	71.9	68	115
IRA x Bb-Cha/Inia-Tk x CMH73.A.758 X-60557-1YP-2MP-5YP-1MP-0Y	6755	101.2	74.2	77	115
Sonalika (bread wheat)	6678	100.0	80.3	60	115

Table 9. Lines with good grain-filling capacity (i.e., producing more than 200 kg of grain per day from flowering to maturity)

Line or variety	Yield (kg/ha)	Rank[a]	Test weight (kg/hl)	Days to flowering	Days to maturity	Days of grain filling	Grain filling (kg/day)
Pnd 'S'-Abn 'S' x IA(2) X-60518-1MP-1Y-1MP-2YP-1MP-2YP-0M	9004	1	74.6	87	123	36	250
Cit 'S'-Spy/Inia-Tk x CMH73A.758 X-60529-2MP-7Y-1MP-9YP-2MP-2YP-0M	7518	9	76.4	85	119	34	221
Cit 'S'-Spy/Inia-Tk x CMH73A.758 X-60529-2MP-7Y-1MP-9YP-2MP-0Y	8015	1	74.8	80	117	37	217

(continued)

Table 9 (continued)

Line or variety	Yield (kg/ha)	Rank[a]	Test weight (kg/hl)	Days to flowering	Days to maturity	Days of grain filling	Grain filling (kg/day)
Tatu 'S' B-5644-778-2Y-3Y-0M	8484	3	76.2	88	128	40	212
Eda 'S' x M_2A-Za75 X61039-6M-1Y-1M-1Y-0Y	8848	1	75.0	86	128	42	211
Kodiak 'S' X-63181-C-1Y-6M-15Y-5Y-0M	7989	1	77.3	77	115	38	210
Pnd 'S'-Abn 'S' x IA(2) X-60518-1MP-1Y-1MP-0Y	8154	4	75.0	78	117	39	209
Mula 'S'-Ram 'S' X-52913-60Y-2M-1Y-1M-1Y-1Y-0B	8159	1	72.0	90	129	39	209
Tapir 'S'(E3-Arm 'S' x M_2A/Adx 'S') CT-1829-9Y-2M-2Y-0M	9588	2	78.8	92	138	46	208
Pnd 'S'-Abn 'S' x IA(2) X-60518-1MP-1Y-1MP-2YP-5MP-1YP-0M	7680	7	75.0	85	122	37	208
Tapir 'S'-Boa 'S' CT-1830-4Y-3M-3Y-0M	9676	1	77.2	83	130	47	206
Lmg 'S'-Pol 'S' X-64270-9Y-4M-2Y-2Y-0M	8041	3	76.2	81	120	39	206
Octo Bulk31-Cin 'S' x Bura 'S' X-52650-19Y-1M-2Y-1M-1Y-0M	7290	2	76.4	87	123	36	203
PF7717 x M_2A-Bn 'S'/Bok 'S'-Lmg 'S' CT-5136-H-2M-3Y-0M	8681	1	77.3	85	128	43	202
Pnd 'S'-Abn 'S' x IA(2) X-60518-1MP-1Y-1MP-2YP-1MP-1YP-0Y	8072	2	75.0	87	127	40	202
Tatu 'S' B-5644-777-1Y-1Y-0M	8062	9	77.2	88	128	40	202
(Ptr 'S'/Rm 'S'-IRA x FS477)Welsh-Bgl 'S' X-53893-E-2Y-1M-1Y-1M-1Y-2Y-0B	7884	2	75.3	81	120	39	202
Gnu 'S' B-6912-073-22Y-3Y-0M	8650	2	75.2	84	127	43	201
Caborca 79	8225	1	72.6	83	124	41	201
M_2A x Cin 'S'-FS658/IA-M_2A X-50234-F-2Y-1Y-1M-2Y-0B	8185	3	75.0	78	119	41	200

Note: Selections based on 35 yield trials, CIANO, 1983-84.
[a] Rank in respective yield trial

Table 10. Materials with the best yield performance under reduced and full irrigation; data from four yield trials, CIANO, 1984

Line or variety	Yield (kg/ha)		Rank in yield trial	
	Reduced irrigation	Full irrigation	Reduced irrigation	Full irrigation
Fawn 'S'-Bsn 'S' X-38864-23M-2Y-2Y-1M-1Y-4M-0Y	4444	7756	2	4
Fawn 'S'-Bsn 'S' X-38864-43M-3Y-2Y-2M-1Y-1M-0Y	4542	7639	1	6
Civet 'S'	4525	8688	4	2
Cml 'S'-Pato x Lmg 'S' X-59462-16M-2Y-1M-0Y	4742	8133	1	3
Civet 'S'	4368	7962	4	2
Pnd 'S'-Abn 'S' x IGA-IRA X-47171-F-4M-7Y-1Y-2M-3Y-4M-0Y	4485	7284	2	5
Df 'S'-Merino 'S' B-2763-457	4240	7398	6	3
Civet 'S'	4300	8204	3	2
M_2A x Cin 'S'-FS658/IA-M_2A X-50234-F-2Y-1Y-1M-2Y-0B	4297	8185	4	3
Pnd 'S'-Abn 'S' x IA(2) X-60518-1MP-1Y-1MP-0Y	4538	8154	1	4

Table 11. Performance of 12 triticale segregating populations after two cycles of sprouting stress, Toluca, 1983 and 1984

Population	No. of seeds from 40 spikes	No. of germinated seeds	No. of ungerminated seeds	Percentage germinated seeds
Jlo-Ptr 'S' x $(IRA\text{-}Bgl)^2$ B-8402	1457	614	843	42.14
Jlo x Drira-Cinucm/Merino-Jlo B-8419	1423	474	949	33.31
Merino 'S'-Jlo/Bgl-Cin x IRA-Bgl B-8413	1441	402	1039	27.90
Bta 'S' x Merino 'S'-Mus 'S' CT-3954	1823	439	1384	24.08

(continued)

Table 11 (continued)

Population	No. of seeds from 40 spikes	No. of germinated seeds	No. of ungerminated seeds	Percentage germinated seeds
Hare 'S'-Yogui 'S' x Jlo B-8232	2063	496	1567	24.04
Df99 x Tj-Bgl/Octo NV x M_2A-Bgl B-8217	1442	319	1123	22.12
Pnd Rye/Lim-IRA x Castor 'S' CT-589	1134	225	909	19.84
Giraf 'S' x Pnd 'S'-Lnc CT-1358	2118	405	1713	19.12
M_2A-Bgl x Jlo[(Fury-7C x WRC31/Mtz x 4C8825(Era-Cno x Gallo)] Drira-MA B-8415	1386	228	1158	16.45
Tapir 'S' x Pnd 'R'-Rm CT-1833	1327	198	1129	14.92
Giraf 'S' x Merino 'S'-Mus 'S' CT-4221	1908	246	1662	12.89
Ted 'S'-PFT 7888 X-66668	1079	117	962	10.84

Table 12. Performance of 17 advanced triticale lines after two cycles of sprouting stress, Toluca, 1983 and 1984

Line	No. of seeds from 40 spikes	No. of germinated seeds	No. of ungerminated seeds	Percentage germinated seeds
Pika 'S' X-39597-4Y-2M-1Y-2Y-0H	1294	19	1275	1.47
Mula 'S' X-18330-3M-2Y-2M-1Y-2M-0Y	1526	121	1405	7.93
Llama-F_3 Spy x Bgl 128-100B-101Y-0B	1864	154	1710	8.26
M_2A-Ktz12 x Bgl B-175	1739	191	1548	10.98
Ptr 'S'-M_1A X-34824-501M-500Y-500B-503Y-501Y-0M	929	115	814	12.38
IA-M_2A x Pi62/Bgl X-16304-500B-501Y-506B-0Y	1209	152	1057	12.57
Anteater 'S' X-16350	1277	169	1108	13.23
Muskox 'S' 15570	1182	245	937	20.73

(continued)

Table 12 (continued)

Line	No. of seeds from 40 spikes	No. of germinated seeds	No. of ungerminated seeds	Percentage germinated seeds
Ptr 'S'-M_1A X-34824-501M-500Y-504B-504Y-501Y-0M	1383	311	1072	22.49
Ptr 'S'-Pnd 'S' X-39599-7Y-1M-1Y-2Y-0H	1024	235	798	22.95
(IGA/UM940 'S'-Arm 'S' x IRA-Bgl 'S') Mpc 'S'/IRA-M_2A x Bush X-47373-A-1M-2Y-1Y-0H	973	235	738	24.15
Mizar	1238	323	915	26.09
Yogui 'S' B2734	1569	443	1126	28.23
FS1795-Lnc X-24369-4H-1X-1M-1Y-0M	962	288	674	29.94
M_2A-UP301 x Bgl 'S' X-16378-2Y-0B-1Y-0M	1264	413	851	32.67
M_2A-FS3284 X-31806-A-4Y-5M-1Y-0M	777	280	497	36.04
Df.99	1237	580	657	46.89

Table 13. Semidwarf triticales that appear to be complete (i.e., to possess the full rye complement)

Triticale	Height (cm)	Triticale	Height (cm)	Triticale	Height (cm)
Stier 'S' B-6712-166-6Y-1Y-2M-501Y	110	ASAD X-49862-3Y-2Y-5M-1Y-1M-0Y	115	Jlo 'S'-Ptr 'S' B-2639-2586	125
Baer 'S' B-5586-462-11Y-2Y-2M-0Y	110	Gnu 'S' B-6912-071-20Y-1Y-1M-500Y	115	Buey-Bgl 'S' X-16215-103B-101Y-1Y-1M-0Y	125
Beauguelita X-22427-101Y-2M-2Y-0M	115	Ram 'S' 2	115	Beagle (Normal)	135
Currency X-15552-33H-2Y-2Y-1M-0Y	115	Hare 134 B-2700-167	120	Eronga (Normal)	145

Pathology

R. Singh, G. Bekele, P.A. Burnett, J.M. Prescott, and E. Warham*

Introduction

Although the adaptability and high yield potential of CIMMYT germplasm have helped increase world cereal production, farmers and researchers alike are still confronted with yield losses and sometimes extensive damage caused by the numerous species of fungi, bacteria, and viruses that attack small grain crops. In its effort to diminish the threat posed by diseases, CIMMYT continues to maintain and improve the rust resistance incorporated into its germplasm base, and to develop additional resistance in bread wheats, durum wheats, and triticales to such pathogens as *Helminthosporium* spp., barley yellow dwarf virus (BYDV), *Tilletia indica* (syn. *Neovossia indica*), *Ustilago nuda* f. sp. *tritici*, and *Fusarium* and *Septoria* spp.

CIMMYT conducts research on these pathogens, sometimes in conjunction with universities and other organizations, and relies on a worldwide network of cooperators from national cereal improvement programs to provide data from the disease screening nurseries distributed by CIMMYT. These activities are the basis of the Wheat Program's attempts to overcome losses caused by diseases and promote greater yield stability in small grain crops.

The major responsibilities of the Wheat Program pathologists are to:

- Conduct applied research on causal agents of major small grain diseases;

* Section on rusts by R. Singh; scab report by G. Bekele; BYDV report by P. Burnett; Karnal bunt and seed health by J.M. Prescott and E. Warham.

Dr. J.M. Prescott (left) and Dr. P. Burnett, pathologists with special responsibility for work on Karnal bunt and barley yellow dwarf diseases, respectively.

- Multiply, collect, and store pathogens, using them to induce artificial epidemics to assist breeders in screening newly developed germplasm;
- Support the resistance screening work of the international nurseries program;
- Conduct disease monitoring and surveillance; and
- Train promising scientists from developing countries.

The Rusts

The fungi *Puccinia graminis* f.sp. *tritici*, *P. recondita* f.sp. *tritici*, and *P. striiformis*, causing stem rust, leaf rust, and stripe rust diseases of wheat, respectively, remain the most important threats to wheat production worldwide. One of the central objectives of the Wheat Program therefore continues to be the development of rust-resistant, high-yielding germplasm for worldwide distribution. Since natural rust epidemics may not occur every year, a successful breeding program must rely on artificially created epidemics with controlled pathotypes.

In the 1983-84 cycle, materials in experimental plots at the CIANO, El Batan, and Toluca research stations were subjected to artificial epidemics produced by using bulked field inoculum and freshly increased inoculum from the greenhouse. Spreader rows for each crop consisted of a mixture of genotypes that had become susceptible after cultivation, as well as certain standard varieties susceptible to rust (Morocco and Baart, among others). Such a genotypic mixture is useful in maintaining variation in the pathogen population.

Prolonged cool and dry weather delayed the establishment of good stem and leaf rust epidemics at CIANO. No severe infection of either disease was found in commercial fields in the Yaqui Valley. At El Batan, excellent epidemics occurred very early, permitting good screening of advanced generation materials. Low levels of natural stripe rust infection also occurred. Leaf and stem rust epidemics created artificially at Toluca progressed very slowly because of the cool weather and frequent, heavy rains that washed the plants. However, natural stripe rust infection at Toluca was good and early, enabling breeding materials to be screened for resistance to the prevalent race(s).

Later in the season, infection with septoria leaf blotch prevented the further spread of stripe rust. At Huamantla, natural epidemics of leaf and stripe rust occurred in experimental plots, and although stem rust was found as well, the intensity was low.

Pathogenicity investigations—Pathogenicity investigations were resumed after a lapse of one year to identify the virulence spectrum of *P. graminis* f.sp. *tritici* and *P. recondita* populations in Mexico. Efforts were initiated to develop an efficient means of storing the various pathotypes. The accomplishment of these objectives will enhance studies on the genetics of resistance, help monitor and conserve variation in pathotypes, and identify any change in the pathogenicity on commercial varieties.

P. recondita* f.sp. *tritici—A total of 145 leaf rust samples were collected from 11 sites in Mexico; 322 single-pustule isolates from these samples were investigated on a set of differential lines. The differential set consisted of 17 isogenic lines and cultivated or advanced bread wheat, durum wheat, and triticale genotypes. Of the 17 single-gene lines used in the differential set, variation occurred only for lines with Lr1, 2a, 2b, 2c, 3, and 10 (Table 1); all other lines were uniformly susceptible.

Results for Genaro 81 (GEN) are reported in Table 1 because this cultivar occupied approximately 35% of the land planted to wheat in the Yaqui and Mayo Valleys of Mexico during 1984. A total of seven pathotype combinations were identified by using 17 single genes for resistance and Genaro 81. The race having a virulence/avirulence combination of Lr1, 2c, 3, 10/2a, 2b, GEN occurred with high frequency on bread wheats (58%) and a very high frequency on durum wheats (93%). Pathotype Lr3, 10/1, 2a, 2b, 2c, GEN was the most prevalent on triticales (58%).

Samples from 9 of the 11 locations where the investigation was carried out did not reflect any variation in the pathogen population; all collections turned out to be pathotype Lr1, 2c, 3, 10/2a, 2b, GEN. At four locations, including El Batan and Toluca, all samples were collected from durum wheats. Although very few samples were collected at the other five locations, it was evident that Lr1, 2c, 3, 10/2a, 2b, GEN was the pathotype that occurred most widely in Mexico in 1983-84.

Reactions of Genaro 81, Glennson 81, and Seri 82—The cultivars Genaro 81, Glennson 81, and Seri 82 were also included in the set of differential lines. Three pathotypes with virulence on Genaro 81 seedlings were identified in samples from artificially inoculated nurseries at CIANO and from naturally occurring infections in the Mayo Valley. The three cultivars exhibited seedling infection type (IT) "0;" to ";1-", with pathotypes avirulent for Genaro 81. With the three pathotypes possessing virulence for Genaro 81 (IT "3"), Glennson 81 and Seri 82 displayed an intermediate response (IT "2" to "22+"). These findings suggest that these three Veery varieties had one gene in common (most likely Lr26), but that Glennson 81 and Seri 82 also possessed at least one additional gene for seedling resistance.

The progress of leaf rust infection on Genaro 81, Glennson 81, Seri 82, and other varieties exposed to the mixture of pathotypes used to create the artificial epidemic at CIANO in the 1983-84 cycle is presented in Table 2. Adult-plant reactions of various materials, measured by the progress of leaf rust infection with Genaro 81-virulent pathotypes, are under investigation.

Reactions of durum wheats and triticales—Of the six durum wheats in the differential set, Mexicali 75 and Yavaros 79 exhibited variation in seedling infection types that ranged from "2-" to "3". Seedling infection types on the other four durum wheats (Cocorit 71, Carcomun 'S', Chen 'S', and Gallareta 'S') varied from low to intermediate. Of the five triticales used in the set, Eronga 83 displayed high seedling infection types to all isolates. The other four triticales (Alamos 83, Caborca 79, Zebra 79, and Euro 'S') exhibited variable degrees of mesothetic infection types. The consistency of variable infection types with various isolates needs to be confirmed.

P. graminis* f.sp. *tritici—At CIANO, 73 stem rust samples were collected, and 131 single-pustule isolates from these samples were investigated on a set of differential lines. The differential set again consisted of isogenic lines and cultivated or advanced bread wheat, durum wheat, and triticale genotypes. Five barley genotypes were also included.

Of the 18 single-gene lines used in the investigation, variation occurred only for lines with Sr7b, 8, 9b, and 11 (Table 3). Results for lines with Sr6 are not reported here because a comparison with the previous year's data indicated that this line could be incorrectly identified. Nine pathotypes were identified.

All key bread wheats (Pavon 76, Ciano 79, Genaro 81, and Tonichi 81), durum wheats (Cocorit 71, Mexicali 75, Yavaros 79, Gallareta 'S', Chen 'S', Carcomun 'S', and Ardea 'S'), triticales (Zebra 79, Caborca 79, Alamos 83, Eronga 83, and Euro 'S') and barleys (Apizaco, Por-U-Sask 1766, Golondrina 'S', Black Hulls, and BlxMari-Coho) included in the differential set exhibited low or intermediate

Dr. G. Bekele (right), pathologist, sorts and checks seed with a trainee.

seedling infection types to all isolates. The durum line Kingfisher was susceptible to all isolates.

Scab

Fusarium head blight (scab) is an important wheat disease in many countries around the world. In wet, humid conditions that favor its development, the disease limits wheat production by reducing yield and grain quality. Scab on wheat is generally caused by *Fusarium graminearum* (Schwabe), the imperfect state of *Gibberella zeae*, which also infects maize. In Mexico, fields once planted to maize and/or wheat can act as a reservoir for the pathogen, which may infect subsequent wheat crops if environmental conditions favor the development of the disease.

Intensive screening for resistance to *Fusarium* spp. commenced in 1981 at CIMMYT, followed by a resistance breeding program. During the first phase of this work, techniques for culturing and increasing fusarium spores (conidiospores) were developed for use under field and greenhouse conditions in Mexico. Methodologies were also created to handle the inoculation and screening of a large amount of material. Two inoculation techniques for screening against *Fusarium* spp. are described in Bekele (1985).

The second phase of this work involves the investigation of CIMMYT germplasm to determine which varieties or lines are resistant to *Fusarium* spp. In Toluca and Patzcuaro during the 1984 summer cycle, 1616 bread wheat lines, mainly from the Crossing Block (CB) and small seed multiplication plots (PC), were planted. At both sites, wheat plants were heavily inoculated at flowering with a conidiospore suspension prepared in the laboratory at CIMMYT. Disease scoring was done 40 days after inoculation, using a 0-5 scale for rating scab severity (0 was completely resistant; 1, resistant; 2, moderately resistant; 3, moderately susceptible; 4, susceptible; and 5, highly susceptible).

Sixty-nine lines with high levels of resistance to *Fusarium* spp. were selected, including eight lines from China (Table 4). Early and heavy rain throughout the growing cycle in Patzcuaro increased the incidence of septoria leaf blotch and complicated the normal scab screening procedure. Therefore, the 69 lines presented in Table 1 are those found to be best in Toluca as well as in Patzcuaro; lines that showed high resistance only in Toluca are not included.

Seed of these 69 lines, which will constitute the Fourth Scab Resistant Screening Nursery (SRSN), will be increased in the 1984-85 cycle and distributed to "hot spots" around the world for further evaluation.

Dr. E. Warham inoculating for Karnal bunt in the greenhouse, where resistant materials identified in the field are routinely retested under heavy disease pressure.

Barley Yellow Dwarf

Barley yellow dwarf (BYD), an ubiquitous disease of cereals, is caused by an aphid-transmitted virus and, like the rust diseases, is not a problem every year. Barley yellow dwarf virus (BYDV) attacks all small grain cereals, including bread wheat, durum wheat, barley, oats, and triticale. The virus also infects at least 100 other grass species, including maize and rice, and these hosts can act as reservoirs for the virus and for aphids.

BYDV has been recognized only recently as a serious constraint to the production of wheat, barley, oats, and triticale in the developing world. The nature of the disease makes it difficult to diagnose, particularly in wheat; consequently, the magnitude of the losses caused by BYDV on a global scale has not be .1 perceived.

Barley yellow dwarf could be considered a second generation disease. Severe epidemics of rust, septoria, or scald can completely mask BYD, and have probably done so in the past. However, once resistance to rust, septoria, or scald has developed, the secondary disease becomes apparent. It should be stressed that BYD has a third biological variable, the aphid vector, and conditions that influence this vector also influence the spread and epidemiology of BYD.

The breeding programs are using BYD-resistant lines in crosses, and the segregating material that is created will be evaluated. A great deal of effort must be concentrated on developing BYD resistance in durum and bread wheat, and especially in durum wheat, because the resistance observed in these crops does not appear to be nearly as strong as that observed in barley or triticale.

The variation in resistance across sites must also be taken into account when breeding cereals for different regions, and data received from cooperators will contribute greatly to the success of the program.

Methods—Since the 1980 BYD workshop held at El Batan, CIMMYT has noted data on lines that cooperators have reported to be resistant to BYD for future use as BYD-resistant parents. Toluca, where natural epidemics of the disease occur, is used as a site for selecting resistant materials. Screening was initially done at this site only in winter, but in 1984, for the first time, screening took place at Toluca in summer as well.

To promote aphid infestation and consequent BYDV infection at Toluca, lines were space-planted in

Dr. R. Singh, pathologist responsible for work on leaf, steam, and stripe rusts.

small plots of 2 rows, each 1 m long. Previous observations indicated that late planting aided infection, so lines were planted in mid-June.

Scores for BYD were recorded in late September and October. Two scores were taken, using a 0-9 scale in which 0 is resistant and 9 is fully susceptible (Qualset, 1984). BYD scores were also taken on the programs' materials if infections were sufficiently severe.

Bread wheat—Approximately 800 lines of bread wheat were screened for resistance to BYD in 1984. From the Crossing Block and the Eighteenth International Bread Wheat Screening Nursery (IBWSN), 228 lines were selected for increase at CIANO; some of this material will be chosen for distribution in the next BYD wheat screening nursery.

Selections of the 1st BYD Screening Nursery and 20 selections from the 16th IBWSN were also screened. This material had appeared resistant in a test run by Dr. A. Comeau at Sainte-Foy in Quebec, Canada. Table 5 lists entries that exhibited good resistance at both Toluca and Quebec.

Durum wheat—During the 1984 Toluca cycle, the 16th IDSN was screened intensively, along with 40 BYD-resistant selections identified from previous nurseries by Dr. A. Comeau and Dr. C.A. St. Pierre of Sainte-Foy. In addition, all of the nurseries grown by the durum wheat program were checked for lines that exhibited apparent resistance. Over 800 lines were examined in all, and twenty-seven were deemed to have acceptable levels of resistance (Table 6).

These lines are being increased at CIANO and will be sent to selected sites as a screening nursery during 1985-86. Currently, the durum wheat program does not appear to have a large number of entries with resistance to BYD.

Triticales—During this same cycle, the 16th ITSN was screened for BYD resistance; lines that looked particularly good are listed in Table 7. Selections were also made from the Crossing Block, and altogether 173 lines were chosen to be increased at CIANO to form a triticale nursery for testing at selected sites in 1985-86. Triticales generally seemed to show good resistance to BYD, but this needs to be tested at more sites.

Barley—Screening for resistance to BYD in barley has been underway for a number of years at CIMMYT. During the 1984 Toluca cycle, the program concentrated on evaluating the 3rd BYD Screening Nursery, plus selections from the Crossing Block and Observation Lines that were noted to exhibit some level of resistance in previous seasons. Data from the 3rd BYD Screening Nursery will be included in a report summarizing all results obtained from this nursery by cooperators.

The best entries from the CB are listed in Table 8; many of these lines were also in the BYD Screening Nursery. This material was sent to CIANO for seed increase and selections will be included in the 4th BYD Screening Nursery, to be distributed in 1985-86.

The program also evaluated a number of F_6 materials for resistance. The results were disappointing because most of the germplasm appeared quite susceptible to BYD or exhibited susceptibility to other diseases for which the barley program was screening (i.e., scald and leaf rust). This means that BYD screening should be carried out when resistance to these other diseases is obtained.

Wide crosses—Only a very few wide cross selections were tested. All of these were from the following cross: Inia 66/*A.dist.*//Inia 66/3/Genaro 81. They appeared moderately resistant but a wider array of material from this program requires testing before definite conclusions can be reached.

ELISA testing of virus isolates in Mexico—During the 1984 season, approximately 200 leaf samples were sent to Dr. Richard M. Lister of Purdue University (USA) for testing by ELISA with the range of antiserum types to BYDV available there. Essentially all samples reacted to the antibodies of an MAV-like isolate (transmitted specifically by the aphid *Sitobion* (*macrosiphum*) *avenae*) of BYD, and approximately 20% reacted to antibodies of a PAV-like isolate (transmitted non-specifically by *Rhopalosiphum padi* and *S. avenae*). It appears that the predominant virus isolates in Mexico in 1984 resembled MAV and PAV and were mixed, but these are preliminary data and further study is needed.

Karnal Bunt

Karnal bunt, caused by *Tilletia indica* (syn. *Neovossia indica*), is a soil-borne disease of wheat and certain other small grains, first reported in India in 1931. The disease appeared in Mexico more than 15 years ago in the Yaqui Valley, near Cd. Obregon, Sonora, and is still confined to a small part of the wheat-growing area of northwestern Mexico.

Tilletia indica teliospores have been reported to remain viable in the soil for up to five years, and a sufficiently high incidence of disease (3% or more) can adversely affect the flavor of products made from teliospore-contaminated flour. Even so, very specific environmental conditions are required for infection to occur, and yield losses due to this nonaggressive pathogen are negligible.

But although Karnal bunt is a minor disease, it is having far-reaching effects on the international movement of germplasm. In 1983, with the aim of averting losses in international trade that could be incurred if Karnal bunt spores were detected in commercial grain shipments, the United States Animal and Plant Health Inspection Service (APHIS) placed quarantine restrictions on the movement of experimental germplasm from

Karnal bunt-infected areas into the USA. Sanidad Vegetal, Mexico's plant protection agency, has also restricted the movement of untreated grain from such areas to other locations within Mexico. Since many developing countries adopt quarantine regulations and actions similar to those of the USA, the APHIS restrictions could eventually limit CIMMYT's international wheat nursery system. These restrictions are presently hindering the movement of nursery materials from Mexico to the USA, Canada, and, to some extent, China and several other countries.

Expanded Karnal bunt research program—In anticipation of the APHIS action, CIMMYT initiated an expanded Karnal bunt research program during the 1983-84 crop season (limited preliminary research had been conducted previously). The program's initial objectives were to:

- Identify germplasm resistant to the disease;
- Identify methods of controlling the disease in the field;
- Screen chemicals for their effectiveness in preventing the transmission of the disease via seed; and
- Develop efficient inoculation techniques.

This research has become a full-scale cooperative effort involving INIA together with research programs in the USA, India, Pakistan, and Nepal. Research in Mexico is conducted by CIMMYT, INIA, and Sanidad Vegetal, with participation by scientists from the USA; the overall program is coordinated by CIMMYT.

Because Karnal bunt is a minor disease that has received almost no research attention in the past, little baseline information on the disease and its causal organism is available. For this reason, the cooperative research program includes such components as the effects of weather and other environmental factors on Karnal bunt infection, studies of teliospore dissemination, an assessment of survey techniques, and sporidia-trapping studies.

Field testing for host plant resistance—Since the 1982-83 season, more than 24,000 lines of bread wheat, durum wheat, triticale, barley, rye, and miscellaneous selections from the *Triticum* species have been field-tested for Karnal bunt resistance. From this material, 290 bread wheats, 510 durum wheats, 739 triticales, and 364 lines from various sources have been selected for apparent resistance. These materials showed no Karnal bunt infection in two successive years of field testing.

Greenhouse screening—Each entry identified as resistant in the field is routinely retested under severe disease pressure with the spray inoculation technique in the greenhouse. All entries tested to date have shown some infection, indicating that physiological resistance may not exist or is very rare. However, the sporidia concentration used in these tests is high (± 50,000 sporidia/ml of water). Nor are there apparent differences between bread wheats, durum wheats, and triticales under these conditions. About 35 lines have shown less than 15% infection under these severe conditions, and will be tested again in the greenhouse.

Since over half the bread wheat lines showing resistance in the greenhouse included either Tzpp or Alondra in their parentage, more attention is being given to materials containing these parents in their pedigrees. In addition, the CIMMYT rye collection, various rye addition lines, and that portion of the world wheat collection resistant to bunts and smuts have been screened for Karnal bunt resistance. *Triticum carthlicum* and ryes have generally shown much lower infection. Ryes might serve as a source of physiological resistance, and consequently all wheat germplasm containing the IB/IR translocation is being screened for this possible trait.

A total of 86 accessions of 21 *Aegilops* species were also evaluated under greenhouse conditions; all accessions of *Aegilops biuncialis*, *Ae. columnaris*, *Ae. crassa*, *Ae. juvenalis*, *Ae. ovata*, and *Ae. speltoides* demonstrated resistance. Several accessions from other *Aegilops* species showed good resistance as well, indicating that *Aegilops* species may be a source of resistance that can be incorporated into bread wheat. Further studies will be conducted, including the screening of Aegilops addition lines.

Fungicide seed treatments—Several systemic fungicides were tested in the field to assess their effects on teliospore germination. None proved effective as a seed treatment, however, because they did not remain active long enough to protect the spike between heading and anthesis.

Controlling Karnal bunt in the field—It has been determined that the application of Terrazan 75WP (PCNB) to the soil prior to heading inhibits teliospore germination for up to six to eight months. When this treatment is coupled with a foliar application of a sporidia-lethal fungicide, nearly complete control of Karnal bunt can be achieved. The most effective sporidia-lethal fungicides tested to date are Tilt, Vangard, Maneb 80, Manzate 200, Busan 38A, Captan, Duter, Baytan, and Terrazan 75WP.

Inoculum production—Since large quantities of inoculum are needed to conduct artificial inoculation studies in the field at CIANO, much time has been spent perfecting this aspect of the program. Potato-dextrose agar (PDA) is presently used for increasing inoculum, and the procedure works well.

A technique to produce primary sporidia in liquid cultures on shakers was also developed. This is a much faster method of producing inoculum, but its usefulness is uncertain since primary sporidia have generally given lower levels of infection in the field. An experiment using higher inoculum concentrations of both primary and secondary

sporidia was done in the 1984-85 cycle and will be repeated in 1985-86 to determine whether primary sporidia can be used as inoculum.

Inoculation techniques—Two inoculation techniques were compared in the greenhouse with susceptible cultivars: boot inoculation, in which a water suspension of secondary sporidia is injected with a hypodermic needle into the boot; and spray inoculation, in which a water suspension of secondary sporidia is sprayed on the spike between heading and anthesis. The boot inoculation technique is the most reliable, but only screens for physiological resistance. The spray inoculation technique more closely resembles natural field infection, and therefore screens for morphological and, to a lesser extent, physiological resistance. Because this technique requires high relative humidity to ensure infection, it is unsuitable as a field screening technique. In the greenhouse, where conditions can be controlled, spray inoculation is the most rapid and efficient technique.

Additional studies—A number of other Karnal bunt research activities are pursued in Mexico. These include 1) studies of the effects of Karnal bunt on seed germination; 2) an investigation to determine which environmental factors affect secondary sporidia production; 3) the effect of Karnal bunt on seed and protein quality; 4) the effects of long- and short-term feeding of Karnal bunt-infected grain to poultry and swine; 5) determination of fungicide residuals in seed following fungicide application at heading time; 6) recovery of and determination of the number of teliospores from soil samples; and 7) the role of irrigation in preventing Karnal bunt infection.

Quarantine status—In the 1985-86 cycle, the Wheat Program will grow all wheat and triticale materials destined for international distribution in a Karnal bunt-free area near Hermosillo, Sonora, Mexico. Entry of germplasm into the USA and Canada will be permitted if Karnal bunt surveys and laboratory inspection during and following harvest in April and May, 1986 are negative.

Future research—CIMMYT will continue screening germplasm for resistance to Karnal bunt. Priority will be placed on germplasm developed by CIMMYT and cooperators in areas where Karnal bunt is a problem. As preliminary findings indicate that there is good resistance among the germplasm from Chi .a and Brazil, germplasm from these countries will also be screened. In addition, materials from CIMMYT's wide cross program will be examined for resistance to the disease, and an effort will be made to screen various winter wheats.

Seed Health

Seed health unit—Since germplasm development is one of CIMMYT's major functions, the Center has always been aware of the necessity of preventing the dissemination of pathogens and pests along with the seed it distributes. In 1984, CIMMYT established a seed health unit to provide more comprehensive and coordinated services for its germplasm development programs and its cooperators abroad (previously, this work was done by the individual crop programs). The activities of the seed health unit are performed in close collaboration with Sanidad Vegetal.

The new seed health unit is responsible for:

- Conducting all standard tests for seed-borne pathogens in germplasm destined for international distribution;
- Developing improved methods of detecting seed-borne pathogens;
- Determining which seed-borne pathogens are present in Mexico;
- Determining improved methods of treating seed for pathogens present in Mexico;
- Testing the efficacy of chemical seed treatments; and
- Conducting all research on the Karnal bunt disease.

Seed health measures—The Center practices several principal seed health measures in the management of its germplasm, which is supplied to national crop improvement programs and other cooperators in response to specific requests. Seed intended for international distribution is produced only at CIMMYT research stations or the cooperating research stations of INIA. Harvested from apparently healthy plants, ears, rows, and/or plots selected by CIMMYT senior scientists, the seed is carefully cleaned and dried to acceptable moisture levels.

Prior to packaging and distribution, all seed is treated with a mixture of approved fungicides and insecticides to protect against pathogens and pests present in Mexico and to prevent their establishment outside the country. Upon completion of these procedures, a phytosanitary certificate for each seed shipment is requested from Sanidad Vegetal.

Additional activities—The seed health unit is working with different seed organizations and quarantine groups to standardize testing methods for pathogens and pests. Training is also a significant part of the unit's activities.

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Table 1. Frequency of identified pathotypes of *Puccinia recondita* f. sp. *tritici* in 1984 survey

Virulence/avirulence	No. of isolates: Bread wheat	Durum wheat	Triticale	Total	Frequency (%)
Lr3,10/1,2a,2b,2c,GEN	5	0	26	31	9.63
Lr1,2c,10/2a,2b,3,GEN	5	6	3	14	4.35
Lr1,2c,3,10/2a,2b,GEN	67	151	7	225	69.88
Lr1,2a,2b,2c,3,10/GEN	10	2	3	15	4.66
Lr1,3,10,GEN/2a,2b,2c	5	3	0	8	2.48
Lr1,2a,2b,2c,3,GEN/10	18	0	3	21	6.52
Lr1,2a,2b,2c,3,10,GEN	5	0	3	8	2.48
Total	115	162	45	322	100.00

Note: 100% avirulence for genes Lr3ka, 9, 11, 16, 19, 20, 21, 24, and 30.
100% virulence for genes Lr14a and 14b.
Variation for genes Lr1, 2a, 2b, 2c, 3, 10, and Genaro 81 (GEN).

Table 2. Progress of leaf rust infection on seven varieties of bread wheat

Variety	Coefficient of infection (no. of days): 0	10	20	30	40	Area under leaf rust progress curve
Seri 82	0.0	0.0	0.6	4.0	4.0	66.0
Glennson 81	0.0	0.0	2.0	9.0	9.0	155.0
Genaro 81	0.0	0.4	3.0	18.0	18.0	304.0
Ures 81	0.0	0.0	3.0	18.0	18.0	300.0
Tonichi 81	0.0	0.4	3.0	12.0	12.0	214.0
Pavon 'S'	0.0	0.8	4.0	8.0	18.0	218.0
Sara 82	0.0	0.8	27.0	60.0	60.0	1178.0

Table 3. Frequency of the identified pathotypes of *Puccinia graminis* f. sp. *tritici* in 1984 survey

Virulence/avirulence	No. of isolates: Bread wheat	Durum wheat	Triticale	Total	Frequency (%)
/Sr7b,8,9b,11	1	6	0	7	5.34
Sr8/7b,9b,11	6	36	26	68	51.91
Sr7b,8/9b,11	0	4	4	8	6.11
Sr8,9b/7b,11	0	4	1	5	3.82
Sr8,11/7b,9b	6	21	4	31	23.66
Sr7b,8,9b/11	0	3	0	3	2.29
Sr7b,8,11/9b	1	3	2	6	4.58
Sr8,9b,11/7b	0	1	1	2	1.53
Sr7b,8,9b,11/	0	0	1	1	0.76
Total	14	78	39	131	100.00

Note: 100% avirulence for genes Sr7a,9e,10,13,24,25,26,27, 30, and 37;
100% virulence for genes Sr5,9a,9d, and 36.
Variation for genes Sr7b,8, 9b, and 11

Table 4. Sixty-nine wheat lines with high levels of resistance to scab at two locations (Toluca and Patzcuaro) in Mexico, 1984

Line and pedigree	Country	Disease score
Bow 'S'-PF74354 OC3217-1M-2Y-3M-2Y-029AL-0Y	Brazil	1
CEP7593-OC731070 OC3235-2M-5Y-0Z-2Y-1M-0Y	Brazil	1
CEP7593-OC731070 OC3235-2M-5Y-0Z-5Y-1M-0Y	Brazil	2
CEP7593-OC731070 OC3235-2M-5Y-0Z-5Y-07AL-0Y	Brazil	2
CEP7593-C731070 OC3235-2M-5Y-0Z-6Y-1M-0Y	Brazil	2
PF74354 x LD-Ald 'S' OC3551-1M-1Y-0Z-2Y-1M-0Y	Brazil	1
PF74354 x LD-Ald 'S' OC3551-1M-1Y-0Z-2Y-2M-0Y	Brazil	1
PF74354 x LD-Ald 'S' OC3551-3M-6Y-1M-1Y-4Z-0Y	Brazil	2
Kea 'S' CM21335-C-9Y-3M-1Y-1Y-1Y-0B	Mexico	2
PF7619-Dove 'S' x CEP7670 B25813-A-1M-1Y-1M-5Y-0Z-6Y-2M-0Y	Brazil	2
Sara CM38088-G-1Y-4M-1Y-3M-1Y-0M	Mexico	1
Bow 'S' CM33203-H-8M-8Y-1M-1Y-1M-0Y-1PTZ-0Y	Mexico	2
Bow 'S' CM33203K-9M-19Y-3M-3Y-0M	Mexico	1
Ald 'S'-Pvn 'S' CM49901-14Y-2Y-1M-1Y-0M	Mexico	1
Ttr 'S'-Bow 'S' CM58 ·57-2M-1Y-1M-2Y-0M	Mexico	2
Ttr 'S'-Bow 'S' CM58857-2M-1Y-1M-3Y-1M-0Y	Mexico	1
[(TpxCno67-No/Bb-Cno67)Za75]Ttm 'S' CM59914-7Y-2M-1Y-1M-1Y-1M-0Y	Mexico	1
F6.74-Bun 'S' x Sis 'S' CM60042-M-1Y-2M-2Y-1M-2Y-0M	Mexico	1
Maya 'S'-Sprw 'S' x Vee 'S' CM64958-27Y-1M-5Y-0Z-8Y-1M-0Y	Mexico	1
Maya 'S'-Sprw 'S' x Vee 'S' CM64958-27Y-1M-5Y-0Z-8Y-2M-0Y	Mexico	2
Dng 'S'-Mon 'S' CM65380-4Y-4M-4Y-1M-2Y-1M-0Y	Mexico	1
Kea 'S'-Buc 'S' CM67354-11Y-1M-3Y-1M-1Y-2M-0Y	Mexico	1
Vee 'S'-Buc 'S' CM67407-8Y-1M-2Y-1M-1Y-2M-0Y	Mexico	2
PF70354-Bow 'S' CM67910-7Y-1M-4Y-0Z-3Y-1M-0Y	Mexico	2

(continued)

Table 4 (continued)

Line and pedigree	Country	Disease score
PF70354-Bow 'S' CM67910-7Y-1M-4Y-0Z-8Y-2M-0Y	Brazil	1
PF70354-Bow 'S' CM67910-7Y-1M-8Y-0Z-1Y-2M-0Y	Brazil	1
PF70354-Bow 'S' CM67910-7Y-1M-8Y-0Z-2Y-1M-0Y	Brazil	1
PF70354-Bow 'S' CM67910-7Y-1M-8Y-0Z-1Y-3M-0Y	Brazil	1
PF70354-Bow 'S' CM67910-17Y-1M-4Y-1M-1Y-1M-0Y	Brazil	1
[(Kvz/Tob-Ctfn x Bb)Blo'S']Ures'S' CM67983-1Y-1M-4Y-1M-1Y-1M-0Y	Mexico	2
[(Kvz/Tob-Ctfn x Bb)Blo'S']Ures'S' CM67983-1Y-1M-4Y-2M-1Y-2M-0Y	Mexico	2
[(Kvz/Tob-Ctfn x Bb)Blo'S']Ures'S' CM67983-1Y-1M-4Y-2M-1Y-3M-0Y	Mexico	2
[(Kvz/Tob-Ctfn x Bb)Blo'S']Ures'S' CM67983-10Y-2M-2Y-1M-0Y	Mexico	1
Yr-Trf 'S' x Bow 'S' CM68336-1Y-1M-1Y-3M-2Y-1M-0Y	Mexico	1
Tan 'S'-Bow 'S' CM68365-6Y-1M-3Y-1M-0Y	Mexico	2
K4500L.6.A.4-Vee 'S'[Cno67-No x Kal-Bb/Bj'S'-On2 x Sx) Buc'S'] CM69093-I-1Y-1M-1Y-3M-1Y-1M-0Y	Mexico	1
K4500L.6.A.4-Vee 'S'[Cno67-No x Kal-Bb/Bj'S'-On2 x Sx) Buc'S'] CM69093-I-1Y-1M-1Y-3M-2Y-1M-0Y	Mexico	1
Vee 'S'-1061.K4[CNT8 (Kvz-Gv 'S' x Ka'S'/Emeck 132)] CM69163-A-1Y-1M-1Y-2Y-1Y-2M-0Y	Mexico	2
Mrng-Buc 'S' x Blo 'S'-Psn 'S' CM69191-A-5Y-1M-1Y-2M-2Y-2M-0Y	Mexico	2
Mrng-Buc 'S' x Blo 'S'-Psn 'S' CM69191-A-5Y-1M-1Y-2M-2Y-3M-0Y	Mexico	2
Mrng-Buc 'S' x Blo 'S'-Psn 'S' CM69191-A-5Y-3M-2Y-1M-1Y-2M-0Y	Mexico	2
Mrng-Buc 'S' x Blo 'S'-Psn 'S' CM69191-A-5Y-3M-2Y-1M-1Y-3M-0Y	Mexico	2
Psn 'S'-Bow 'S' CM69560-6M-2Y-1M-1Y-1M-0Y	Mexico	1
Bow 'S'-Vee No.5 CM69600-1M-1Y-1M-4Y-1M-0Y	Mexico	1
Aufn-Tsh 'S' CM70024-1M-5Y-1M-1Y-1M-0Y	Mexico	2
Bow 'S'-Prl 'S' CM70307-1Y-1M-4Y-2M-0Y	Mexico	1

(continued)

Table 4 (continued)

Line and pedigree	Country	Disease score
PF7339 x Mrs-Coc CM70378-11Y-2M-1Y-1M-0Y	Mexico	1
[(Bez2B/CC-Inia66 x Cal) Ald 'S'] Crow 'S'-Pri 'S'	Mexico	2
IAS20-H567-71 x IAS205 CMH77.205-1Y-1B-7Y-1B-1Y-3B-0B	Mexico	2
H567.71-P.AR^3 CMH77.308-1Y-4B-1Y-1B-3Y-2B-2Y-2B-1Y-0Y	Mexico	2
H567.71-P.AR^3 CMH77.308-1Y-4B-1Y-1B-3Y-2B-2Y-3B-0Y	Mexico	1
IAS20-H567.71 x IAS205 CMH78A.544-7B-1Y-1B-1Y-0B	Mexico	1
IAS20-H567.71 x IAS205 CMH78A.544-7B-1Y-1B-1Y-2B-1Y-0B	Mexico	2
IAS20-H567.71 x IAS205 CMH78A.544.7B-1Y-1B-1Y-2B-1Y-1B-0Y	Mexico	2
YMI No.6	China	2
Fan No.1	China	1
Shanghai 3	China	1
Shanghai 4	China	1
Shanghai 5	China	1
Suzhoe F3 No. 1	China	1
IOC 813	Mexico	2
IAS20-H567.71 x IAS205 CMH78A.544-7B-1Y-1B-1Y-2B-1Y-2B-0Y	Mexico	2
IAS20-H567.71 x IAS205 CMH78A.544-7B-1Y-1B-1Y-2B-1Y-3B-0Y	Mexico	2
IAS20-H567.71 x IAS205 CMH78A.544-7B-1Y-1B-1Y-3B-0Y	Mexico	2
P.AR-Cj71 x P.AR^5 CMH80.278-2Y-8B-2Y-1B-0Y	Mexico	2
P.AR-Cj71 x P.AR^5 CMH80.278-2Y-8B-2Y-3B-0Y	Mexico	2
Thb 'S' F11915	Brazil	1
Sumai 3 Jiangsu (resistant check)	China	1
Nanjing 7840 (resistant check)	China	0

Table 5. Bread wheat lines that exhibited BYD resistance at Toluca, Mexico and Sainte-Foy, Quebec, Canada, 1984

Variety or cross and pedigree	Variety or cross and pedigree
Vee No.5 'S' CM33027-F-15M-500Y-0M	Buc 'S'/Flk 'S' CM50070-24Y-1M-1Y-0Y
Jup/4/7C/Pato B/3/LR64/Inia66// Inia66/Bb/5/Ana CM37760-C-21Y-2M-1Y-3M-0Y	Jac/Ald 'S' CM50523-3Y-3F-1Y-1Y-0Z-0Y
Pato/On//Maya 'S'/3/Bb/Ron//Maya 'S' CM40739-36M-1Y-1M-1Y-1M-0Y	Buc 'S'/Chrc 'S' CM52421-6M-2Y-2Y-1M-0Y
Mus 'S'/Ptm//Maya/Ald 'S' CM44740-A-3Y-1M-1Y-2M-1Y-2M-0Y	Buc 'S'/Chrc 'S' CM52421-10M-6Y-1Y-1M-1Y-0M
YR/Pam 'S' CM46091-16M-1Y-6M-3Y-1Y-1M-0Y	IAS58/IAS55//Ald 'S'/3/Mrng/4/Ald 'S'/ IAS58.103A//Ald 'S' CM55517-B-1F-701Y-1F-707Y-1F-0Y
PF70354/Ald 'S' CM47090-14M-1Y-1F-703Y-10F-705Y-3F-0Y	Ald 'S'/Pima/3/CMH74A.630/Bui 'S'// CMH74A.630 CM57542-H-8Y-8B-4Y-0B
Tob//CC/Pato/3/Bb/Gll/4/Nac CM49624-14Y-5M-1Y-1Y-2M-2Y-0M	Cqt/Az//IAS55/Ald 'S'/3/Ald 'S'/Nafn/4/ Pjn 'S'/PELSL1276.69 CM58478-B-ZY-1Y-2M-1Y-0M
4777*2//FKN/Gb/3/Pvn 'S' CM49912-37M-1Y-1Y-2M-1Y-0M	

Table 6. Durum wheats that visually appeared to have resistance to BYD, selected at Toluca, 1984

Variety or cross and pedigree	Variety or cross and pedigree	Variety or cross and pedigree
Yav 'S' CM9799-126M-1M-4Y-0Y	* Afn 'S'/Ibis 'S'//Coo 'S'/3/Goo 'S' CD-22951-5Y-1M-1Y-2Y-1M-0Y	* PI178083/Frig 'S'//Goo'S' CD-34957-D-2Y-3M-1Y-0M
Sapi 'S'/Ber 'S' CD15313-4M-1Y-1M-3Y-1M-0Y	* Carc 'S' CD-24831-E-3Y-3M-1Y-1Y-0M-22Y-0B	* QFN/Memo 'S'/3/Oyca 'S'// Ruff 'S'/Fg 'S' CD-35212-A-1Y-1M-2Y-0M
Chen 'S' CD23184-2Y-3M-1Y-1Y-0M	* Gs 'S'/Cr 'S'//Sba81/3/Ho/4/ Mexi 'S'/5/Memo 'S' CD-27215-5B-2Y-1Y-0M	* Zud ICD-74122-2L-1AP-0AP-1KE-0Y
Sapi 'S'/Teal 'S' CD25739-11Y-2M-1Y-1Y-0M	* Seo 'S'/Rabi 'S'//Mexi75 CD-28164-B-2M-1Y-2Y-0M	Gia 'S' CD28222-D-1M-2Y-2Y-0M
Gediz 'S'/Bcy 'S' CD25689-1B-1Y-0Y	* Mo'S' CD-29063-3Y-4Y-3M-0Y	**FCA 'S' CD35181-E-2Y-2M-1Y-1M-1Y-0M
Nile L74.123-OAP-1AP-OAP	* Gediz 'S'/Cit71 CD-32575-1B-1Y-1M-0Y	Yva 'S'/Fg 'S'//Roh 'S' CD43739-C-2Y-1M-1Y-1M-0Y
M75 Cr 'S'/Gs 'S'//Pg 'S' CM-13434-5Y-1M-4Y-0Y	* Yav 'S'/Snipe 'S'/3/Mexi 'S'/ P66.270//Gta 'S'* CD-33863-1B-3Y-2M-0Y	**GoVZ448/Mal 'S'//Tez 'S' CD43752-F-1Y-1M-1Y-1M-0Y
* Cit 71	* Yav 'S'/Snipe 'S'/3/Mexi 'S'/ P66.270//Gta 'S' CD-33863-2B-3Y-2M-0Y	**Stint 'S' CD7474-A-1M-3Y-5M-4Y-0M
* Moa 'S' CD 3935-1Y-1M-0Y		**Corm 'S'/Rufo 'S' D48693-10Y-1M-1Y-0M

* Showed resistance in Sainte-Foy, Quebec, Canada

**Looked particularly good in Toluca

Table 7. Entries from the 16th ITSN that exhibited very good resistance to BYD, Toluca, 1984

Variety or cross and pedigree	Variety or cross and pedigree	Variety or cross and pedigree
FS179/Lnc 'S' X-24369-4A-1Y-1M-1Y-0M	Ptr 'S'/M_2A X-44650-12M-1Y-1Y-2M-2Y-1M-0Y	Abn 'S'//M_2A/IRA/4/Pnd 'S'/Castor 'S'/3/416/Spy//Ted 'S' X-63377-C-1Y-2M-1Y-1Y-0M
Mula 'S'/Ram 'S' X-52913-42Y-1M-2Y-1M-2Y-2Y-0B	FS381/FS477//Toro 'S'/3/Tge 'S' X6270-B-1M-2Y-1M-1Y-1Y-0B	Caborca79//Ptr 'S'/Castor 'S' X-63844-1M-3Y-1M-2Y-0M
Cit 'S'/Spy/3/Inia/Tk//CMH73A.785 X-60529-2MP-7Y-1MP-9YP-2MP-0Y	Tapir 'S'/Boa 'S' CT-1830-4Y-3M-3Y-0M	Rm 'S'//Kal/Bb/3/Spd 'S' X-66160-1M-3Y-2M-2Y-0M
Pnd 'S'/Abn 'S'//IA X-60518-1MP-1Y-1MP-2YP-1MP-1YP-0M	Caborca79/Ptr 'S'//Lmg 'S'/Toro 'S' CT-2500-C-1Y-1M-1Y-0M	Pnd 'S'/Abn 'S'/3/Tob/Cno 'S'//M_2A/4/IRA/Cml 'S'//M_2A X-67798-A-1M-2Y-4M-3Y-0M
Pnd 'S'/Abn 'S'//IA X-60518-1MP-1Y-1MP-2YP-5MP-1YP-0M	Pnd 'S'/Ye75//Ptr 'S'/3/Lmg 'S'/Toro 'S' CT-2695-F-1Y-2M-2Y-0M	Lnc 'S'/Abn 'S'//Ted 'S' X-66075-4M-3Y-2M-2Y-0M
Ptr 'S'/Yo 'R'//Pnd 'S' X-52202-3Y-3M-1Y-3M-0Y	Lmg 'S'/Pol 'S' X-64270-9Y-4M-2Y-2Y-0M	

Table 8. Barley lines resistant to BYDV in Toluca, 1984

Variety or cross and pedigree	Variety or cross and pedigree	Variety or cross and pedigree
Dorada	ESCII-72-83-3E-7E-5E-1E	Yoa 'S' CMB77-125-1Y-1B-1Y-2B-1Y-0B
MCU33/Fza//Tib/3/PI356456 DII-3958-27D	Cedro CMB77-1267-B-1Y-1BV-1Y-1B-1Y-1B-0Y	Brea/Sutter//F3 Bulk Hip CMB79A-1062-C-501B-1Y-1B
CI2325/CI12225//Boy(2)/Surb(3) II15263-3PT-3V	CM72	Ojillo 'S' CMB79A-1362-B-501B-1Y-1B
Boy/MCU3048.1D//CI1463.3D II14127-1P1-5V	Sutter	Ojillo 'S' ACMB79A-1362-B-501B-3Y-1B
PI14116.13D/CI12225//CI12917.37D II1516-1PV-1PV-1V	UC566	Palo Santo 'S' CMB79A-1524-D-500B-1Y-1B
CI2375/CI12225//Can/MCU29/3/Tib/4/CI12225.23D II14845-3V	CI 3906.1	CI 3208.2
Boy(2)/Surb(3)//CI12225.2D II15199-1PV-5V	Promesa	Yori 'S' CMB-77A-402-1B-1Y-4B-3Y-1B-0Y
Row 906.73	79 W 40762	PI 2325/Mag102//Cossack CMB/78-452-2Y-1B-1Y-1B-1Y-0B
Proctor/Prior/Gospick E-II-69-117-5E-2E-7E	79 W 41762	
	PI 382406	
	79 An/Mn 123-NV-1B-0Y4	
	M66.85/Aths/3/Api/CM67//DS/Apro CMB75A-1617A-7B-500Y-500B-0Y	
	Api/CM67//Ager CMB76-408-27Y-1B-4Y-1B-1Y-0B	

Wide Crosses

A. Mujeeb-Kazi

Introduction

In many cases, the practical motivation to make wide hybrids stems from the possibility of introducing desirable characteristics into cultivated species from related, alien forms. Further motivation arises from the possibility of acquiring basic cytological, evolutionary, or phylogenetic information about the parental species in the hybrid. It is not surprising, therefore, that wide hybrids in the Triticeae have been attempted and studied for a long time.

The first wide hybrid between wheat and rye was purposely made in the Triticeae over 100 years ago. Similar studies of wheat/barley hybridization were made in 1904, although it is improbable that any true hybrids were obtained. Many hybrids involving *Triticum* spp. and species of *Aegilops* were made during the 1920s and 1930s. The genomic relationships of the genus were derived from these hybrids, but their large-scale, practical use was delayed until the advent of the colchicine treatment in the late 1930s.

CIMMYT began work on wide hybridization in 1979 (with the exception of the Center's triticale work, which dates from 1962). In 1979, the major problems limiting the use of wide hybrids were the barriers of crossability and embryo development. These initial constraints have been overcome to a great extent, and annual and perennial hybrids have been produced. It is highly probable that if other developmental constraints are removed, the possibilities of even wider hybrids can be realized. Such investigations are a continuous, integral part of the program, because the only practical approach to resolving the difficulties encountered in making hybrid combinations is to increase the range of parental genotypes and to attempt to make reciprocal combinations.

Different methodologies exist for making intergeneric (wheat/alien species) combinations. In one method, alien germplasm is screened for specific disease resistance or stress tolerance and then combined with wheat. An alternative approach is to combine the alien species or genera with several wheat varieties, obtain valid hybrids, clonally propagate the hybrids, and test the clones for disease or stress factors. Where clonal testing is not feasible, the F_1 hybrid may be advanced to a backcross self-fertile stage and then tested. Each procedure has advantages and limitations, and each is used by the program (until 1983, the latter method was given priority).

The wide cross genetic base now available in the program enables several objectives to be pursued. These objectives include the incorporation of resistance to three diseases (*Helminthosporium sativum*, *Tilletia indica* (syn.

Dr. A. Mujeeb-Kazi of the wheat wide crosses program.

Neovossia indica), and *Fusarium graminearum*), and three types of stress tolerance (salt, aluminum toxicity, and copper deficiency). The genetic base undoubtedly could be screened for other purposes should the need arise.

Hybrid Maintenance and BCI Seed Production

Perennial hybrids are cloned twice each year, in January and June. A few of these clones are treated with colchicine for amphiploid production and the remainder are pollinated by different bread wheats to produce new backcross I (BCI) combinations. A list of all F_1 hybrids produced in CIMMYT is presented in Tables 1 and 2.

New Hybrids and a Range Grass Nursery

The highly productive summer crossing cycle undertaken in collaboration with the USDA in 1982 and 1983 at Logan, Utah ceased this year. Instead, the program's efforts were directed toward establishing a functional nursery of the range grasses in El Batan so that hybrid production at CIMMYT would be possible. Although the establishment of grasses in the field has not been too successful, the species have responded well to greenhouse conditions. In the greenhouse, seed of various *Agropyron* and *Elymus* species was germinated in 5-inch pots in a soil mix of 2 soil : 1 sand : 1 leaf manure or peat. Seedlings continued growing under approximately 14 hours of natural light, temperatures of 22°C by day and 12°-14°C at night, and about 55% relative humidity. After a juvenile growth phase of eight weeks, accessions were transferred to a growth chamber for vernalization regimes set at 8°C continuous temperature and 8 hours of light for six to eight weeks.

After vernalization, accessions were kept under the greenhouse conditions described above and flowered synchronously. (This procedure may aid researchers in planning intergeneric research for countries where growing range grasses may be difficult.) The accessions will be planted in the field at El Batan following vernalization in summer 1985.

Disease Resistance

Helminthosporium sativum—In Poza Rica, 7514 lines belonging to derivatives of crosses of *T. aestivum* with *A. distichum* (4691), *A. elongatum* (416), and *E. giganteus* (2407) were tested for resistance to *H. sativum*. Selections from each combination demonstrated satisfactory resistance to the pathogen. These resistant selections had good agronomic type or were tall and late maturing. Final selections were based on grain finish (absence of the blackish-brown end point).

Selections were next tested in the greenhouse for seedling resistance, and resistant seedlings were cytologically analyzed prior to screening as adult plants. The material had chromosome numbers of either 42, 43, or 44. If the chromosome number of the material was 42, progenies were either euploids or carried an alien substitution chromosome pair (40 wheat plus a pair of alien chromosomes) that could be detected cytologically using C-banding. Where this analysis was not feasible, limited biochemical testing of the euploids provided evidence of alien gene introgression. This conclusion is based upon isozyme analyses in progress; data for the *A. distichum* derivatives are provided by the program's collaborators at the Plant Breeding Institute (PBI), Cambridge, England. Detailed cytological analysis for a large portion of the material has been deferred until the quantity of selected plants can be reduced from 2080 to a more manageable number.

Alien species were tested in the greenhouse for seedling resistance and several species had acceptable levels (Table 3). The program will produce additional hybrids of these species with *Triticum* species, and advance the hybrids to field testing on a large scale in Poza Rica by November, 1986.

Fusarium graminearum—*Triticum aestivum* derivatives from combinations with *A. distichum* (2137), *A. elongatum* (763), and *E. giganteus* (506) were field tested in Toluca following inoculation. Of the 367 selections resistant to *F. graminearum*, 132 were from *E. giganteus* and 235 for *A. distichum* derivatives. The material was highly susceptible to *Septoria* spp. and it appears that screening the alien species in a wheat background for resistance to this pathogen may have merit (Tables 1 and 2). The severe septoria damage on the *A. elongatum*-based progenies did not permit satisfactory scab screening. The *A. distichum* derivatives seemed resistant to barley yellow dwarf virus (BYDV) and selections were made for further study.

Tilletia indica—The *Aegilops* species accessions obtained from PBI have been screened for resistance to Karnal bunt (caused by *Tilletia indica*) using the boot inoculation technique under greenhouse conditions of 22°C day temperature, 12-14°C night temperature, 14 hours of natural light, and approximately 55% relative humidity. Disease scoring ranged from 0% to 100% infection; species with less than 5% infection appear in Table 4. Hybridization of these species with *T. aestivum*, *T. turgidum*, or chromosome 5B genetic stocks has begun.

Salt Tolerance

Salt-tolerant alien species among the close relatives of wheat are *A. elongatum* (2x, 10x), *A. distichum*, *E. giganteus*, *E. sabulosus*, *A. junceum* (2x, 4x, 6x), and *A. scirpeum*. Hybrids have been produced with wheat of all of these species except for *E. sabulosus*. Advanced derivatives from *A. distichum*, *A. junceum* (2x, 4x), and *A. scirpeum* have been made available to CIMMYT's collaborators to test for salt tolerance in the field and in liquid culture. Results were satisfactory for all materials.

Salt tolerance is a complex polygenic trait, and may not be easily transferred to or expressed in wheat. Given this difficulty, the

diploid *A. junceum* (2n = 2x = 14) received priority as the elite alien source; its chromosomes are amenable to C-banding (Figure 1) and the backcross derivatives have normal cytology. Second priority was given to *A. scirpeum*, in which the E_1 and E_2 genomes have the potential to be combined synthetically to form a modified genomic complex. This combination will presumably allow salt tolerance genes to be assembled in a compact, practical unit. The methodology used is as follows:

(a) Normal procedure with no significant modification expected as a consequence of recombination among chromosomes of the E_1E_2 genomes of *A. scirpeum* (Figure 2).

(b) Procedure permitting significant modification of the E_1E_2 genome chromosomes of *A. scirpeum*: When the BCI (2n = 6x = 42 AABBDD + 14 E_1E_2) derivatives were selfed, fertile progeny resulted, seemingly because of pairing between the E_1 and E_2 genome chromosomes. If this autosyndetic phenomenon of the E_1E_2 genomes is taken advantage of, and the BCI is permitted to self for several generations, it is probable that a new genome would be synthesized, which might offer valuable insights into the transfer of salt tolerance genes. The program has now advanced up to $BCIF_2$ for the modified genome and up to BCIII for the routine addition line route.

The synthetic genome concept appears to be valid for most polygenically inherited characters and is associated with those alien species that are not strict autopolyploids; these are classified as partial allopolyploids. The tetraploid *A. junceum* fits this category, but selfing the BCI has not given a high turnover of 56-chromosome progeny, indicating that the two Ju-differentiated genomes are not associating perfectly through autosyndesis.

Aluminum Tolerance

Several *Aegilops* species and their accessions have been screened for aluminum tolerance in the laboratory at CIMMYT. The first screening was at 1.70 mM or 46 ppm of aluminum. Tolerant seedlings were obtained from *Ae. triaristata* (2n = 6x = 42), and excellent tolerance was expressed by *Ae. uniaristata* (2n = 2x = 14) and *Ae. ventricosa* (2n = 4x = 28). When these accessions and species were tested at 1.85 mM or 50 ppm

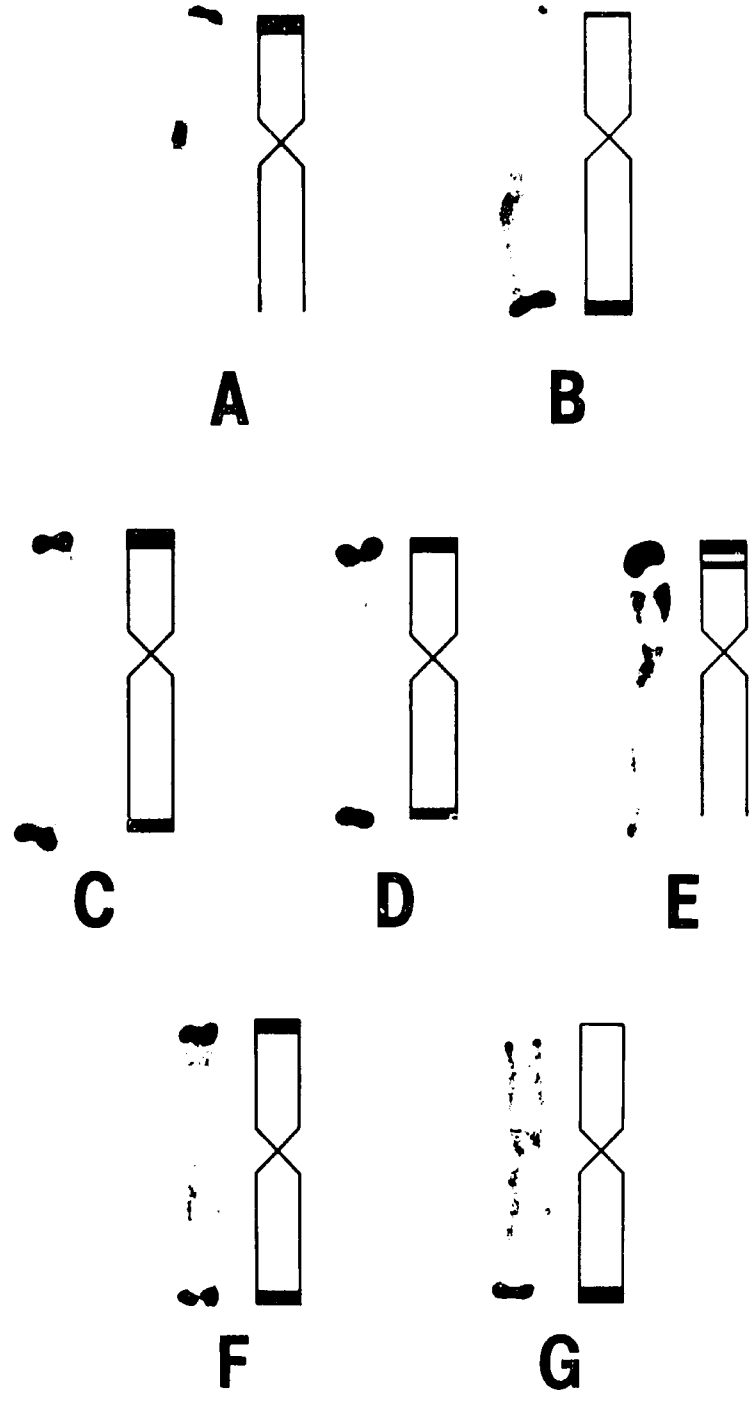


Figure 1. C-banded chromosomes of *Agropyron junceum* (2n=2x=14), a species used for transfer of salt tolerance to wheat (*T. aestivum*)

aluminum, *Ae. triaristata* seedlings did not survive, but *Ae. uniaristata* and *Ae. ventricosa* remained highly tolerant. The program has begun to hybridize tolerant accessions to *Triticum* species.

Copper Deficiency

The 5A/5RL stock was obtained from PBI; the 5RL rye arm is reported to carry the copper efficiency gene. The validity of this genetic stock must be tested before this trait can be transferred to elite CIMMYT wheat lines.

CIANO 1983-84 Cycle

In the 1983-84 cycle at CIANO, 10,246 advanced lines were planted to evaluate plant type and leaf and stem rust resistance. The material comprised the following combinations (the objective(s) of each combination is indicated in parentheses):

1. *T. aestivum/E. giganteus* (4x) (Salt, *Fusarium* spp., *Helminthosporium* spp., *Tilletia indica*)
2. *T. aestivum/A. distichum* (4x) (Salt, *Fusarium* spp., *Helminthosporium* spp.)
3. *T. aestivum/A. elongatum* (10x) (Salt, *Fusarium* spp., *Helminthosporium* spp.)
4. *T. aestivum/E. dahuricus* (6x) (*Helminthosporium* spp.)
5. *E. canadensis* (4x)/*T. aestivum* (*Helminthosporium* spp.)
6. *T. aestivum/A. junceum* (6x)(Salt)
7. *T. aestivum/A. junceum* (4x) (Salt, *Helminthosporium* spp.)
8. *T. turgidum/A. distichum* (4x) (Salt, *Fusarium* spp., *Helminthosporium* spp.)
9. *T. turgidum/A. elongatum* (10x) (Salt, *Fusarium* spp., *Helminthosporium* spp.)
10. *T. aestivum/H. vulgare* (2x) (High protein/high lysine)

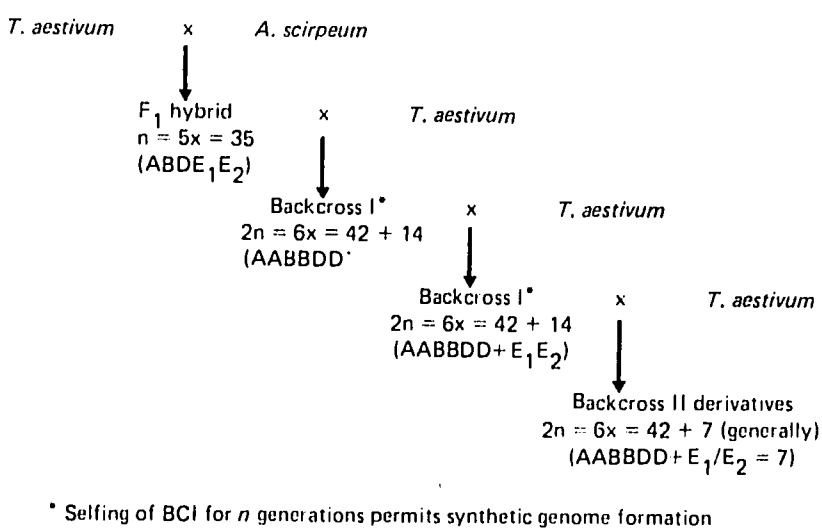
The most promising combinations for desirable plant type were from *A. distichum*, followed by *E. giganteus*. The *A. distichum* derivatives included selections for earliness, reduced plant height, erect leaves, white grain, absence of the 1B/1R translocation (derivatives have Genaro 81 and Inia 66 in the pedigree), excellent agronomic type, and *Agropyron* spp. spike type characterized by stiff awns. A combination of several of these characters was observed in an advanced line as well. Selections resistant to leaf rust were identified even though both Inia 66 and Genaro 81 were susceptible. The *E. giganteus* derivates had problems with leaf yellowing that are not characteristic of Pavon. Presumably the Chinese Spring female parent in the F_1 was still contributing its poor agronomic traits. All other hybrid derivatives are still in the early stages of testing.

Early field testing of the different hybrids allows the program to make predictions concerning their ultimate practicality. After field testing, it appears that satisfactory plant types will not be obtained from wheat combinations with *E. dahuricus* and *E. canadensis*, even though both species are excellent sources for resistance to *H. sativum*. The principal defects in their BC derivatives were chlorotic foliage, weak and open tillers, tall progeny, asynchronous spike initiation, and small, tapering, poorly-filled heads.

El Batan 1984 Cycle

The 1984 cycle at El Batan included all selections made at CIANO in the 1983-84 cycle. Altogether, 3338 lines were tested and the BC derivatives produced in CIANO were also planted. New combinations that were field tested in El Batan consisted of several BCII or BCIIF_1 lines. The alien species involved were *A. scirpeum*, *A. junceum* (2x), *A. junceum* (4x), *A. intermedium*, *A. trichophorum*, *A. varnense*, *A. pulcherrimum*, *A. acutum*, *A. curvifolium*, *A. repens* - *A. desertorum*, and *A. stipifolium*. Additional backcrosses were made on plants from all of these derivatives using elite wheat lines as the BC parents. The incidence of leaf rust was high, but the derivatives of *A. scirpeum* were remarkably resistant. All lines had a cytological history, thus enabling selection criteria to be relaxed, since the presence of 7-19 alien chromosomes is positively correlated with poor agronomic type. Three additional crossing and field testing cycles will bring about considerable improvement in plant type in these lines.

Nursery sets from *A. distichum* and *E. giganteus* advanced lines were sent to Pakistan, Bangladesh, and



* Selfing of BCI for *n* generations permits synthetic genome formation

Figure 2. Procedure for advance of *T. aestivum/A. scirpeum* for development of BCI progeny

the Philippines. A field site in Mexico will be used in 1985 to test the salt tolerance of these derivatives.

Greenhouse Studies

In the greenhouse, 6031 individual plants were subjected to cytological analysis. These plants included early generation wide crosses of *T. aestivum* and/or *T. turgidum* with the various *Aegilops*, *Agropyron*, *Elymus*, *Haynaldia*, *Hordeum*, and *Secale* species. Some selection is practiced in the greenhouse material, and plants with unsatisfactory agronomic type are discarded. The chromosome history of each plant is a strong selection indicator; for progenies with a large number of extra chromosomes, the selection criteria are less stringent. Selections from the greenhouses were planted for field observation in El Batan, and other selections from the greenhouse were planted in the fall in the CIANO 1984-85 cycle. The basic working format for greenhouse material is shown in Figure 3.

Special Research Areas

Mono-5B chromosome—The transfer of the mono-5B chromosome stock from *T. aestivum* cv. Chinese Spring to three CIMMYT wheats (Ciano 79, Nacozari 76, and Pavon 76) is progressing satisfactorily. Some BCIV seed has been produced and despite the difficulties inherent in advancing mono-5B-based intergeneric hybrids, the program will attempt to produce hybrids using these stocks in 1985.

***A. junceum* hybrids**—The *A. junceum* diploid species x *T. aestivum* hybrid has been crossed successfully with *T. turgidum*, yielding a 42-chromosome progeny (AABBDJu). The derivatives were then crossed to wheat, leading to progeny that are genomically expected to be AABBD(D/Ju). If a translocation between D and Ju occurs it will be heterozygous and may be detected by C-banding, if chromosomes AS, BL, CS + CL, DS + DL, ES, FS + FL, GL are involved (S = short arm, L = long arm). Single addition chromosomes to wheat have also been developed and these will be crossed with *T. turgidum* to produce AABBD + alien (i.e., 36-chromosome) progeny. The translocation products of this alien/D genome chromosome are yet to be assessed for the salt tolerance potential of the alien species.

Service Functions

Several durum and bread wheat lines were crossed to different rye sources to provide CIMMYT's triticale program with new primary triticales. Approximately 400 hybrid embryos were produced and plants possessing n = 3x = 21 or n = 4x = 28 chromosomes were identified. These have been treated with colchicine and the production of fertile amphiploids is expected.

Bread wheat lines in the 1983-84 cycle in small multiplication plots (PCs) and the Crossing Block (CB) were analyzed for the 1B/1R translocation chromosome. The choice of lines to be evaluated was based on analyses conducted in 1982, in which the contributing sources of 1B/1R were Kavkaz, Aurora, Weique x Red Mace, or their recipient derivatives. Approximately 52% of the entries in the PCs and CB possessed the 1B/1R translocation. Analyses were conducted by isozyme assay at PBI (C.Ainsworth-M.Gale) and/or by N-banding at the CIMMYT laboratory.

Future Trends

In the future, the emphasis in wide crosses will shift to the production of intergeneric hybrids of wheat with diploid alien species, and intergeneric hybrids of polyploid alien species (identified for disease resistance or stress tolerance) with PhPh mutant stocks of the *Triticum* species. The diploid species will also be hybridized with wheat genetic stocks to obtain recombinations in the F_1 hybrids. *Aegilops* species will receive priority, as they are considerably easier to hybridize with wheat (for example, *Aegilops umbellulata* for Karnal bunt resistance, and *Aegilops uniaristata* for aluminum tolerance).

The predominant constraint in about 95% of the hybrids produced by the program is the lack of wheat/alien chromosome recombinations through chromosome pairing in the F_1 (Figure 4). Ideally, the high pairing meiotic associations of *T. aestivum/A. scythicum* (Figure 5) or *T. aestivum/A. junceum* (Figure 6)

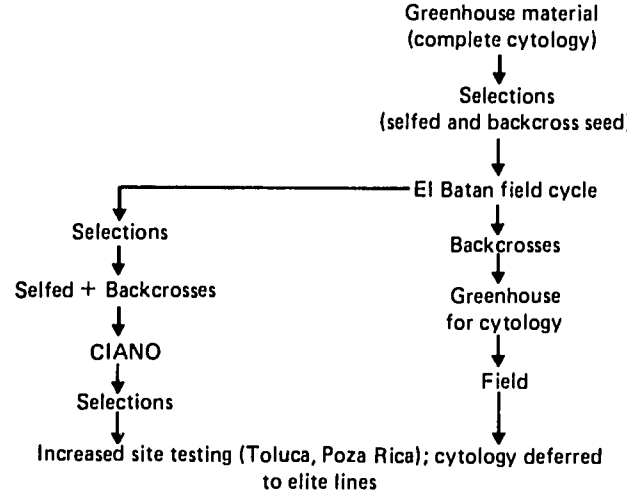


Figure 3. Procedures for cytology and field testing of derivatives from intergeneric hybrid combinations.

are desired. The shift in the program's hybridization efforts could overcome this constraint in the future. Another solution to the problem may be homoeologous exchanges by suppressing the Ph locus in advanced generations, as well as the development of practical alien substitution lines that would induce wheat/alien chromosome translocations in a manner similar to the natural production of the 1B/1R translocation.

Irradiation and tissue culture will receive a lower priority in the future, primarily because alien gene transfers cannot be controlled with precision. Wide cross material will be made available to related cereal tissue culture groups for making alien gene transfers.

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- Dr. G. Bekele (CIMMYT): *Fusarium graminearum* screening
- Dr. P. Burnett (CIMMYT): BYDV screening
- E. Warham (CIMMYT): Karnal bunt screening
- G. W. Jones (Wales): Salt tolerance screening
- M. Gale and C. Ainsworth (P.B.I., England): Isozyme analyses for 1B/1R detection and *A. distichum* introgressions

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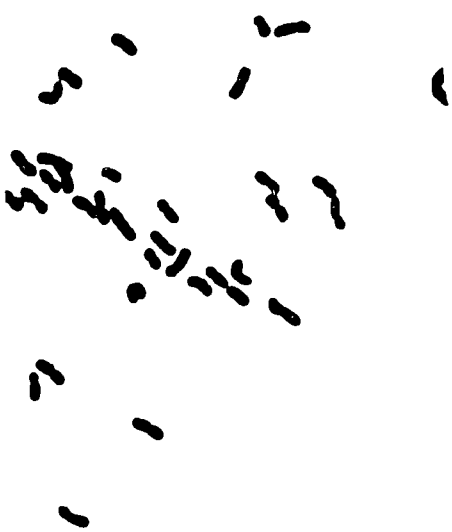


Figure 4. A *T. aestivum*/alien species (*A. repens-A. desertorum*) hybrid with 35 chromosomes at meiotic metaphase I showing predominance of univalents (lack of recombination).

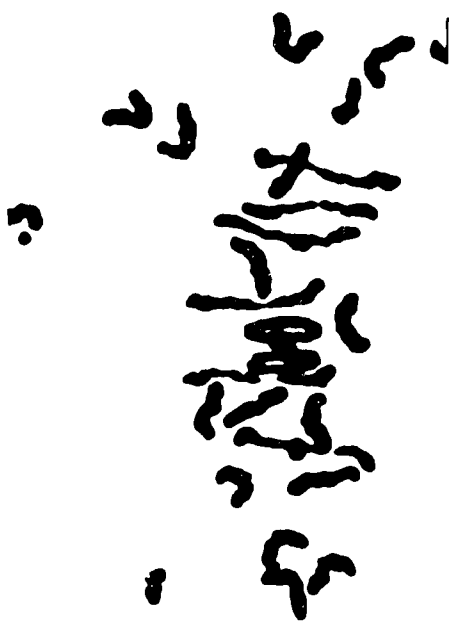


Figure 5. A *T. aestivum/A. scythicum* hybrid with 35 chromosomes, showing high recombination at meiotic metaphase I.

Figure 6. *T. aestivum/A. junceum* hybrid with 35 chromosomes at meiotic metaphase I showing rod and ring bivalents attributed to autosyndetic and/or homoelogous pairing.

Table 1. Some perennial intergeneric and trigeneric hybrids maintained at El Batan under greenhouse and/or field conditions

Cross combination	Cross number[a]	Chromosome number
T. aestivum/Agropyron spp.		
Chinese Spring/*A. acutum*	B82-10824	n = 6x = 42
Fremont/*A. acutum*	B82-11004	n = 6x = 42
Nacozari 75/*A. acutum*	B82-11058	n = 6x = 42
Chinese Spring/*A. caespitosum*	B82-10692	n = 5x = 35
Chinese Spring/*A. campestre*	B82-10759	n = 7x = 49
Chinese Spring/*A. curvifolium*	B82-10939	n = 5x = 35
Chinese Spring/*A. elongatum* (10x)	B81-1084	n = 8x = 56
Chinese Spring-Cno (E)/*A. elongatum* (10x)	B81-1176	n = 8x = 56
Nyu Bay/*A. elongatum* (10x)	B81-1194	n = 8x = 56
Pavon 76/*A. elongatum* (10x)	B81-1064	n = 8x = 56
Zaragoza/*A. elongatum* (10x)	B81-1065	n = 8x = 56
Chinese Spring/*A. intermedium*	B82-10516	n = 6x = 42
Glennson 81/*A. intermedium*	B82-10848	n = 6x = 42
Nacozari 75/*A. intermedium*	B82-10656	n = 6x = 42
Chinese Spring/*A. podperae*	B82-5063	n = 6x = 42
Chinese Spring/*A. pulcherrimum*	B82-10643	n = 6x = 42
Chinese Spring/*A. junceum* (2x)	B82-10840	n = 4x = 28
Chinese Spring/*A. junceum* (4x)	B82-10780	n = 5x = 35
Fielder/*A. junceum* (4x)	B82-10990	n = 5x = 35
Fremont/*A. junceum* (4x)	B82-10910	n = 5x = 35
Pavon 76/*A. junceum* (4x)	B82-10995	n = 5x = 35
Chinese Spring/*A. junceum-mediterranean* (6x)	B82-11049	n = 6x = 42
Tobari 66/*A. junceum-mediterranean* (6x)	B79-1006	n = 6x = 42
Chinese Spring/*A. rechingeri*	B82-10682	n = 5x = 35
Pavon 76/*A. rechingeri*	B82-10669	n = 5x = 35
Chinese Spring/*A. repens*	B82-5049	n = 6x = 42
Chinese Spring//*A. repens/A. desertorum* (C-3)	B82-10559 to 10585	n = 35 = 57
Chinese Spring/*A. scirpeum*	B82-11042	n = 5x = 35
Chinese Spring/*A. scythicum*	B82-10865	n = 5x = 35
Fremont/*A. scythicum*	B82-10861	n = 5x = 35
Chinese Spring/*A. trichophorum*	B82-10602	n = 6x = 42
Chinese Spring/*A. varnense*	B82-10899	n = 6x = 42
Nacozari 75/*A. varnense*	B82-10948	n = 6x = 42
Pavon 76/*A. varnense*	B82-10975	n = 6x = 42
Fielder/*A. varnense*	B82-11008	n = 6x = 42
Chinese Spring Ph Ph/*A. acutum*	B83-4630	n = 6x = 42
Chinese Spring Ph Ph/*A. caespitosum*	B83-4614	n = 5x = 35
Chinese Spring Ph Ph/*A. elongatum*	B84-5984	n = 8x = 56
Chinese Spring Ph Ph/*A. intermedium*	B84-5995	n = 6x = 42
Chinese Spring Ph Ph/*A. trichophorum*	B84-6002	n = 6x = 42
Chinese Spring Ph Ph/*A. varnense*	B83-4626	n = 6x = 42

(continued)

Table 1 (continued)

Cross combination	Cross number[a]	Chromosome number
T. aestivum/Haynaldia spp.		
Chinese Spring/*H. villosa*	B32-2528	n = 4x = 28
T. aestivum/Elymus spp.		
Fremont/*E. angustus*	Log82-135	n = 9x = 63
Chinese Spring/*E. cinereus*	B82-10694	n = 5x = 35
Chinese Spring/*E. giganteus*	B79-1002	n = 5x = 35
Chinese Spring/*E. giganteus*	B82-10652	n = 5x = 35
Chinese Spring/*E. triticoides*	B82-10653	n = 5x = 35
Agropyron spp./*T. aestivum*		
A. elongatum (10x)/Bonza	B81-1058	n = 8x = 56
A. elongatum (10x)/Jupateco 73	B80-1054	n = 8x = 56
A. fibrosum/Pavon 'S'	B81-1037	n = 5x = 35
A. fibrosum/Pavon 76	B81-1038	n = 2x = 14
Elymus spp./*T. aestivum*		
E. agropyroides/Chinese Spring-Ciano (E)	B81-1012A	
E. agropyroides/Nyu Bay	B79-1018	n = 6x = 42
E. agropyroides/Zaragoza 75	B79-1019	n = 6x = 42
E. dahuricus/Pitic 66	B81-1009A	n = 6x = 42
Other combinations		
A. elongatum (4x)/*H. vulgare*	B79-1009	n = 3x = 21
A. junceum (2x)/*A. junceum* (4x)	B84-5982	n = 3x = 21
A. elongatum (4x)/*S. cereale*	B79-1008	n = 3x = 21
A. trachycaulum/E. giganteus	Log80-70	n = 4x = 28
E. agropyroides/E. giganteus	Log80-22	n = 5x = 35
E. canadensis/H. vulgare	B79-1027	n = 3x = 21
Elymus spp./*S. cereale* (4x)	B81-1008	n = 4x = 28
H. vulgare/E. canadensis	B79-1031	n = 3x = 21
H. vulgare/E. patagonicus	B79-1015	n = 4x = 28
T. turgidum/Agropyron spp.		
Cocorit 71/*A. acutum*	B-4316	n = 5x = 35
G-803/*A. acutum*	B83-4604	n = 5x = 35
Yavaros 79/*A. acutum*	B83-4297	n = 5x = 35
Cocorit 71/*A. littorale-campestre*	B83-4337	n = 6x = 42
Cocorit 71/*A. intermedium*	B83-4346	n = 5x = 35
Mexicali 75/*A. intermedium*	B83-4438	n = 5x = 35
Yavaros 79/*A. intermedium*	B83-4309	n = 5x = 35
Cocorit 71/*A. junceum* (4x)	B83-4373	n = 4x = 28
Cocorit 71/*A. junceum-mediterrancan* (6x)	B79-1004	n = 5x = 35

(continued)

Table 1 (continued)

Cross combination	Cross number[a]	Chromosome number
Cocorit 71/*A. podperae*	B81-5036	n = 5x = 35
Mexicali 75/*A. podperae*	B83-4416	n = 5x = 35
Cocorit 71/*A. pulcherrimum*	B83-4385	n = 5x = 35
Mexicali 75/*A. pulcherrimum*	B83-4470	n = 5x = 35
Mexicali 75/*A. scythicum*	B81-5040	n = 4x = 28
Mexicali 75/*A. trichophorum*	B83-4524	n = 5x = 35
Mexicali 75/*A. varnense*	B83-4536	n = 5x = 35
G-803/*A. varnense*	B83-4572	n = 5x = 35
Cappelli Ph Ph/*A. acutum*	B83-4552	n = 5x = 35
Cappelli Ph Ph/*A. intermedium*	B83-4545	n = 5x = 35
Cappelli Ph Ph/*A. varnense*	B83-4546	n = 5x = 35
T. timopheevii/Agropyron spp.		
T. timopheevii/A. elongatum (10x)	B81-1241	n = 7x = 49
Agropyron spp./*T. turgidum*		
A. elongatum/Cocorit 71	B79-1012	n = 3x = 21
A. fibrosum/Cocorit 71	B81-1040	n = 4x = 28
A. fibrosum/Mexicali 75	B80-1046	n = 4x = 28
A. fibrosum/Quilafen	B80-1050	n = 4x = 28
A. scabrifolium/Mexicali	L80-1765B	
A. sibericum/Cocorit 71	L80-1062	n = 4x = 28
A. trachycaulum/Cocorit 71	B80-1033	n = 4x = 28
A. trachycaulum/Mexicali	B80-1032	n = 4x = 28
Elymus spp./*T. turgidum*		
E. virginicus/Cocorit 71	B81-5035	
Trigeneric hybrids		
A. fibrosum/T. turgidum//S. cereale	L80-1758B	n = 5x = 35
E. canadensis/T. aestivum//S. cereale	B84-6025	n = 6x = 42
T. aestivum/A. curvifolium//S. cereale	B83-6112	n = 6x = 42
T. aestivum/A. intermedium//S. cereale	B83-6153	n = 7x = 49
T. aestivum/A. junceum (4x)*//S. cereale*	B83-5269	n = 6x = 42
T. aestivum/A. pulcherrimum//S. cereale	B84-6023	n = 7x = 49
T. aestivum/E. giganteus//A. elongatum	B81-1255	n = 10x = 70
T. aestivum/E. giganteus//T. aestivum/3/ *A. elongatum*	B81-1259	n = 59-66
T. aestivum/E. giganteus//S. cereale	B81-1270	n = 6x = 42
*T. timopheevii/H. bogdanii**//S. cereale*	B81-5109	n = 4x = 28

* F_1 source G. Kimber obtained as amphidiploid

[a] The cross number assigned to each combination will be the reference number used for that combination in the future

Table 2. Annual intergeneric hybrids between *Triticum turgidum* and *T. aestivum* with some alien species

Cross combination	Cross number[a]	Chromosome number
T. turgidum/Aegilops spp.		
Cocorit 71/*Ae. biuncialis* (11B)	B84-546	n = 4x = 28
Yavaros 79/*Ae. biuncialis* (10A)	B84-549	n = 4x = 28
Yavaros 79/*Ae. caudata* (16A)	B84-561	n = 3x = 21
Cocorit 71/*Ae. ovata* (3A)	B84-539	n = 4x = 28
Mexicali 75/*Ae. ovata* (3A)	B83-3823	n = 4x = 28
Yavaros 79/*Ae. sharonensis* (29A)	B84-563	n = 3x = 21
Cocorit 71/*Ae. umbellulata* (1A)	B84-538	n = 3x = 21
Mexicali 75/*Ae. uniaristata* (22B)	B84-572	n = 3x = 21
Yavaros 79/*Ae. vavilovii* (41A)	B84-570	n = 5x = 35
T. aestivum/Aegilops spp.		
Genaro 81/*Ae. biuncialis* (11B)	B84-176	n = 5x = 35
Nacozari 76/*Ae. biuncialis* (10A)	B84-212	n = 5x = 35
Pavon 'S'/*Ae. biuncialis* (10A)	B84-90	n = 5x = 35
Pavon 'S'/*Ae. biuncialis* (11B)	B84-161	n = 5x = 35
Alondra 'S'/*Ae. caudata* (16A)	B83-1007	n = 4x = 28
Ciano 79/*Ae. caudata* (16A)	B84-533	n = 4x = 28
Chinese Spring/*Ae. columnaris* (9A)	B84-82	n = 5x = 35
Nacozari 76/*Ae. columnaris* (9A)	B83-2517	n = 5x = 35
Genaro 81/*Ae. crassa* (40c)	B83-1035	n = 6x = 42
Genaro 81/*Ae. cylindrica* (18G)	B83-2523	n = 5x = 35
Glennson 81/*Ae. cylindrica* (18G)	B83-2508	n = 5x = 35
Pavon 'S'/*Ae. cylindrica* (17A)	B83-2468	n = 5x = 35
(Tibet source)/*Ae. cylindrica* (17A)	B84-207	n = 5x = 35
Chinese Spring Ph Ph/*Ae. juvenalis* (45A)	B83-2459	n = 6x = 42
Nacozari 76/*Ae. longissima* (27A)	B83-2655	n = 4x = 28
Chinese Spring mono 5B/*Ae. ovata* (3A)	B83-1005	n = 5x = 35
Ciano 79/*Ae. ovata* (3A)	B84-259	n = 5x = 35
Fremont/*Ae. ovata* (3A)	B83-2515	n = 5x = 35
Nacozari 76/*Ae. ovata* (3A)	B84-145	n = 5x = 35
Alondra 'S'/*Ae. sharonensis* (29A)	B83-1060	n = 4x = 28
Fremont/*Ae. sharonensis* (30B)	B84-3818	n = 4x = 28
Genaro 81/*Ae. sharonensis* (29A)	B84-229	n = 4x = 28
Nacozari 76/*Ae. sharonensis* (29A)	B84-201	n = 4x = 28
Nacozari 76/*Ae. sharonensis* (30B)	B84-129	n = 4x = 28
Pavon 'S'/*Ae. sharonensis* (29A)	B84-117	n = 4x = 28
Pavon 'S'/*Ae. sharonensis* (30B)	B84-113	n = 4x = 28
Zaragoza 75/*Ae. sharonensis* (29A)	B83-1062	n = 4x = 28
Genaro 81/*Ae. triaristata* (5F)	B83-2526	n = 5x = 35
Inia 66/*Ae. triaristata* (5F)	B83-1038	n = 5x = 35

(continued)

Table 2 (continued)

Cross combination	Cross number[a]	Chromosome number
Inia 66/*Ae. triaristata* (6G)	B83-1009	n = 5x = 35
Pavon 'S'/*Ae. triaristata* (6G)	B83-2491	n = 5x = 35
Fremont/*Ae. triaristata* (7A)	B84-2525	n = 6x = 42
Nacozari 76/*Ae. triaristata* (8B)	B84-81	n = 6x = 42
Genaro 81/*Ae. triuncialis* (14A)	B84-191	n = 5x = 35
Glennson 81/*Ae. triuncialis* (14A)	B83-2432	n = 5x = 35
Nacozari 76/*Ae. triuncialis* (14A)	B84-185	n = 5x = 35
Pavon 'S'/*Ae. triuncialis* (14A)	B84-97	n = 5x = 35
Chinese Spring/Genaro 81//*Ae. umbellulata* (1A)	B83-1055	n = 4x = 28
Ciano 79/*Ae. umbellulata* (1A)	B84-530	n = 4x = 28
Genaro 81/*Ae. uniaristata* (21A)	B83-1084	n = 4x = 28
Chinese Spring mono 5B/*Ae. variabilis* (13 E)	B84-238,239	n = 5x = 35
Ciano 79/*Ae. variabilis* (12A)	B84-272	n = 5x = 35
Ciano 79/*Ae. variabilis* (13E)	B84-270	n = 5x = 35
Genaro 81/*Ae. variabilis* (12A)	B84-222	n = 5x = 35
Genaro 81/*Ae. variabilis* (13E)	B84-246	n = 5x = 35
Pavon 'S'/*Ae. variabilis* (12A)	B83-2527	n = 5x = 35
Chinese Spring mono 5B/*Ae. vavilovii* (42B)	B83-1039	n = 6x = 42
Genaro 81/*Ae. vavilovii* (41A)	B83-1037	n = 6x = 42
Genaro 81/*Ae. ventricosa* (44B)	B83-1070	n = 5x = 35
Aegilops spp./*T. aestivum*		
Ae. longissima/Ciano 79	B84-277	n = 4x = 28
H. vulgare/*T. turgidum*		
Mauker/Cocorit 71	B79	n = 3x = 21
H. vulgare/*T. aestivum*		
Mauker/Tobari 66	B79	n = 4x = 28
T. aestivum/*H. vulgare*		
Tesia/Calmr. Dickson Hiproly	B81-L-1003	n = 4x = 28

[a] The cross number assigned to each combination will be the reference number used for that particular combination in the future

Table 3. Alien species exhibiting seedling resistance to *Helminthosporium sativum* in greenhouse testing at El Batan, 1984

Alien species	Chromosome number	Disease score[a]
*Agropyron junceum**	2n = 2x = 14	1
*Agropyron elongatum**	2n = 2x = 14	1
Agropyron yezoense	2n = 4x = 28	1
*Agropyron scabrifolium**	2n = 4x = 28	1
Aegilops squarrosa (several accessions)	2n = 2x = 14	1
Aegilops triuncialis	2n = 4x = 28	1
*Haynaldia villosa**	2n = 2x = 14	1
*Agropyron campestre**	2n = 8x = 56	2
*Agropyron scirpeum**	2n = 4x = 28	2
*Agropyron rechingeri**	2n = 4x = 28	2
*Agropyron trachycaulum**	2n = 4x = 28	2
Agropyron ferganensis	2n = 4x = 28	2
*Agropyron subsecundum**	2n = 4x = 28	2
*Agropyron scythicum**	2n = 4x = 28	2
Elymus junceus	2n = 2x = 14	2
*Elymus dahuricus**	2n = 6x = 42	2
Elymus arenarius	2n = 4x = 28	2

[a] Scoring scale: 1 = Resistant, 5 = Susceptible

* Hybrid germplasm available in CIMMYT

Table 4. Alien species with less than 5% infection following boot inoculations with *Neovossia indica*

Alien species	CIMMYT accession number	Chromosome number	% Infection
Aegilops umbellulata	1A	2n = 2x = 14	0
Ae. ovata	3A	2n = 4x = 28	0
Ae. ovata	4E	2n = 4x = 28	0
Ae. triaristata	5F	2n = 4x = 28	0
Ae. triaristata	6G	2n = 4x = 28	0
Ae. triaristata	7A	2n = 6x = 42	0
Ae. columnaris	9A	2n = 4x = 28	0
Ae. variabilis	12A	2n = 4x = 28	3
Ae. variabilis	13E	2n = 4x = 28	0
Ae. triuncialis	15x	2n = 4x = 28	1
Ae. cylindrica	17A	2n = 4x = 28	2
Ae. cylindrica	18G	2n = 4x = 28	1
Ae. crassa	37A	2n = 4x = 28	0
Ae. crassa	38d	2n = 4x = 28	0
Ae. vavilovii	41A	2n = 6x = 42	0
Ae. ventricosa	43A	2n = 4x = 28	0
Ae. juvenalis	45A	2n = 6x = 42	0
Agropyron fibrosum		2n = 4x = 28	0

Germplasm Development

R. Rodríguez R.

Introduction

The basic objectives of germplasm development in the Wheat Program are to develop bread wheats, durum wheats, triticales, and ryes possessing such special characteristics as disease resistance or tolerance to high levels of free aluminum. After the yield and plant type of this germplasm have been improved, it becomes available to the breeding programs and is used in developing new CIMMYT lines.

In 1984, special priority was given to combining broad disease resistance and aluminum tolerance, assessing isogenic lines for rust resistance, improving certain yield components, and evaluating triticales derived from triticale x wheat crosses. Work on early maturity quality characteristics (especially loaf volume), and interspecific crosses in wheat increased. Attempts to raise the protein content of bread wheat have continued, but this project received less attention in 1984 than in previous years.

Ing. R. Rodríguez, head of the germplasm development program, examines materials that may prove useful in improving yield components in bread wheat.

Bread Wheats

Protein content—Experiments were performed during the 1983-84 cycle to determine grain and protein yield in the uniform lines designed for this purpose, and results similar to those obtained in the 1982-83 cycle were obtained. The grain yield, protein content expressed as kg/ha, and loaf volumes of the best lines in these trials are given in Tables 1, 2, and 3.

Grain yields of several lines were similar to those of the commercial check varieties, and some lines produced more protein per hectare than the checks, Tesia 79 and Ciano 79. Moreover, entry 31, third in yield in Experiment 2, was equal or superior to Tesia 79 in protein content and superior in loaf volume over two cycles (1982-83 and 1983-84) (Table 2). Yields of entry 69 were equal to those of Tesia 79, and this line surpassed Tesia 79 and Genaro 81 in protein content and loaf volume (Table 3). Compared to Ciano 67, entries 31 and 69 yielded better and had a higher protein content, although their loaf volumes were similar to that of CIANO 67 (Table 3).

These data cannot be considered conclusive after only two cycles of tests, but they do indicate that it is possible to raise protein content. A concomitant improvement in loaf volume, which is a characteristic of great importance in bread making, may also be possible (Tables 1, 2, and 3).

In 1985, new material will be evaluated in yield trials to collect more data on protein content, grain yields, and loaf volume of bread wheats.

Early maturity—Time to maturity can determine the acceptability of a variety for production in a given region. An early-maturing variety of wheat makes sowing possible where environmental conditions necessary for the crop's development exist only for a brief part of the year, and permits cultivation of land that lies fallow for short periods of time. This characteristic also enhances the ability to grow two or even three crops in one year.

For these reasons, the germplasm development program has been selecting for this trait for some time, and has identified early maturing lines (Table 4). The earliest maturing lines are derived from Bb No. 7/Nap Hal//Mahratta/Maya 'S' (cross CMH73A.497); some of them head five days before Ciano 67 and Sonalika. For several cycles, this material has been used in crosses with higher yielding varieties of bread wheats in an attempt to maintain earliness while increasing yield potential. Efforts are also being made to transfer earliness to durum wheat and triticale.

Disease resistance in aluminum-tolerant germplasm—CIMMYT's cereal improvement programs have recognized the advantage of developing germplasm that is both resistant to diseases and tolerant to high levels of aluminum. Nearly isogenic lines, in which height and earliness were modified, were developed from aluminum-tolerant Brazilian varieties having resistance to diseases prevalent in Brazil. The second phase of the breeding work involves crossing the better isogenic lines (material similar to that shown in Table 5) to obtain material with good agronomic type, aluminum tolerance, and resistance to prevalent diseases. Numerous single and multiple crosses have been made to achieve this goal, and crosses that demonstrated the best agronomic performance in the 1984 summer cycle are included in Table 6. If this project is successful, the improved material can be used to develop wheats for subtropical regions.

Leaf rust resistance—In the 1983-84 cycle, yield tests were conducted on nearly 100 advanced isogenic lines of such varieties as Yecora 70, Inia 66, Sonalika, and Jupateco 73, each of which carried one of the genes Lr9, Lr19, Lr20, Lr21, or Lr24. Their performance was similar to that observed in yield tests performed in past cycles. Many lines yielded more than their recurrent parents, and Agatha-Yecora 70 was outstanding, continuing to show yields comparable to those of the highest yielding current commercial varieties. The overall performance of Agatha-Yecora 70 should be further evaluated to determine the feasibility of using this isogenic line as a variety as well as in multilines.

Yield components—Several uniform lines of large-spiked wheat that demonstrated agronomic type and grain development suitable for the conditions of the Yaqui Valley were identified in 1984. The agronomy program began to study the performance of these lines under different cultural practices to evaluate their yield potential. By 1985, more advanced lines with better agronomic type and grain-filling potential will also be submitted for screening under different agronomic practices. Information obtained from these trials will help determine how this material might be made to yield better.

Variability for yield potential does not appear to be exhausted in wheat, especially if its related species are considered. The large-spiked wheats obtained so far, which have more than 50 spikelets per spike, are tremendously useful because they provide more space for grains to develop, a quality that will make any increase in yield readily apparent. This attribute could prove to be helpful in the program's search for bread wheat germplasm with higher yield potential.

Durum Wheat

Breeding objectives in durum wheat mainly concern such characteristics as solid stem, stem rust resistance, lax spikes, early maturity, and yield components. Considerable progress has been made in breeding for these traits, although material with the best agronomic type has been obtained in solid stem wheats. The following lines showed homozygosity for solid stems under conditions at El Batan during summer, 1984:

- CMH74.1053/6*ZB//
  Corm 'S'/3/CMH74.1053/6*ZB
  CMH82A.1014-A-1B-1Y
- CMH76A.169/3*Mex75
  CMH82A.844-1B-3Y
- CMH76A.169/2*Mex75//Yav 'S'
  CMH82A.847-2B-2Y
- CMH76A.169/2*Mex75//Hui 'S'
  CMH82.692-3Y-1B-2Y
- CMH76A.169/2*Mex75//
  Mex75/2*Shwa 'S'
  CMH82A.858-2B-2Y
- CMH76A.169/2*Mex75//
  Mex75/2*Shwa 'S'/3/Corm 'S'
  CMH82A.853-2B-3Y

Since this material is homozygous for solid stem and good agronomic type under conditions at El Batan, no problems are anticipated with the incorporation of this characteristic into durum wheat advanced materials.

Triticale

Past reports on germplasm development have mentioned that breeding work with triticales is based mainly on triticale x wheat crosses. From these crosses, lines that are phenotypically triticales, in which one or several traits come from wheat, have been selected, as well as lines that are phenotypically wheat, but possess some characteristics of triticale. In this way, triticale lines were recovered whose height, early maturity, texture, and grain-filling potential were modified by factors transferred from the wheat. These lines show good uniformity and are apparently more stable than conventional triticale varieties. They also show low alpha-amylase activity, and their grain yields are comparable to those of normal triticales (Table 7).

These advantages have two implications for future work in germplasm development. First, triticale's agronomic type and grain-filling potential can be improved through triticale x wheat crosses; second, if triticale has greater biomass potential than wheat, then triticale lines should be developed for cultivation not only on marginal lands, but also on the best land currently set aside for wheat production. In the next few years, the program will have at its disposal material that can be studied with regard to these two points.

Some of the triticale lines that are phenotypically wheat, or very nearly so, contain rye chromosomes. During the 1983-84 season at CIANO, Dr. A. Merker collected samples of this material to study it cytologically and determine its chromosome composition (Table 8). Since disease resistance, high lysine content, drought and cold tolerance, tolerance to low pH and to aluminum, and an efficient assimilation of copper are found in the chromosome complement of rye (A. Merker, personal communication), this analysis helped indicate which lines were useful.

Interspecific Crosses

The Wheat Program has recently shown great interest in setting up a program for interspecific crosses in the hope of discovering new sources of disease resistance, drought and salt tolerance, and generally broadening the genetic variation essential for developing better wheat varieties. The program currently possesses several collections, including such species as *Triticum araraticum*, *T. boeoticum*, *T. monococcum*, *T. urartu*, *T. dicoccum*, *T. dicoccoides*, and *T. zhukovsky*.

During the 1984-85 season, these species will be observed for the first time at CIANO. This initial crop will provide an opportunity to increase seed of these species, since a considerable quantity will be necessary to evaluate their disease resistance and performance under different environmental conditions.

International Nurseries

In 1984, four nurseries were prepared for cooperators upon request, and distributed to appropriate testing sites. The following is a list of nurseries and the number of sets distributed:

Yield component lines (bread wheat)	67
Yield component lines (durum wheat)	30
Leaf rust resistant lines	68
Aluminum tolerant and disease resistant lines	61
Total	226

Table 1. Germplasm with high protein content and grain yield in experiment 1, CIANO, 1983-84

Rank in yield	Variety or cross and pedigree	Entry no.	Yield (kg/ha)		Protein[a] content (kg/ha)		Loaf volume (cc)		Days to flowering
			1982-83	1983-84	1982-83	1983-84	1982-83	1983-84	1983-84
1	Tesia 79	24	6250	6822	521	565	635	840	76
2	Ciano 79	25	7306	6450	520	440	715	695	74
3	Ron2/Fnd//Nac76 CMH77A.11-3B-3Y-4B-1Y-1B-2Y-1B-1Y-1B-0Y	9		6311		529		660	70
4	Ron2/Fnd//Pato/3/ Ron2/Fnd/4/2*Pvn 'S' CMH80A.82-4B-1Y-0B	3		6294		536		840	74
5	CMH75A.66/Cno79 CMH80.15-3Y-5B-4Y-1B-1Y-0B	12		6239		580		870	69
6	CMH75A.66/Cno79 CMH79A.21-5B-4Y-7B-3Y-0B	22		6017		477		770	73
7	CMH75A.66/Cno79 CMH79A.21-5B-4Y-7B-3Y-2B-5Y-0B	20		5889(+)		555		740	69
17	Ciano 67	23	4236	5006	420	507	865	975	68

Coefficient of variation = 12.1%
LSD 5% = 1074 kg/ha (+)

[a] Obtained by converting the percentage of flour extracted to kg/ha, and multiplying by the percentage of protein
[b] Figures from the milling and baking laboratory, El Batan

Table 2. Germplasm with high protein content and grain yield in experiment 2, CIANO, 1983-84

Rank in yield	Variety or cross and pedigree	Entry no.	Yield (kg/ha)		Protein[a] content (kg/ha)		Loaf volume[b] (cc)		Days to flowering
			1982-83	1983-84	1982-83	1983-84	1982-83	1983-84	1983-84
1	Tesia 79	50	6250	6850	521	579	635	815	78
2	CMH75A.66/Cno79 CMH80.15-3Y-1B-0Y	30	5542	6294	450	540	710	825	71
3	CMH75A.66/Her77// CMH75A.66 CMH80.127-2Y-1B-0Y	31	4833	6183	521	595	865	950	74
4	Cal/NH//2*Sx CMH79A.45-1B-4Y-4B-1Y-0B	34		5906		414		695	78
5	CMH75A.66/Her77// CMH75A.66 CMH80.127-2Y-5B-1Y-1B-0Y	32		5861		586		1025	75
6	KC10863/2*Hork 'S' CMH79.41-1Y-1B-1Y-1B-2Y-0B	42		5805		497		815	71
7	PMN5//Aga/4*Ti71 CMH80.70-1Y-6B-0Y	48		5711(+)		557		1025	77
21	Ciano 67	49	4236	4638	420	470	865	1025	66

Coefficient of variation = 13.5%
LSD 5% = 1172 kg/ha (+)

[a] Obtained by converting the percentage of flour extracted to kg/ha and multiplying by the percentage of protein
[b] Figures from the milling and baking laboratory, El Batan

Table 3. Germplasm with high protein content and grain yield in experiment 3, CIANO, 1983-84

Rank in yield	Variety or cross and pedigree	Entry no.	Yield (kg/ha)		Protein[a] content (kg/ha)		Loaf volume[b] (cc)		Days to flowering
			1982-83	1983-84	1982-83	1983-84	1982-83	1983-84	1983-84
1	Genaro 81	75		6800		477		720	86
2	Cal/NH//CMH73A.497/3/ Her77 CMH79.196-6Y-3B-4Y-1B-0Y	69	6097	6122	628	568	865	965	69
3	Tesia 79	74	6250	6006(+)	521	469	635	840	78
12	Ciano 67	73	4528	4606	461	483	860	945	64

Coefficient of variation = 14.7%
LSD 5% = 1133 kg/ha (+)

[a] Obtained by converting the percentage of flour extracted to kg/ha, and multiplying by the percentage of protein
[b] Figures from the milling and baking laboratory El Batan

Table 4. Days to flowering of earliest maturing wheats, El Batan, 1984

Variety or cross and pedigree	Days to flowering
Ciano 67	60
Sonalika	58
CMH73A.497/Giorgio//2*CMH73A.497 CMH83.45-1Y	54
CMH73A.497/Cno79//CMH73A.497 CMH81A.78-11B-1Y-1B-2Y	56
CMH76.173/Gen81 CMH81A.47-8B-2Y-1B-1Y	55
Son64/3/Y50/H570.71//2*Y50 CMH81A.396-11B-1Y-2B-1Y	56
CMH78.168/2/Aga/4*Ti71 CMH81A.49-6B-3Y-3B-4Y	56
CMH78.168/Ska CMH81.31-4Y-1B-4Y-3B-1Y	56
CMH73A.497/Giorgio//CMH73A.497 CMH81.105-1Y-4B-5Y-1B-1Y	55
CMH73A.497/Bb7/NH//Mta/Maya 'S' CMH73A.497-4B-1Y-1B-0Y	53
CMH78.168/Hork 'S'//CMH73A.497 CMH78.168-3Y-3B-1Y-5B-0Y	52

Table 5. Performance of nearly-isogenic lines tolerant to aluminum toxic soils

Cross and pedigree	Height[a] (cm)	Aluminum tolerance		Recurrent parent	
		Lab(%)[b]	Field[c]	Height[a] (cm)	Aluminum tolerance[d]
H567.71/5*Pat73121 CMH80.292-1Y-9B-4Y-6B-2Y-0Y	60	0.0	R	100	Tolerant
IAS20/H567.71//4*IAS20 CMH79A.209-11B-4Y-0B	90	83.3	MR-R	105	Tolerant
IAS20/H567.71//4*IAS20 CMH79.243-1Y-5B-1Y-0B	90	60.0	MR-R	105	Tolerant
IAS20/H567.71//4*IAS20 CMH79.243-1Y-5B-1Y-0B-3B-0Y	90	46.7	MR	105	Tolerant
IAS20/H567.71//5*IAS20 CMH78A.544-1B-1Y-4B-1Y-2B-0Y	60	70.0	MR	105	Tolerant
S948A1/4*Bza//4*IAS58 CMH79A.221-1B-1Y-1B-4Y-0B	80	96.7	MR	100	Tolerant
CMH80.279/CNT8 CMH80A.253-3B-1Y-1B-2Y-0Y	60	0.0	S	100	Tolerant
Par/Cj71//5*Par CMH80.278-2Y-8B-2Y-1B-0Y	100	96.7	R	110	Tolerant
Par/Cj71//5*Par CMH80.278-2Y-8B-2Y-3B-0Y	100	83.3	MR	110	Tolerant
H567.71/3*Par CMH77.308-1Y-4B-1Y-5B-1Y-3B-0Y	80	33.3	MR	110	Tolerant
CMH75A.323/6*PF71131 CMH80A.247-3B-1Y-3B-0Y	60	86.7	MS	120	Tolerant
S20/H567.71//4*S20 CMH80A.256-2B-3Y-4B-0Y	60	73.3	MS	100	Tolerant
CMH79A.307/BH1146 CMH81.137-4Y-7B-2Y-0Y	45	83.3	MR	100	Tolerant
CMH75A.271/3*Mrng CMH79A.219-5B-1Y-1B-0Y	60	76.7	R	120	Tolerant
CMH75A.271/3*Mrng CMH80A.211-3B-1Y-5B-0Y	85	100.0	R	120	Tolerant

(continued)

Table 5 (continued)

Cross and pedigree	Height[a] (cm)	Aluminum tolerance		Recurrent parent	
		Lab(%)[b]	Field[c]	Height[a] (cm)	Aluminum tolerance[d]
CMH75A.271/5*Mrng CMH80A.212-2B-1Y-2B-0Y	85	100.0	R	120	Tolerant
CMH75A.271/5*Mrng CMH80A.212-2B-1Y-2B-0Y-1B-0Y	80	100.0	R	120	Tolerant
CMH75A.270/5*Mrng CMH80.328-12Y-3B-1Y-3B-1Y-0Y	90	100.0	MR	120	Tolerant
Pel13298.65/H569.71//5*Pel13298.65 CMH81.260-8Y-2B-4Y-0Y	75	63.3	S	115	Tolerant
Clt//S948A1/4*Cno 'S'/3/2*Clt CMH81.190-3Y-5B-4Y-1B-0Y	45	100.0	S	125	—
Gra/CMH76A.977//3*Gra CMH80A.233-1B-2Y-1B-3Y-0Y	90	10.0	MR	100	Tolerant
H569.71/5*Jacui CMH80.288-2Y-3B-1Y-3B-0Y	60	96.7	MR	105	Tolerant
H569.71/5*Pat7219 CMH80.291-5Y-5B-2Y-1B-3Y-0Y	85	90.0	S	105	Tolerant

a Data from El Batan, summer 1984
b Data from CIMMYT aluminum testing laboratory
c Data supplied by Ottoni de Sousa Rosa of EMBRAPA, 1984. R = Resistant; MR-R = Moderately resistant to resistant; S = Susceptible; MS = Moderately susceptible.
d Data from various sources

Table 6. Crosses among advanced lines to combine good agronomic type with disease resistance and aluminum tolerance

Cross	No. of cross
Par/Cj71//5*Par/3/Cno79	CMH82A.85
Par/Cj71//5*Par/3/Aga/4*Yr70	CMH82A.90
IAS20/H567.71//4*IAS20/3/ 2*PF70354/Ald 'S'	CMH82.230
IAS64/Ald 'S'//CMH78.390/ 3/IAS64/Ald 'S'	CMH82A.293
Aga/Yr70//Aga/3/2*Ald1	CMH81A.457
Ald1//Mrng/Ald 'S'/3/Ald1	CMH82.220
Pekin8/Cno79	CMH82A.116
Pekin8/Ald1	CMH82A.117
Fan415//RL6010/4*Jup73/3/Fan415	CMH82A.248
Fan415//Mrng/Ald 'S'/3/Fan415	CMH82.195
NyuBay/Nac76//NyuBay	CMH81A.190
CMH78.443//RL6010/4*Jup73/3/ CMH78.443	CMH82.205
Mrng/Ald 'S'/3/S20/H567.71// 3*S20	CMH82.144
Ald 'S'/CMH75A.270//2*Ald 'S'	CMH80A.206
CMH78.390/Ald 'S'	CMH81A.111
H569.71/4*Jacui//Cno79	CMH82.138
CMH80.279/CNT8//H567.71/ 5*Pat7219	CMH82A.192
H569.71/4*Pat7219//Cno79	CMH81A.172
H569.71/4*Pat7219//Gen81	CMH81A.226
H569.71/4*Pat7219//RL6010/4*Jup73	CMH81A.173
Fan415/CMH76A.977	CMH82.76
Ald 'S'/CMH76A.977	CMH82.101
IAS20/H567.71//5*IAS20/3/ RL6010/4*Inia66/4/Ald 'S'/ CMH76A.977	CMH82A.288
H569.71/4*Pat7219/3/Bad/ H567.71//2*Bad	CMH81A.176
Gra/CMH76A.977//4*Gra/3/Cno79	CMH82A.198
Gra/CMH76A.977//2*Gra/3/CMH80.279	CMH82.112
Gra/CMH76A.977//2*Gra/3/ Bad/H567.71//4*Bad	CMH82.113
Gra/CMH76A.977//2*Gra/3/IAS20/ H567.71//4*IAS20	CMH82.129
BH1146/H567.71//BH1146/3/ J8212.67/4/Gra/CMH76A.977// 2*Gra/3/Bad/H567.71//4*Bad	CMH82A.302

Table 7. Performance and yield components of lines resulting from triticale x wheat crosses, CIANO, 1983-84

Rank in yield	Variety or cross and pedigree	Yield (kg/ha)	Days to flowering	Height (cm)	Test weight[a] (kg/hl)	Hardness index[a]	Flour yield[a] (%)	Falling no.[ab]
1	CMH77A.1024/CMH77A.1165 CMH80 1022-3Y-7B-3Y-6B-0Y	6544	87	85	73.3	42.5	59.9	379
2	CMH77A.1024/CMH77A.1165 CMH80.1022-3Y-7B-3Y-4B-0Y	6233	87	90	73.2	42.5	56.9	336
3	CMH77A.1024/CMH77A.1165 CMH80.1022-3Y-7B-1Y-5B-4Y-0B	5788	88	95	73.3	51.5	63.6	343
4	Juanillo Triticale check	5577	81	120	74.1	48.5	69.1	116
5	Seri 82 Wheat check	5538	82	80	81.6	—	68.8	—
6	CMH77A.1024/CMH77.1135// CMH77A.1024 CMH81.1148-6Y-3B-5Y-0B	5461	79	80	73.0	48.5	66.7	295
7	CMH72A.576/Nac76/ /CMH77.1135 CMH80.1145-2Y-6B-2Y-2B-0Y	5416(+)	71	65	73.5	60.5	64.5	132
8	CMH77A.1024/CMH77.1135// CMH77A.1024 CMH81.1148-6Y-1B-2Y-0B	5172	80	80	74.6	49.0	67.7	223
10	Ciano 79 Wheat check	5044	79	80	82.6	—	68.0	—
11	Beagle Triticale check	4894	82	120	69.1	52.5	64.5	80
13	CMH72A.576/Nac76/ /CMH77.1135 CMH80.1145-2Y-6B-2Y-2B-1Y-0B	4772	70	65	74.3	56.5	62.2	116
14	CMH77A.1024/CMH77A.1165 CMH80.1022-3Y-7B-1Y-5B-5Y-0B	4722	90	90	72.5	54.0	65.8	431
15	CMH77A.1165/3/CMH72A.576/ CMH74.1072//GD CMH81.1219-3Y-4B-3Y-0B	4711	70	65	72.8	30.0	49.8	199
16	CMH77A.1165/3/CMH72A.576/ CMH74.1072//GD CMH81.1219-3Y-4B-2Y-0B	4705	74	70	74.9	28.5	46.7	228
17	CMH74.1211//4*M_2A/Cml CMH79A.1309-2B-1Y-1B-1Y-1B-0Y	4677	80	55	75.0	48.5	64.4	302

(continued)

Table 7 (continued)

Rank in yield	Variety or cross and pedigree	Yield (kg/ha)	Days to flowering	Height (cm)	Test weight[a] (kg/hl)	Hardness index[a]	Flour yield[a] (%)	Falling no.[ab]
21	CMH73.802/CMH73.648// CMH77.1135/3/CMH77A.1165 CMH80.1212-3Y-1B-2Y-3B-1Y-0B	4355	77	75	76.2	27.5	48.9	102
22	CMH72A.576/H569.71 CMH77.1135-3Y-1B-2Y-4B-0Y	4233	75	65	73.1	61.0	58.9	229
24	CMH73.802/CMH73.648// CMH77.1135/3/CMH77A.1165 CMH80.1212-3Y-1B-2Y-3Y-2Y-0B	3850	77	75	76.5	28.0	45.6	141
25	CMH74.1211/4*CMH74A.888 CMH80.1058-1Y-1B-3Y-4B-0Y	3666	77	55	73.5	29.5	58.7	363

a Information reported by CIMMYT milling and baking laboratory
b Falling number = measure of alpha-amylase activity

Coefficient of variation = 16.8
LSD 5% = 1356 kg/ha (+)

Table 8. Rye chromosomes identified in wheat-like lines collected at CIANO, 1983-84

Cross and pedigree	Rye chromosomes	Leaf rust[a]
Grizzly 'S'/CMH77A.917 CMH82A.1233-2B	1R	0
CMH73.802/2*Nor67 CMH80.1170-1Y-2B-1Y-5B-2Y-1B	1R,2R	0
CMH73.802/2*Nor67 CM80.1170-1Y-2B-1Y-5B-2Y-2B	1R,2R	0
CMH73.802/NV//Nac76 CMH81A.1261-4B-3Y-2B	1R,2R	TR
Pnd6/Inia66 CMH81A.1250-1B-2Y-1B	1R,2R,6R	0
Chiva 'S'/CMH74A.487 CMH82.967-2Y-1B	1R,6R	TMR-MS
CMH73A.785/3*Sx CMH81A.1243-7B-2Y-2B	1R,5R	0

Source: A. Merker, personal communication
a T = Trace, MR = Moderately resistant, MS = Moderately susceptible

Germplasm Bank

H.A. Sencer

Introduction

CIMMYT's wheat germplasm bank became operational in October 1981, and by 1984 most of the installations were completed. The program's first objectives were to eliminate unnecessary and duplicate entries in the active collection, increase the seed of each entry, and rejuvenate and evaluate entries in the base collection. Upon completion of the seed drying room in late 1983, the program gave priority to the tasks of seed drying and medium- and long-term storage of the base collection. A video terminal and printer obtained during the second half of 1984 connected the bank to CIMMYT's VAX computer.

Seed Introduction

The bank received requests from the breeding programs to obtain primitive and wild entries as potential sources for stress tolerance and disease resistance. Introductions from the breeding programs during 1982-84 and the elimination of unnecessary and/or duplicate materials brought the base collection up to 22,722 entries of bread wheat, durum wheat, triticale, barley, and interspecific crosses by the end of 1984. In addition, stored materials from other sources totaled 19,526 entries.

During 1984, 18,193 entries were added to the bank's inventory (Table 1). Numerous introductions were made from other banks and sources.

Seed Increase and Rejuvenation

Nurseries were sown at CIANO and El Batan during the winter of 1983-84 (Table 1). The nursery at CIANO contained only part of the base collection (spring growth habit materials). Winter habit materials and CIMMYT wheat introductions were sown at El Batan. These materials were sown without fertilizer, but small doses of fertilizer were applied later during the growth period. Seed setting rates at El Batan were generally low because of hot, dry weather during flowering. In most cases seeds were harvested, but late-flowering materials had to be cut down before seed setting.

Seed Storage and Distribution

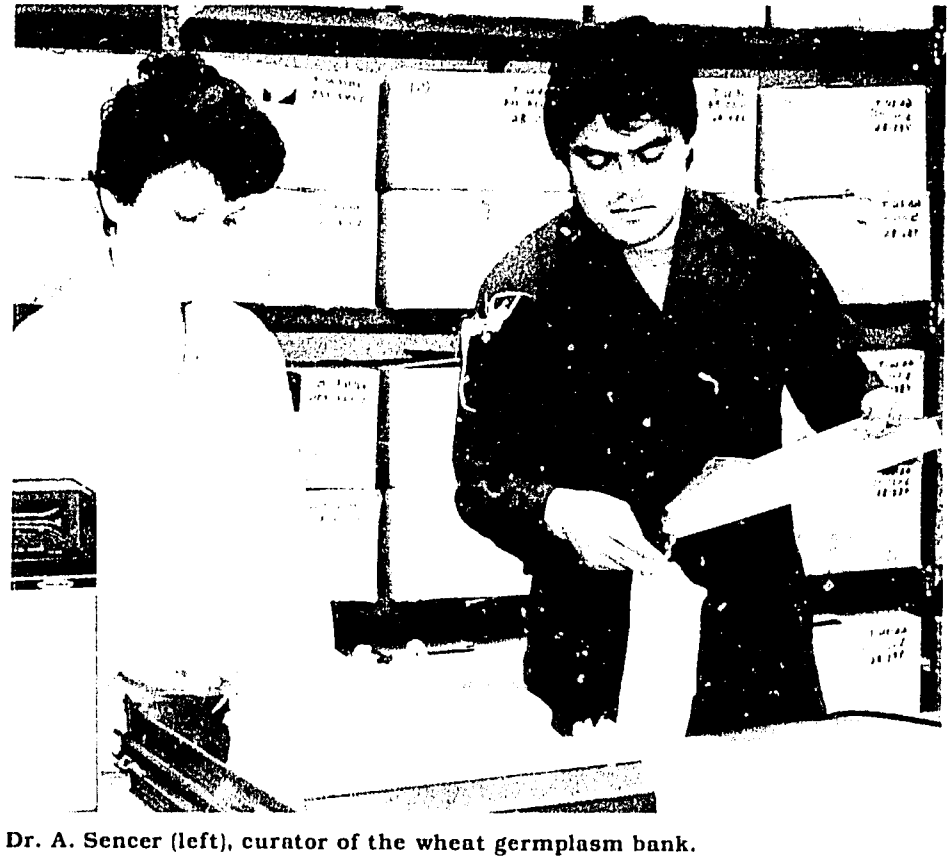
Seeds of all entries rejuvenated at CIANO and El Batan during 1982, 1983, and 1984 were placed in medium-term storage (Table 1). Fifty-gram samples of these entries also were placed in short-term storage (the active collection). The bank's 1984 seed distribution activities are also summarized in Table 1.

Evaluation

The morphological and agronomic characteristics of entries sown for seed increase and rejuvenation at CIANO and El Batan were recorded. Disease reaction data for the first disease evaluation nurseries, which were sent to cooperators in 1983, were received in 1984.

Information Bank

To facilitate the introduction of new entries into the base and active collections, unnecessary and/or duplicate entries were eliminated from the germplasm bank. This procedure, as well as the preparation of books and distribution lists, continued to be done manually in 1984. Computerization of introduction data for the base collection moved forward in 1984. Introduction data for the 9th through the 18th IBWSN were entered, as were the lists of commercial varieties, primitive cultivars, and special lines contained in the base and active collections. Summary lists were compiled of nurseries contained in the bread wheat, durum wheat, triticale, barley, and CIMMYT wheat introduction inventories.



Dr. A. Sencer (left), curator of the wheat germplasm bank.

Table 1. Summary of wheat germplasm bank activities, 1984

Type or source of materials	Seed introductions	Activities (no. of entries)				
		Seed increase, rejuvenation, and evaluation		Seed storage		Seed distribution
		CIANO	El Batan	Medium- and long-term (base collection)	Short-term (active collection)	
Bread wheat	1305	3035	1217	6866	3502	493
Durum wheat	344	305	726	3044	894	402
Triticale	423	893	137	3790	835	112
Barley	226	1211	332	4153	1303	34
Germplasm development	173	202	—	115	31	—
CIMMYT wheat introductions	15,722	—	2179	—	1516	2170
Total	18,193	5646	4591	17,968*	8081	3211

* Three sets prepared for long-term storage at Fort Collins and for long- and medium-term storage at El Batan

Training

H. Hepworth, G. Kingma, and E. Knapp

Introduction

Every year, CIMMYT offers several training programs designed to strengthen and support national research programs engaged in cooperative work with CIMMYT throughout the world. In 1984, formal training programs were carried out in Cereal Improvement (breeding/pathology), Crop Management (production/agronomy), Industrial Quality (cereal technology), and Experiment Station Management. Programs for visiting scientists and post-doctoral and pre-doctoral researchers continued as well. "Seed Week" was held again with the assistance of Dr. Juan Carlos Garcia from Chapingo University, Mexico, and Dr. Johnson E. Douglas from the seed unit at the International Center for Tropical Agriculture (CIAT), Colombia.

The need to train scientists from countries where wheat is not a traditional crop continues to increase. These colleagues bring to CIMMYT's training program diverse viewpoints and requirements, all of which enlarge the scope of CIMMYT training, making it into a truly international exchange and not a mere series of classroom and field exercises.

In CIMMYT courses, a team approach is used to identify and resolve wheat production problems. The team is composed of senior CIMMYT staff members working closely with the scientists from cooperating countries. Classroom training is supplemented by training in the field at CIMMYT, at other research stations throughout Mexico, and in farmers' fields. After returning to his or her country, each student may use the set of textbooks, manuals, and other publications supplied by CIMMYT as a basic reference library.

Some non-technical facets of the training program are also of enduring value to participants and to CIMMYT. Although professional attitude and motivation are not considered formal subject matter at CIMMYT, these are important characteristics to be developed. The friendships, the cultural exchanges, and the feeling of internationalism that arise are all positive factors in the creation of a worldwide network of scientists cooperating to improve global wheat production and rural welfare.

Cereal Improvement

The fact that breeders and pathologists trained by CIMMYT are active in over 100 national programs indicates the importance of the Cereal Improvement training course for increasing the research capacity of personnel from crop institutions throughout the world. At CIMMYT, trainees gain the scientific knowledge and the practical skills necessary to conduct successful varietal development programs. They also have the opportunity to select germplasm from CIMMYT nurseries to use in their own programs after returning home. The concept of international cooperation — the exchange of information as well as breeding materials — is a significant part of CIMMYT training, and senior staff from CIMMYT visit country programs to continue to assist scientists who have studied in Mexico.

In 1984, 24 trainees from 15 countries attended the Cereal Improvement course and became familiar with methods of crossing, selection, disease inoculation and scoring, harvesting, nursery management, and grain quality evaluation (Table 1). CIMMYT places

Dr. H. Hepworth, head of the wheat training program.

heavy emphasis on selecting disease-resistant materials, and trainees learn how to induce artificial rust epidemics to ensure the selection of such materials.

Crop Management

The Crop Management course was attended by 22 trainees in 1984 (Table 1). The goal of this course is to help agronomists from national research programs develop methods to close the gap between crop yields actually obtained by farmers and yields that may be achieved through improved crop management practices.

To achieve this result, production agronomists participating in this course develop a range of skills. They learn to diagnose problems contributing to low crop yields, and to design research experiments to determine possible solutions to the problems identified. Finally, course participants analyze the results of their research to develop practical recommendations to be adopted by farmers.

Many socioeconomic factors influence farmers' decisions and, ultimately, the crop yields they achieve. Therefore, the CIMMYT production agronomy training course is conducted with close support from CIMMYT's Economics Program. Experiments and demonstrations are performed by trainees themselves in the fields of cooperating farmers. A CIMMYT "training farm" also provides hands-on experience in producing a crop. Land preparation, seeding, fertilizing, weeding, irrigation, and harvest operations are learned in the field. This practical training is supplemented by lectures and field trips.

A survey of the crop management class of 1984 showed that 90% of the trainees agreed on the importance of the major topics studied during the training course. Because agriculture changes continually, such evaluations will be used regularly as one means of determining whether the course is relevant to trainees' needs.

Cereal Technology

Scientists who participate in the Cereal Technology course learn to evaluate the baking and nutritional characteristics of wheat, and how to assist breeding programs in selecting varieties that have desirable quality traits. They learn to operate the equipment used for quality evaluations and study laboratory management procedures. Five scientists took part in this program in 1984 (Table 1).

Experiment Station Management

Improved experiment station operation results in better control of non-experimental variables in trials, and greater confidence in the data obtained. In 1984, five scientists from four countries spent four and a half months at CIMMYT participating in the Station Management training course. These trainees mastered the operation and maintenance of a variety of tractors and machines used in agricultural research. Considerable time was also devoted to studying types of irrigation, tillage, seeding, fertilization, weed control, and harvesting methods and machines.

Pre-doctoral Training

CIMMYT provides a limited number of opportunities for young scientists to do research towards the Ph.D. degree. Students conducting research that has broad applications and is of interest to CIMMYT are chosen for these positions. Three scientists from South America and one from the United Kingdom were engaged in this program in 1984.

Post-doctoral Training

Some scientists who have just finished graduate school and are interested in international agriculture get an opportunity to explore this interest at CIMMYT. They are integrated into the scientific programs and participate as staff members under the guidance of CIMMYT senior staff. In 1984, the Wheat Program had post-doctoral fellows from Germany (2), the Netherlands (1), India (1), Sudan (1), and Mexico (1).

Visiting Scientists

One of CIMMYT's most active training efforts is the visiting scientist program. Each year, senior scientists from many countries come to CIMMYT for short periods, usually two to three weeks (Table 2). Those with special interests or problems may remain longer. These visitors bring knowledge and experience to share with CIMMYT staff, trainees, and colleagues from other countries. Information is exchanged through personal contacts, group discussions, and seminars.

Another important aspect of this program is the exchange of germplasm. Visiting scientists send germplasm to CIMMYT, and while they are at the Center, they can observe the performance of their materials. These scientists also select germplasm from CIMMYT's extensive nurseries for use in their own varietal development programs.

CIMMYT senior staff from Mexico and from regional and bilateral programs visit many national programs each year. These trips provide opportunities to continue the personal contacts made at CIMMYT, and to evaluate the performance of hundreds of CIMMYT germplasm nurseries sent to national programs each year.

Training Outside Mexico

Regional and country training programs received support from CIMMYT staff in planning and conducting training exercises last year. As these programs expand and progress, CIMMYT will be requested to help, and is preparing to offer the greater amount of assistance that cooperating countries will need.

The Future

Well-trained young scientists are essential to the progress of national programs. To help the staff of such programs achieve their goals, CIMMYT will continue to offer, improve, and if necessary increase the courses it offers. CIMMYT is also committed to assisting national training programs wherever and whenever possible.

Table 1. Area of origin and number of trainees in 1984

Area	Training course			
	Cereal Improvement	Crop Management	Cereal Technology	Experiment Station Mgt.
Latin America	8	9	1	2
Africa	4	2	1	0
East Asia	8	11	3	1
Mediterranean	2	0	0	2
Other	2	0	0	0
Total	24	22	5	5

Table 2. Visiting scientists, 1984

Area	Number
Latin America	73
Africa	10
East Asia	20
Mediterranean	9
Other	67
Total	188
Countries represented	33

Anna Mrema
Tanzania

Kanchana Natesomranik
Thailand

Cereal Technology Trainees

Siwaporn Siwawej
Thailand

MIROSLAW S. POJMAJ
POLAND

RAFAEL MACIEL CANO
MEXICO

BEATRIZ ALICIA PEREZ
ARGENTINA

MAJID AKHTAR KHALID
PAKISTAN

M. SALEEM CHAUDHARY
PAKISTAN

TA DUY MINH
VIET NAM

CASIANO QUINTANA C.
BOLIVIA

FRANCIS C. DRAKUDE
NIGERIA

HYDAR ALI M. MOLLAH
BANGLADESH

PITHUMAL BHATIA
PAKISTAN

ANTONIO BOLAÑOS ALANIA
COLOMBIA

GETACHEW BELAY
ETHIOPIA

ALEJANDRO GALLARDO S.
MEXICO

GERARDO VALDEZ J.
MEXICO

SALVADOR AGUILERA O
MEXICO

MOHAMED EL HADI
MOROCCO

SEGUNDO ABAD GIPON
ECUADOR

KYEONG JU CHOI
KOREA

SHAHEED M. ANWAR
BANGLADESH

SHU-HUA LIU
CHINA

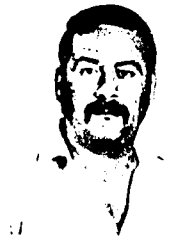
DEOGRATIAS B. KISANDU
TANZANIA

ROMAN SARZECKA
POLAND

Breeding and Pathology Trainees

NASSEPLEHAQ NSARELLAH
MOROCCO

JOSE H. CABELLOS
PERU



JUAN G. SALAS
PERU

SALVADOR GALVAN
MEXICO

ZAKAYO J. OWENYA
TANZANIA

MD.SAIFUZZAMAN
BANGLADESH

NOOR-UL HADI
PAKISTAN

JOSE PARRA H.
PERU

NOEMI P. OROLAZA
PHILIPPINES

SHAH MD NURUL ISLAM
BANGLADESH

DOMINADOR B. GARCIA
PHILIPPINES

SUMAN HANVIRIYAPANT
THAILAND

R.P. SHRESTHA
NEPAL

KELAI PRASAD YADAV
NEPAL

HECTOR D. CACERES
PARAGUAY

CH. MOHAMMAD AKRAM
PAKISTAN

ENDALE ASMARE
ETHIOPIA

JOSE A. ROBLES C.
GUATEMALA

JUNG TAE KIM
KOREA

BENJAMIN VALENZUELA A.
MEXICO

ARTURO FIGUEROA
ECUADOR

SOMPONG BHUPUANG
THAILAND

Wheat Production Trainees

EDGAR A. GARCIA
GUATEMALA

Agronomy

J. Ransom, M. Osmanzai, and S. Waddington

Introduction

At the CIANO station during the winter cycle, the agronomy program conducts research on problems related to the management of breeders' nurseries and on agronomic problems that are not site-specific. During the summer cycle, the agronomy program staff is part of the production training team, conducting on-farm and station research directed toward solving production problems for farmers in the high plateau near the El Batan station. In addition to these activities, the program evaluates germplasm being developed by the breeding programs for its performance in environments possessing and lacking different kinds and levels of stress. Much of this latter work is described in the sections of the annual report giving research results for the breeding programs. This section of the report focuses on station research done during 1984.

Weed Control

The herbicides currently recommended at the experiment stations are for the most part providing very good weed control. However, nutsedges (*Cyperus* spp.) continue to be a serious problem in Toluca and, to a lesser extent, in El Batan. A study was conducted at Toluca to evaluate several herbicides for activity against this weed. Emphasis was placed on the timing of bentazon, a chemical known to be effective against nutsedge.

Herbicides other than bentazon were not effective in controlling nutsedge at the rates and timing used in this trial (Table 1). Bentazon, regardless of rate or time of application, was as effective as hand weeding in reducing the final number of nutsedge plants. The best control was achieved by applying bentazon at 20 and 40 days after crop emergence. This treatment gave 100% control at the highest rate. A single application at 20 days appears to be better than a single application at 40 days. These data also suggest that little advantage is to be gained by mixing bentazon with dicamba or oil. No crop toxicity was noted with any of the treatments. Based on these data and results from a previous experiment, 0.48-0.96 kg bentazon/ha applied at 20 and 40 days after crop emergence is recommended when the population of nutsedge is sufficiently high to warrant such a treatment.

Fertilizer Studies

The fourth and final year of a nitrogen and phosphorus trial was completed during the 1983-84 cycle at CIANO. The objectives of this research were to determine an appropriate fertilizer recommendation for the CIANO station, and to follow the decline in soil fertility when no fertilizer is applied. In the first two years of this trial, yields did not increase in response to either nitrogen or phosphorus. In the third

Dr. J. Ransom, agronomist, reviews trials at CIANO.

year, yields were increased with the application of 60 kg N/ha. Nitrogen in excess of 60 kg/ha and phosphorus regardless of rate failed to increase yields further.

In the 1983-84 cycle, there was a significant response to the application of both nitrogen and phosphorus (Table 2). Yields increased as nitrogen increased up to 120 kg/ha, resulting in a 52% higher yield over the yield of the 0 nitrogen level. The application of 17.5 kg P/ha resulted in a 14% yield increase, with no further response at the 35 kg/ha rate. There was no significant nitrogen x phosphorus interaction.

These data show for the first time the importance of phosphorus applications for optimum wheat production on the CIANO station. However, they also suggest that yearly applications of phosphorus are not essential. The present recommendation of 100-150 kg N/ha and 19.5 kg P/ha is more than meeting the needs of wheat crops at the CIANO station.

Treatments in this trial were also split with sources of nitrogen. Urea was applied on one half of each main treatment and ammonium sulfate on the other half. Urea gave a 5% greater yield (averaged across all treatments) when compared to ammonium sulfate. This small difference was probably due to the actual nitrogen content in the fertilizer, as the ammonium sulfate was brown, suggesting some type of contamination. However, no lab analysis was performed to confirm this assumption.

Studies with Early Maturing Barleys

Seeding rate and row spacing— Several short-cycle barleys with good yield potential have recently been developed at CIMMYT. Barleys such as these, which mature in 90 days in a normal growing season at El Batan and CIANO, have potential for late planting when rains are delayed in the high plateau of Mexico, or for use as a crop between soybean and cotton in the irrigated valleys of northern Mexico. Because of the rapid development of these genotypes prior to anthesis, their tillering is relatively limited and their ground cover is noticeably poor compared to full season genotypes. Considerable yield gains could probably be obtained by altering the row spacing and seeding rate of these early barleys so that the crop could use sunlight more effectively.

A trial was conducted in 1984 in El Batan to compare two early barleys with a full-season genotype under a range of row spacings and seeding rates. The full-season cultivar, Pistacho, was as responsive to row spacing as were the two early genotypes, Mona-Gateway and Mona-Mezquite (Table 3).

The highest yield for all genotypes was obtained with 10 cm row spacing. Furthermore, yields declined linearly as row spacing increased. Poor yields in the broadcast plots were caused by severe lodging; all cultivars were more than 90% lodged in this treatment. The lowest seeding rate, 100 seeds/m^2, generally resulted in the highest yield (data not shown). These results were unexpected, but may have occurred because the unusually cool, wet summer permitted heavy tillering and uniform shoot production even in the rapidly developing genotypes.

Irrigation requirements—A trial was conducted to devise an irrigation schedule for early barleys grown in a cropping niche after soybean and before cotton in the irrigated valleys of Sonora, Mexico. Both Mona-Gateway and Mona-Mezquite were included in this trial. The results indicate that these early barleys can, in fact, be grown between soybean and cotton, as both genotypes reached physiological maturity in 90 days or less. Mona-Mezquite, a 6-row barley, consistently yielded about 17% better than Mona-Gateway, a 2-row barley (Table 4). Water stress was experienced in all irrigation treatments except treatment 3. In the stress-free treatment, yields averaged nearly 5.5 t/ha, indicating a high yield potential for these lines in the Yaqui Valley. The treatment with only the seeding irrigation produced grain yields of 2.7 t/ha, exactly half of the yield for the no-stress treatment. With the other two treatments, the crops came into stress at about the same time, during mid-grain filling, and this is reflected by their similar yields.

These preliminary data from a single production cycle indicate that a seeding irrigation and supplementary irrigations at mid-tillering and anthesis would give a good yield without wasting water and would be easy for the farmer to manage. Further research on the irrigation timetable for early barleys is planned for next year.

Emergence Studies

Poor seedling emergence has been observed in the Yaqui Valley, particularly in years when rains occur shortly after seeding. Seedling emergence has also been detrimentally affected by high levels of applied nitrogen in research plots at CIANO. A trial was designed to investigate factors affecting seedling emergence in the heavy soils of the Yaqui Valley. Treatments in this trial consisted of a factorial combination of length of irrigation, level of nitrogen fertilizer (0 kg N/ha and 250 kg N/ha, and depth of seeding (2 cm and 6 cm). This experiment included 32 genotypes, 8 from each small grain species, to evaluate genetic variability for emergence ability in certain suboptimal environments.

The trial indicated that the detrimental effect of excess water is apparent only when seed is deeply sown. The decline in seedling emergence produced by this combination of factors is further aggravated by the application of nitrogen fertilizer. There was a significant nitrogen x seeding depth x length of irrigation interaction: the poorest emergence occurred at the 6 cm depth, with a 4 hour irrigation, and with the

application of 250 kg N/ha. Despite the fact that nitrogen application significantly reduced emergence (11% difference) at the 6 cm seeding depth, it did not affect emergence at the 2 cm depth.

Percent emergence decreased as length of seeding irrigation increased up to 4 hours, though seed sown at 2 cm was less affected by irrigation length than seed sown at 6 cm (Table 5). The double irrigation of 15 minutes resulted in emergence similar to the single 15 minute irrigation, probably because most germination had occurred by the time of the second irrigation.

Reduced emergence with increased irrigation length is logically related to a lack of oxygen for the germinating seed. It is unclear why nitrogen reduces seedling emergence, but reduced emergence is not thought to be an effect of salt, because that effect would diminish as irrigation time increased.

There was a significant genotype x treatment interaction. Genotypes that appeared to be more tolerant to adverse conditions were Georgia (barley), Tonichi 81 and Yecora 70 (bread wheats), Memo 'S'-Goo 'S' (durum wheat), and Zebra 'S' (triticale). Genotypes least tolerant to these adverse conditions were Jorote 'S' (barley), Ciano 79 and Seri 82 (bread wheats), Carc 'S' (durum wheat), and Dack-WLOS7 Anowskie x M_2A^2 (triticale). Triticales were slightly more tolerant than the other species.

These results suggest that a shallow seeding depth is very important in the heavy soils of the Yaqui Valley in years when excess moisture occurs during germination, and that nitrogen fertilizer can play an important role in achieving optimal seedling establishment. Furthermore, genetic variability exists and can be exploited to increase emergence percentage in suboptimal environments.

Yellow Berry in Durum Wheat

A cooperative trial with the durum breeding program was established to determine procedures for selecting durum genotypes with less yellow berry. The main factors in this trial were levels of nitrogen (0, 40, 80, and 120 kg N/ha), which were applied to soil that had its fertility reduced by an unfertilized summer maize crop. Forty durum genotypes were screened at each nitrogen level. At harvest, the number of grains with yellow berry, and the percentage of each grain affected by yellow berry, were determined visually for each plot. By multiplying these two numbers, a yellow berry index was calculated, which is roughly equivalent to visually estimating the total area of all grains affected by yellow berry.

As nitrogen increased, the percentage of yellow berry decreased linearly (Table 6). The average percentage yellow berry at the 0 kg N/ha level was more than twice that at the 120 kg N/ha nitrogen level. No genotype x nitrogen interaction appeared, which suggests that the relative effect of nitrogen on the development of yellow berry is similar for all genotypes tested. Furthermore, a single level of nitrogen can be used as effectively as several levels in identifying genotypes with less yellow berry. The durum program now plans to systematically screen advanced material on land that has not been fertilized with nitrogen. This will allow the development of an intermediate level of yellow berry in most genotypes, as the normal level of residual nitrogen is approximately equal to 50-60 kg N/ha after a summer maize crop.

Testing a Gradient Irrigation System

Drought tolerance is an important characteristic for widely adapted germplasm. Selection for drought-tolerant genotypes is currently done at the CIANO station. However, since a normal flood irrigation at CIANO applies more than 150 mm of water, it is difficult to create high levels of water stress during early stages of growth. In 1983-84, research was initiated with a sprinkler system designed to apply water in a linear fashion, i.e., the amount of water applied decreased as distance from the irrigation line increased.

To evaluate the system for its usefulness in screening for drought tolerance, 25 genotypes were sown in plots perpendicular to the irrigation line. More than 2.5 times as much water was applied near the line than was applied at the plot farthest from the line (Table 7). Five plots per genotype were harvested at 3 m intervals in order to obtain information on the relative performance of each genotype at differing levels of irrigation.

There was a positive correlation between average yield and the amount of water applied. The genotypic response to applied water was evaluated using regression analysis. The following lines were determined to be the best adapted to environments with water stress: Junco (bread wheat), Yavaros 79 (durum wheat), and Civet 71 and Ulka 'S' (triticales).

This system offers several advantages over the previous method used at CIANO. Plants can be subjected to a wider range of water-stress levels, whereas previously only two levels were possible. Provided no rains interfere, plants can be stressed during the entire growing cycle; under the old system, after the single seeding irrigation, stress would not occur until after heading. The disadvantages of the new sprinkler system are that water must be applied during very calm periods of the day, and that the researcher is restricted in the type of experimental design used. Further research will be done in the 1985 cycle to evaluate how effective this system will be for screening large numbers of genotypes.

Aphid and Nematode Experiments

Aphids—Research was continued at the El Batan and CIANO stations to determine the yield loss caused by natural infestations of aphids, and to identify an insecticide spray program that could be recommended to station management personnel at both locations.

At El Batan in 1984, there was no difference in yield between the non-sprayed control and the aphid-free control. Lack of response to the insecticide was probably caused by heavy rains that washed the aphids off the foliage and kept their population low. During grain filling, a relatively high population of the insects was observed, but their late arrival and the severe lodging that occurred before harvest precluded any measurable insect damage. At CIANO, aphid infestations occurred early but the aphid population declined rapidly, so that very few of the insects were found by the boot stage. This decline was largely a result of high levels of predators. Yield did not differ significantly between treatments.

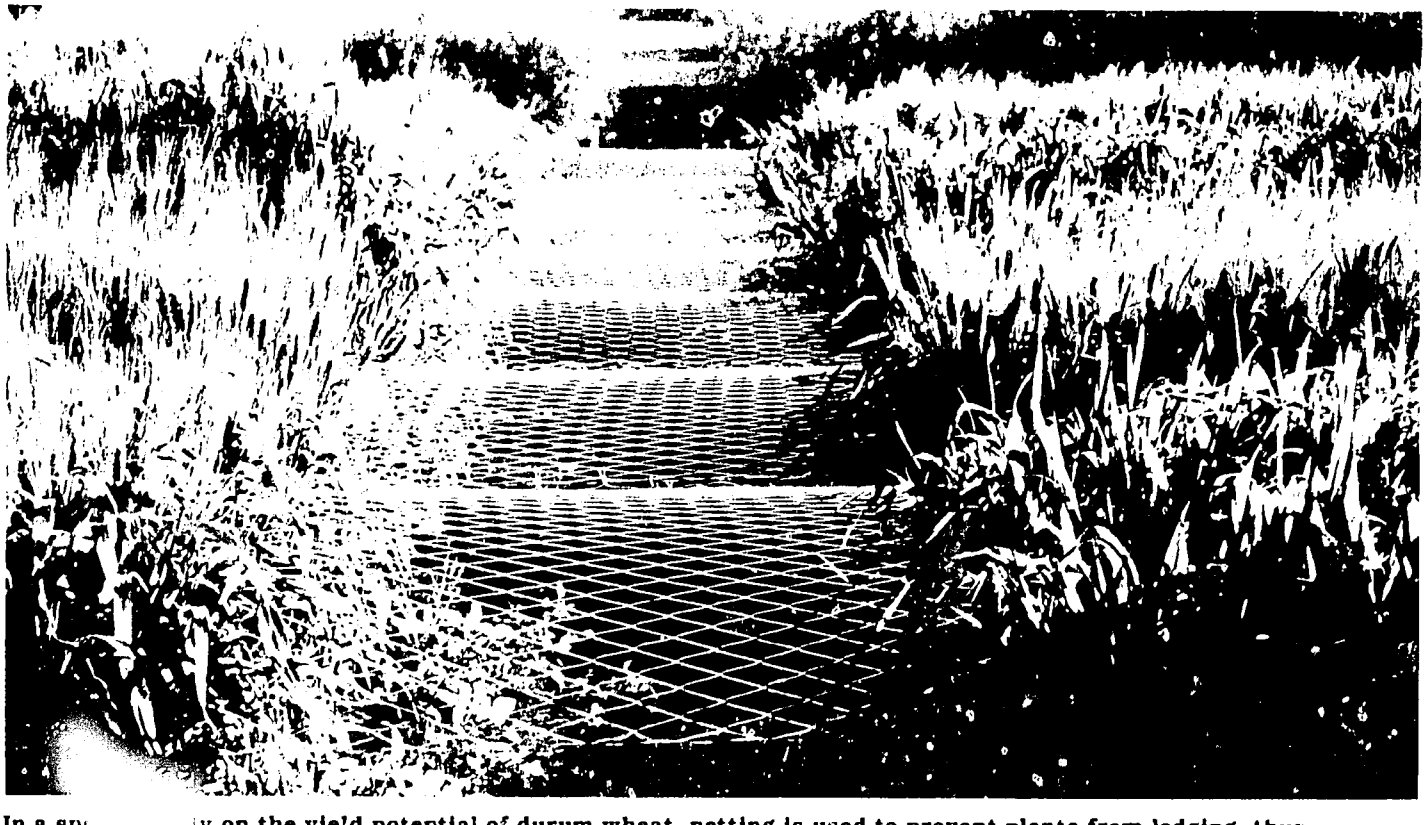
These data, as well as data obtained previously, suggest that the yield loss due to aphid infestation is minor in most years. However, a single application of a systemic insecticide may be necessary to keep aphid levels down.

Nematodes—A trial using two rates of aldicarb (Temik) and two rates of fenamiphos (Nemacur) was conducted to determine if plant-parasitic nematodes significantly reduce wheat yields at CIANO. The average yield of treated plots (6.0 t/ha) was about 10% higher than the yield of the non-treated controls (5.5 t/ha). There was no statistically significant difference between nematocide treatments. Several plant-parasitic nematodes were found in the soil, indicating that further research should be conducted.

Durum Yield Potential

A study was conducted at CIANO in 1983-84 to determine gains in genetic yield potential of durum wheat cultivars released in northwestern Mexico over the last 30 years. Non-limiting levels of nitrogen, phosphorus, and water were supplied to the plots, and a preventive pest and disease program was implemented. Netting was used to deter lodging, allowing genotypes to express their full genetic yield potential.

The highest yielding genotypes were three new advanced lines, Care 'S', Ga 'S', and Guil 'S', which averaged 8.3 t/ha (Table 8). This represents an increase of more than 80% over the average yield of cultivars released in the 1960s. Furthermore, grain yield among the 13 genotypes increased linearly when regressed against year of release (r^2 = 0.88**, 9 d.f.). The annual rate of increase



In a spe[illegible]y on the yield potential of durum wheat, netting is used to prevent plants from lodging, thus permitting them to express their full yield potential.

in yield potential has been relatively steady at 190 kg/ha and shows no signs of leveling off.

These data show that the yield increases obtained prior to the late 1970s were largely a result of improvement in the harvest index. However, an apparent increase in total phytomass production was also found in the three most recently developed genotypes; they averaged 17.1 t/ha, a figure that compared favorably with the average of the three next best genotypes, 16.0 t/ha. The greater partitioning of dry matter into the grain was largely accomplished by raising the number of grains/m^2 (yield vs grains/m^2, $r^2 = 0.88^{**}$, 9 d.f.). Improvements in grain number from the mid-1960s to the mid-1970s were the result of higher numbers of spikes/m^2, whereas the improvement in later years was the result of increasing the grains/spike while maintaining the number of spikes/m^2. Grain size has basically remained unchanged during the past 30 years. These data indicate that, even without further increases in phytomass, a grain yield of nearly 10 t/ha (12% moisture) should be possible by raising the harvest index to a modest 50%, and maintaining phytomass at 17 t/ha.

Complete and Substituted Triticales

Yield potential—Experiments were conducted in 1982-83 and 1983-84 to compare the genetic yield potential of complete and substituted triticales. Seven complete and seven substituted genotypes (Table 9) were grown under near-optimal agronomic conditions. As with the durum yield potential trial, a preventive program of insect, disease, and weed control was used, and netting was used to deter lodging. Water and nutrients were not limiting factors. In 1982-83, there was no significant difference between the two groups for grain yield, phytomass, harvest index, and 1000-kernel weight (Table 10). However, the complete types produced more grains/spike, and the substituted types produced a higher number of productive tillers/m^2.

Results of the 1983-84 trial indicate that complete types were superior to substituted types in phytomass, grain yield, and 1000-kernel weight. The pooled analysis of the two years indicates that the complete triticales used in this trial have a slightly higher yield potential than the substituted types. This yield advantage is a result of larger spikes with slightly larger grains.

Though these results do suggest a yield advantage of the complete types over the substituted types, the difference is so small that one type should not be bred preferentially over the other when considering only yield potential. Of course, when other factors are considered, one type may be superior and accordingly should receive more emphasis.

Water stress—In 1983-84, an experiment was conducted to compare yields of complete and substituted triticales subjected to water stress during grain filling. The same 14 genotypes used in the yield potential trial were included in this experiment (Table 9), and were grown with stress (seeding irrigation only) and without stress (5 irrigations).

When grown without water stress, the complete types yielded 10% more than the substituted types (Table 11). Moreover, when grown under conditions of water stress, the complete types performed even better relative to the substituted types, yielding an average of 14% more.

These data suggest a slight advantage of complete types over substituted types in water stress environments. Possible reasons for this difference will be investigated.

Triticale grain growth—Grain shriveling and low test weights are undesirable characteristics associated with many triticales. Preliminary research on the grain growth pattern of triticales showed that they reach a higher moisture content during grain filling than bread wheats. It was suggested that this higher water requirement may be why triticale grain shrivels when moisture is limited. Further research in El Batan with 29 genotypes identified substantial variability in the water content of triticale grain relative to its final dry matter content. From these 29 genotypes, 12 lines were grown at CIANO with and without water stress to determine if the grain-filling pattern was related to other characteristics such as water-stress tolerance or test weight.

Triticale genotypes included in this research varied greatly in their grain-filling patterns. Some had a high water content relative to dry weight during the cell expansion phase of endosperm development, others were quite similar to bread wheat and had a low relative water content, and others were intermediate between the two extremes. Triticale lines with grain growth patterns similar to bread wheat were all late maturing.

The relative amount of water in the grain (peak water weight/peak dry weight) was calculated to quantify the moisture requirement of the grain (those with the lowest relative amount of water are most like bread wheat). Though grain shriveling was not evaluated, the actual percent reduction in 1000-kernel weight with water stress was calculated, and was used as a relative measure of drought tolerance in the triticale lines. There was no correlation between the relative water content and percent reduction in 1000-kernel weight. Moreover, test weight and relative water content were not correlated, though the late genotypes had the highest test weights and the lowest water content.

These data suggest that the water content during grain filling varies greatly among triticale genotypes, and although triticales (relative to bread wheat) require more water during this stage, the high relative water content does not seem to be related to any undesirable characteristic such as low test weight or susceptibility to drought stress.

Table 1. Effect of different herbicide treatments on the number of living nutsedge plants/plot (10 m^2) at the end of the growing season, Toluca, 1984

$LSD_{.05}$ = 13

[a] Days after crop emergence
[b] Pre-emergence

Treatment	Time of application[a]	No. of nutsedge plants/plot
No chemical control	—	18
Hand weeded (4 times)	—	6
Hand weeded (1 time)	—	9
Bentazon 0.48 kg/ha	20	5
Bentazon 0.96 kg/ha	20	2
Bentazon 0.48 kg/ha + dicamba 48 g/ha	20	3
Bentazon 0.48 kg/ha + oil 21 kg/ha	20	6
Bentazon 0.96 kg/ha + dicamba 48 g/ha + oil 21 kg/ha	20	4
Bentazon 0.48 kg/ha	40	9
Bentazon 0.48 kg/ha and 0.48 kg/ha	20 and 40	1
Bentazon 0.96 kg/ha and 0.96 kg/ha	20 and 40	0
Propachlor 2.25 kg/ha[b]	—	16
Propachlor 4.50 kg/ha[b]	—	26
Bromoxynil 0.48 kg/ha	20	10
Bifenox 2 kg/ha[b]	—	39
Bifenox 4 kg/ha[b]	—	12
Bifenox 0.75 kg/ha	20	14

Table 2. Grain yield of Seri 82 (t/ha) as influenced by levels of applied nitrogen and phosphorus, after four years of treatment in a longer-term experiment, CIANO, 1983-84

$LSD_{.05}$ = 0.3 t/ha for N and P main effects

Phosphorus applied (kg/ha)	Nitrogen applied (kg/ha) 0	60	120	180	$\bar{x}$
0	2.5	3.1	3.7	3.6	3.2
17.5	2.6	3.7	4.3	4.4	3.7
35	3.0	3.3	4.3	4.7	3.8
$\bar{x}$	2.7	3.4	4.1	4.2	

Table 3. The effect of row spacing on yield (t/ha) of three barley genotypes, El Batan, 1984

Genotype	Row spacing (cm) Broadcast	10	15	20	$\bar{x}$
Mona-Gateway	3.3	5.8	5.1	4.5	4.7
Mona-Mezquite	3.9	6.6	5.9	5.3	5.4
Pistacho	3.2	7.5	6.0	5.1	5.4
$\bar{x}$	3.5	6.6	5.7	5.0	

$LSD_{.05}$ = 0.4 t/ha for row spacing main effects
$LSD_{.05}$ = 0.4 t/ha for genotype main effects

Table 4. Effect of irrigation treatment on yield (t/ha) of two early barley genotypes, CIANO, 1983-84

Irrigation treatment	Mona-Gateway (t/ha)	Mona-Mezquite (t/ha)	$\bar{x}$[a] (t/ha)
1. Seeding irrigation only	2.44	3.01	2.73d
2. Seeding irrigation + 1 supplementary at 50% DAM[b]	3.76	4.17	3.97c
3. Seeding irrigation + 2 supplementaries at 50% DAM	5.07	5.83	5.45a
4. Seeding irrigation + 2 supplementaries (mid-tillering + 50% anthesis)	4.00	4.88	4.44b

[a] Means followed by the same letter were not significantly different at 5% level using Duncan's Multiple Range Test
[b] DAM = Depletion of available moisture

Table 5. Effect of length of irrigation, nitrogen fertilizer application, and seeding depth on emergence of small grains (average of 32 genotypes)

Irrigation length (hrs)	Seeding depth 2 cm 0 N	2 cm 250 N	6 cm 0 N	6 cm 250 N	$\bar{x}$
	% emergence				
0.25	70	61	[illegible]	34	54
1.0	55	52	42	35	46
4.0	58	57	32	25	43
.25 + .25 4 days later	58	61	46	33	50
$\bar{x}$	61	58	43	32	

$LSD_{.05}$ N x depth x irrigation = 6%
N x depth = 3%
Irrigation = 5%

Table 6. Effect of levels of applied nitrogen on the development of yellow berry in durum wheats; data are an average of 40 genotypes

Nitrogen applied (kg/ha)	Yellow berry index (%)
0	63
40	58
80	42
120	30

Table 7. Effect of plot location relative to the irrigation line on the amount of water applied, amount of water used, and average yield, CIANO, 1983-84

Plot location[a]	Water applied (mm)	Estimated total water used[b] (mm)	Yield mean[c] (t/ha)
1	354	467	5.22
2	332	445	4.84
3	263	376	4.48
4	194	307	3.76
5	138	251	3.02

a Plots were 3 m in length; the end of Plot 5 was 15 m from the irrigation line

b Includes 113 mm uniformly available to all plots due to rain and residual soil moisture

c Average of 25 genotypes included in trial

Table 8. Grain yield, above ground phytomass, harvest index, and yield components for durum wheat genotypes, CIANO, 1983-84

Variety or line	Yield[a] 12% moisture (t/ha)	Phytomass dry weight (t/ha)	Harvest index (%)	No. of spikes/m^2	No. of grains/m^2	No. of grains/ spike	1000-kernel dry weight (g)
Care 'S' CD24831-E-3Y-5M-1Y-0M	8.68a	17.53a	44.4abc	373abcde	16,500a	45a	46.2e
Ga 'S' CD22344-A-8M-1Y-1M-1Y-2Y-1M-0Y	8.20a	16.60ab	43.7abcd	377abcd	14,000ab	38ab	51.6cd
Guil 'S' CM14646-C-1Y-1M-1Y-0Y	7.50ab	17.09a	38.8bcde	394abc	12,700bc	32bc	52.0cd
Yavaros 79	7.18abc	14.50abc	40.[illegible]ab	320cdefg	11,900bcde	38ab	53.1bcd
Mexicali 75	7.16abc	12.74c	49.9a	329bcdef	12,200bcd	37b	51.6cd
Jori 69	6.33bcd	15.97abc	35.2def	352abcde	9,800defg	28cd	56.9a
Cocorit 71	6.26bcd	15.73abc	35.6cdef	413ab	11,000cdef	26cde	50.4d
Chapala 67	5.68cde	14.58abc	34.3ef	438a	9,000gh	21de	55.6ab
Barrigon Yaqui	5.54def	15.60abc	31.4efg	288efg	9,600efg	33bc	50.9d
Pabellon 67	5.20def	16.25ab	28.2fg	353abcde	10,300cdef	29c	44.4e
Oviachic 65	4.35efg	15.34abc	25.1gh	298defg	8,300gh	28cd	46.0e
Tehuacan 67	4.09fg	14.58abc	24.8gh	239g	9,100fgh	38ab	39.7f
Tehuacan 60	3.34g	12.86c	22.9gh	252fg	5,300i	21de	55.1abc

a Means followed by the same letter were not significantly different at 5% level using Duncan's Multiple Range Test

Table 9. Triticale genotypes used in experiments evaluating the performance of complete and substituted types

Complete		
Merino 'S'-Juanillo	B-2736	
M_2A-Bui x Drira-Kgr	B-2683	= Sika 'S'
IRA-Bgl x Drira-Kgr	B-2658	= Civet 'S'
IRA-Drira 37	B-507	= Elk 'S'
Juanillo 159		= Eronga 83
IRA-Bgl x Drira-Kgr	B-2658	= Civet 'S'
Zebra 357	B-2672-476-OM	
Substituted		
Ptr 'S'-MA106	X39860-7Y-2M-3M-2Y-0H	= Tesmo 'S'
Ptr 'S'-MA106	X39860-2Y-7M-1Y-0Y	= Tesmo 'S'
Ptr 'S'-Castor 'S'	X31731-24Y-9M-0Y	
Cml 'S'-Kal x IA-IRA	X39651-1Y-1M-2Y-1Y-0H	
Lemming 'S'	X33208-1-500Y-500M-500Y-500B-503Y-0Y	
Cananea 79		
(Corm 'S' D673 x Gta 'S'/Spy)Gpr	X-65163-7Y-1M-0Y(PM No.25)	

Table 10. Yield and yield components (averaged over genotypes) of complete and substituted triticales, CIANO, 1982-83 and 1983-84

Type	Yield 12% moisture (t/ha)	Phytomass dry weight (t/ha)	Harvest index (%)	No. of spikes/m^2	No. of grains/ spike	1000-kernel weight (g)
1983						
Complete	7.33	15.33	42	316**	52**	39
Substituted	7.18	15.11	42	356	47	38
1984						
Complete	6.96	16.77**	37	315**	45	44**
Substituted	6.50	15.50	37	361	43	37
Pooled 1983-84						
Complete	7.19*	16.02	40	319**	49*	42*
Substituted	6.89	15.46	40	350	40	38

* Differ significantly at the 5% level
** Differ significantly at the 1% level

Table 11. Yield comparison (t/ha) of complete and substituted triticales grown under water stress and without water stress, CIANO, 1983-84

Treatment	Type		Percentage difference
	Complete	Substituted	
5 irrigations	5.78	5.19	10
1 irrigation	2.78	2.40	14
% reduction	52	54	

Milling and Baking Laboratory

A. Amaya C. and R.J. Peña

Introduction

The acceptability of CIMMYT germplasm for national programs depends not only on the agronomic characteristics and disease resistance of the materials, but also on the quality characteristics required for preparation of local food products. To help ensure that these requirements are met, the CIMMYT milling and baking laboratory evaluates and screens early generation materials (F_2 to F_5) for good grain type. Early generation lines with good grain type are subsequently tested for additional characteristics, including gluten strength, protein content, alpha-amylase activity, and pigment content (in durum wheat only). Advanced lines are evaluated for test weight, rheological characteristics, gluten strength, protein content, and milling and baking qualities. Breeders integrate these data with information on yield, disease resistance, agronomic characteristics, and other factors to make crosses and select for high-yielding and widely adapted bread and durum wheats and triticales.

Aside from performing these evaluations, the laboratory provides training in its methods and procedures for personnel from national crop improvement programs throughout the world.

Bread Wheat

During 1984, 2294 advanced lines and varieties were evaluated for quality. This material included the spring Crossing Block (CB) harvested at CIANO in 1983-84 and the same CB harvested at Toluca in 1983. These CBs were evaluated to determine the effect of the contrasting environments at Toluca and CIANO on quality. Lines from both locations showed little variability in gluten strength. Alpha-amylase activity, although more variable than gluten strength because of high humidity at Toluca, was rarely greater than the level desirable for good baking performance.

Forty percent of the lines from the winter Crossing Block at Toluca, 1984-85, showed weak gluten with good extensibility. The entire range of gluten types was present in the 212 entries of the 18th IBWSN. Flour protein varied from 9% to 12% and loaf volume from 520 cc to 965 cc for a 100 g loaf.

Durum Wheat

Individual plants selected by the durum wheat program for good seed type were evaluated for pigment content. Of 8550 plants tested, 35% were discarded because their pigment content was less than 5 ppm. A total of 753 advanced lines, most of them included in the spring and winter CBs and the 16th IDSN,

Dr. A. Amaya (right), head of the milling and baking laboratory, works with a participant in the Cereal Technology training course.

were evaluated for yellow berry, black point, test weight, protein and pigment content, and semolina characteristics. Many of these varieties and lines possessed good quality characteristics for pasta production, although some still had a high incidence of yellow berry, resulting in lower semolina yields. Black point, which lowers semolina quality, was discovered in several lines. Pigment content values ranging from 7.0 to 11.2 ppm were recorded for 12% of the lines in the spring CB. Weak gluten in 7.5% of the lines limited their suitability for pasta production.

In the 16th IDSN, only 4.5% of the lines had weak gluten. From this nursery, three lines were selected for increase as possible future commercial varieties because of good yield and disease resistance. These were Gallareta 'S' (pigment content 5.6 ppm, 10.5% protein), Chen 'S' (pigment 5.4 ppm, 11.7% protein), and Carcomun (pigment 5.0 ppm, 9.2% protein) (protein assessed using 14% moisture basis).

Triticale

In 1984, 995 advanced lines from the CB, 16th ITSN, and Fifteenth International Triticale Yield Nursery (ITYN) were evaluated. Compared to earlier triticale materials, the 1984 CB was composed of 300 lines and varieties that were much improved with respect to sprouting resistance, gluten strength and quality, flour yield, and bread loaf volume. Of the 300, only 12 had flour yields lower than 60%, and 8 samples had more than 70% flour extraction. Bread loaf volume was higher than 700 cc for 48 samples and higher than 800 cc for 11.

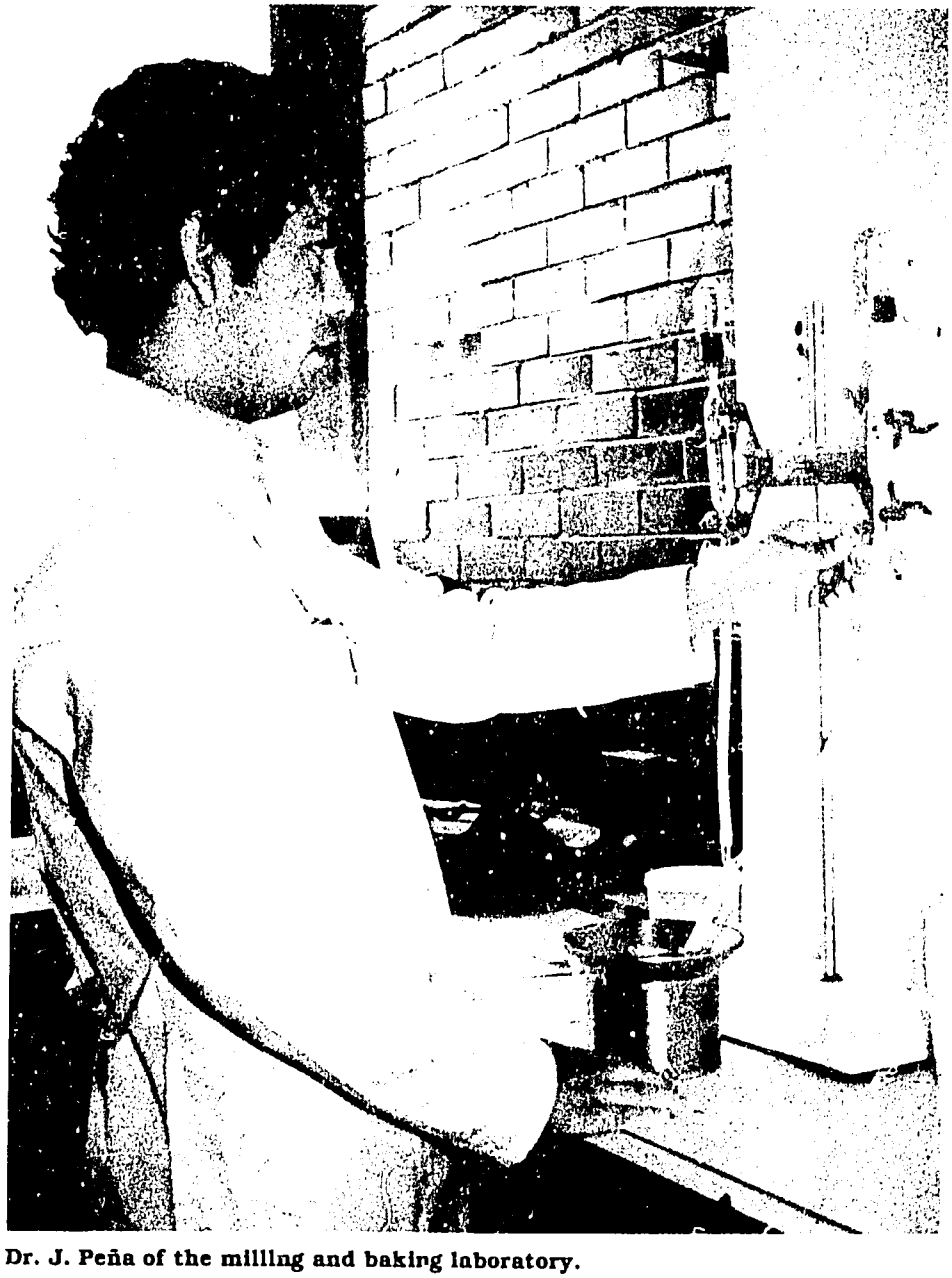
All 250 lines in the 16th ITSN had flour yields higher than 60%, and 58 of the samples equaled or surpassed 70% flour extraction. Loaf volumes for 20 lines were equal to or greater than 800 cc, and 61 possessed cookie quality ranging from good to very good.

Basic Germplasm Development

The basic germplasm development program sent 611 lines for evaluation in 1984. Of these, 43% had a flour protein percentage of 12% or more (the highest value was 15.4%), and loaf volumes higher than 800 cc. Several lines with excellent baking characteristics produced bread with volumes higher than 1025 cc.

Training

The laboratory received three trainees in 1984. Anna M. Mrema (Tanzania), Kanchana Natesomranh, and Swaporn Siwawey (Thailand) spent three months at CIMMYT learning techniques for evaluating breeding material, studying the uses and types of wheat, and learning how to handle and service equipment used in the laboratory. Denise Granger (Chile) came to the laboratory for one month as a visiting scientist. Yolanda Morales Ruiz, Odilia Campos Padron, and Luz Maria Dueñas Alvarado (Mexico) spent three weeks in the laboratory studying the preparation of triticale products, since these staff members are to run a bakery where triticale is used for making bread.



Dr. J. Peña of the milling and baking laboratory.

International Nurseries

M. Alcalá S.

Introduction

Each year, CIMMYT sends numerous nurseries—sets of lines to be planted for different kinds of evaluation—to cooperating agricultural scientists throughout the world. The nurseries, distributed only upon request, are grown under a range of conditions, in which the adaptability, disease resistance, stress tolerance, and yielding ability of entries can be rapidly and accurately assessed. Cooperators are asked to provide performance data to CIMMYT for compilation, analysis, and eventual publication and dissemination to interested parties. In return, cooperators are free to use the germplasm they receive in their own programs, for crossing with local varieties, or perhaps even for seed multiplication and subsequent varietal release. CIMMYT stipulates only that the source of the germplasm be acknowledged.

In the summer of 1984, CIMMYT distributed a total of 2413 bread wheat, durum wheat, triticale, barley, and germplasm development nurseries to cooperators in 97 different nations. Tables 1 and 2 provide details of the types, numbers, and distribution of these nurseries.

Nursery Categories

Six categories of nurseries were sent out in 1984:

Crossing Blocks—Potential parental lines are selected for use in crossing programs, and entries in each Crossing Block (CB), which may include as many as 500 lines, are arranged according to their previously identified genetic superiority for one or more traits. Criteria for grouping varieties and lines within the nursery include high yield and/or wide adaptation, disease resistance, adaptation to a specific region, agronomic characters, tolerance to high levels of free aluminum, and milling and baking quality.

F_2 segregating populations—These materials, whose genetic and phenotypic variation is great, are chosen with reference to local climatic conditions, soil types, moisture availability, disease spectrum, and cultural practices prevalent where the nurseries will be evaluated.

Screening nurseries—Lines showing outstanding performance under conditions in Mexico may be included in one or more screening nurseries. Lines in these nurseries are assessed for agronomic type, adaptation to local conditions, and disease resistance, though not for yield.

Screening nurseries have three basic functions:

- They introduce new genetic variability into the germplasm bases of national wheat improvement programs, and may be used in crosses, reselected and released as a variety, or used directly;
- They provide a means of evaluating new advanced lines from Mexico; and
- They provide information on performance of germplasm over a wide range of climatic and disease conditions.

Yield nurseries—Yield nursery (or trial) entries may be taken from national programs or the CIMMYT program. These entries are usually advanced materials (F_5—F_7) or commercially released varieties. Materials from national programs are first grown and evaluated in Mexico prior to being selected for inclusion in yield nurseries.

1) Dr. M. Alcalá, head of the international nurseries program.

2) In 1984, staff of the international nurseries program prepared 2413 nurseries for distribution to cooperators in 97 countries.

These nurseries have four purposes:

- They permit the performance of advanced lines to be evaluated over a wide range of conditions;
- They make it possible to compare performance characteristics of materials from numerous sources at each trial location;
- They are sources of genetic variability that cooperators may take advantage of directly or in crosses; and
- They generate information on the principles of adaptation.

Disease nurseries—These nurseries are distributed to locations where particular diseases are likely to occur with regular incidence and intensity. They are a means of identifying and evaluating potential sources of disease resistance, and agronomic evaluation receives less emphasis.

Yield components—These nurseries from the germplasm development program are sent to locations that permit the evaluation of yield components (i.e., number of spikes per plant, spikelets per spike, grains per spike) as well as grain characteristics and biomass, in different environments. Data gathered from these evaluations provide information about the stability of yield components and help formulate guidelines for further wheat improvement. Cooperators use these data in their crossing programs.

New Wheat Storage Facilities

New bulk storage bins were developed at CIMMYT to replace sack storage and satisfy daily demands for seed from the yield and screening nurseries (Figure 1). Seed is kept at room temperature and a relative humidity of 50%. The bin has two advantages over sack storage: small quantities of seed may be removed more easily, and seed is protected from rodents. Since it is not hermetically sealed, the bin provides no protection against insects, and must be fumigated when necessary. Otherwise, no special care is required.

The bins, each designed to store up to 100 kg of wheat seed, are constructed from a metal sheet 1.24 mm thick. The parts are butted together, with the exception of the nozzle, which is welded in place. A lever lid at the top of the bin allows it to be filled easily using a mobile seed elevator. Different quantities of seed can be withdrawn from the bin through the nozzle, which is made of a funnel with a separator plate that can be opened and shut easily. Precise quantities of seed can be measured if a hose is attached to the funnel and a sack is placed on a balance on the floor beneath the bin. Two angle brackets at the front and back of the bin are used to hang the bin on an adjustable frame; ideally, the bin should be placed high enough to permit a standing person to use the funnel. Shelves can be built underneath to store small tins of reserve seed. More complete specifications for constructing these storage bins are available from CIMMYT on request.

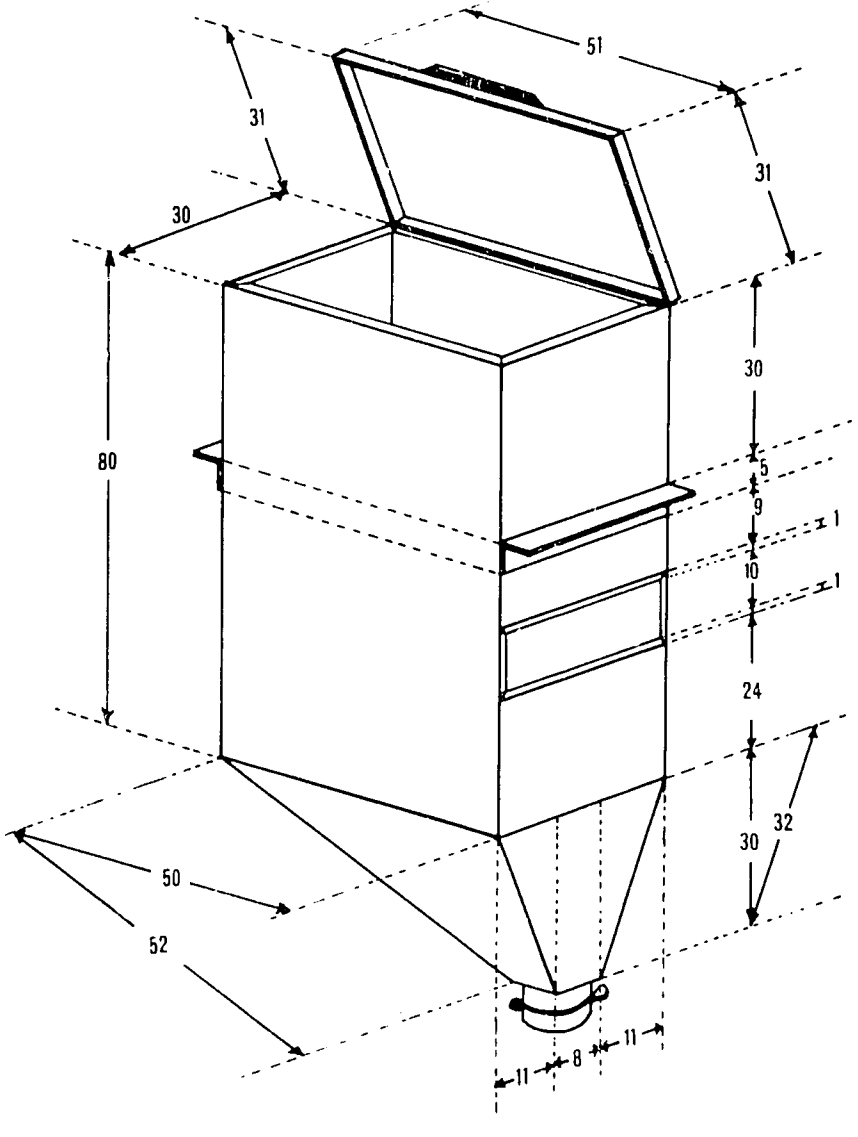


Figure 1. Bulk storage bin developed at CIMMYT.

Table 1. Bread wheat, durum, triticale, and barley nurseries distributed by the International Nurseries Program, summer, 1984

	Bread wheat	Durum wheat	Triticale	Barley	Germ. dev.
Latin America	**306**	**94**	**88**	**40**	**59**
Argentina	49	26	7	-	7
Bolivia	18	10	5	3	3
Brazil	80	7	20	7	16
Chile	26	13	7	2	8
Colombia	13	-	7	4	2
Costa Rica	5	-	2	1	-
Dom. Republic	4	-	1	3	-
Ecuador	13	1	5	3	1
Guatemala	15	-	3	-	2
Guyana	2	-	-	-	-
Mexico	28	16	10	11	11
Paraguay	15	-	4	1	3
Peru	26	20	15	5	3
Uruguay	10	1	1	-	2
Venezuela	2	-	1	-	1
Africa	**246**	**90**	**58**	**54**	**34**
Algeria	16	12	2	5	1
Angola	1	1	1	1	-
Burkina Faso	5	-	-	-	-
Burundi	3	-	1	-	1
Cameroon	6	1	2	1	1
Congo	2	-	-	-	-
Egypt	24	18	8	6	8
Ethiopia	15	8	3	4	4
Kenya	15	6	4	5	3
Libya	7	5	-	2	-
Malawi	7	-	2	2	-
Morocco	18	6	2	1	1
Mozambique	6	3	4	1	-
Niger	1	1	1	1	-
Nigeria	6	-	-	1	-
Rwanda	8	-	3	2	1
Senegal	3	1	-	-	-
Somalia	1	-	-	-	-
South Africa	19	8	7	7	5
Sudan	14	5	2	1	1
Swaziland	3	-	1	-	-
Tanzania	16	3	5	3	1
Tunisia	10	12	4	6	5
Uganda	6	-	1	-	-
Zaire	4	-	1	-	1
Zambia	17	-	4	-	-
Zimbabwe	13	-	-	5	2

(continued)

Table 1 (continued)

	Bread wheat	Durum wheat	Triticale	Barley	Germ. dev.
Middle East	**140**	**69**	**43**	**51**	**27**
Cyprus	6	6	3	3	1
Iran	10	-	2	3	-
Iraq	6	6	4	4	1
Israel	19	9	3	4	8
Jordan	9	13	6	3	2
Lebanon	6	3	1	-	1
Qatar	3	-	-	2	-
Saudi Arabia	7	3	2	2	1
Syria	30	19	10	12	5
Turkey	35	23	11	18	7
Yemen, North	4	1	1	-	-
Yemen, South	5	1	-	-	1
Asia	**240**	**38**	**36**	**37**	**39**
Afghanistan	8	4	2	4	1
Bangladesh	21	1	2	1	2
Bhutan	4	1	1	1	-
Burma	10	1	2	2	1
China	79	9	6	9	15
India	13	3	1	2	4
Indonesia	6	-	1	1	-
Japan	1	-	-	-	-
Korea, South	4	-	2	4	-
Nepal	14	-	2	-	1
Pakistan	37	12	9	6	6
Philippines	17	2	4	1	3
Sri Lanka	4	-	-	1	2
Taiwan	5	-	-	2	2
Thailand	17	5	4	3	2
Oceania	**23**	**9**	**11**	**4**	**2**
Australia	16	4	6	2	2
New Zealand	7	5	5	2	-
Europe	**166**	**98**	**96**	**58**	**40**
Albania	2	1	1	-	-
Austria	-	3	-	1	-
Belgium	1	-	-	-	1
Bulgaria	5	6	3	-	1
Czechoslovakia	5	-	2	2	4
England	6	1	6	3	3
Finland	1	-	-	1	-
France	11	3	9	6	4
Germany E.	-	-	2	1	-
Germany W.	4	8	4	3	-
Greece	11	10	6	6	3
Hungary	3	2	2	1	1
Ireland	5	-	-	5	-
Italy	9	18	4	6	4
Netherlands	5	-	-	-	-

(continued)

Table 1 (continued)

	Bread wheat	Durum wheat	Triticale	Barley	Germ. dev.
Norway	4	-	2	2	2
Poland	10	1	7	4	4
Portugal	15	8	7	5	1
Rumania	5	1	6	1	3
Spain	39	33	29	11	6
Sweden	6	-	4	-	-
Switzerland	2	1	1	-	1
USSR	7	-	-	-	1
Yugoslavia	10	2	1	-	1
North America	**40**	**21**	**10**	**20**	**6**
Canada	9	2	1	4	-
USA	31	19	9	16	6
Totals:					
Countries:	**97**				
Nurseries:	**44**				

Table 2. Number of lines in each of the 1984-85 nurseries

Nursery	No. of entries
Bread wheat	
F_2 Spring x Winter	38
F_2 Irrigated	345
F_2 Dryland	112
F_2 Highland	163
F_2 Helminthosporium	76
F_2 Scab	76
F_2 Southern Cone	129
F_2 Aluminum	117
2nd Early Maturity Screening Nursery	189
3rd Drought Screening Nursery	126
2nd Heat Tolerant Screening Nursery	113
3rd Helminthosporium Screening Nursery	76
3rd Aluminum Screening Nursery	88
18th International Bread Wheat Screening Nursery (IBWSN)	212
21st International Spring Wheat Yield Nursery (ISWYN) - 3 replications, 50 entries	150
6th Elite Selection Wheat Yield Trial (ESWYT) - 3 replications, 30 entries	90
Parcela Chica (PC)	1145
Special nurseries	
2nd International Disease Trap Nursery (IDTN)	275
15th International Septoria Observation Nursery (ISEPTON)	156
1st Karnal Bunt Screening Nursery	1759

(continued)

Table 2 (continued)

Nursery	No. of entries
Durum wheat	
F_2 Spring x Winter	63
F_2 Irrigated	171
F_2 Dryland	128
F_2 Stem Rust Resistance	75
16th International Durum Yield Nursery (IDYN) — 3 replications, 30 entries	90
14th Elite Durum Yield Trial (EDYT) — 3 replications, 30 entries	90
16th International Durum Screening Nursery (IDSN)	155
Crossing Block (CB)	111
Advanced Lines	224
Triticale	
F_2 Spring x Winter	50
F_2 Bulk	163
16th International Triticale Yield Nursery (ITYN) — 3 replications, 25 entries	75
16th International Triticale Screening Nursery (ITSN)	250
Parcela Chica (PC)	729
Barley	
F_2 Spring x Spring	183
F_2 Spring x Winter	85
F_2 Zona Andina	107
7th International Barley Yield Trial (IBYT) — 4 replications, 25 entries	100
12th International Barley Observation Nursery (IBON)	106
3rd Barley Yellow Dwarf Virus Nursery (BYDV)	115
Germplasm development	
Yield Components (bread wheat)	30
Yield Components (durum wheat)	23
Leaf Rust Resistance Material	112
Aluminum Tolerant and Disease Resistant Material	67

Andean Region

H.J. Dubin, P.N. Fox, and P.C. Wall

Introduction

Several features of wheat production in the Andean region over the past five years are significant. Percentage changes in yield and production from 1979-84 are shown in Table 1, together with approximate production and import statistics for 1984.

In Colombia, government policies, especially a stimulatory price, have been instrumental in increasing yields and the amount of land on which wheat is grown. However, the amount of land sown to barley in Colombia was reduced enormously by disease epidemics, first of *Puccinia striiformis* f. sp. *hordei* (PSH) beginning in 1976, and then by *P. hordei* on the PSH-resistant varieties released to overcome the first epidemic.

The great percentage increase in barley yields in Ecuador and Peru may be attributed to the adoption of varieties resistant to PSH, and, in Peru, to the impact of a barley production program that extends credit and other facilities to growers, and is conducted by the breweries. Wheat production in Ecuador was reduced in 1984 because of heavy rains that interfered with seeding.

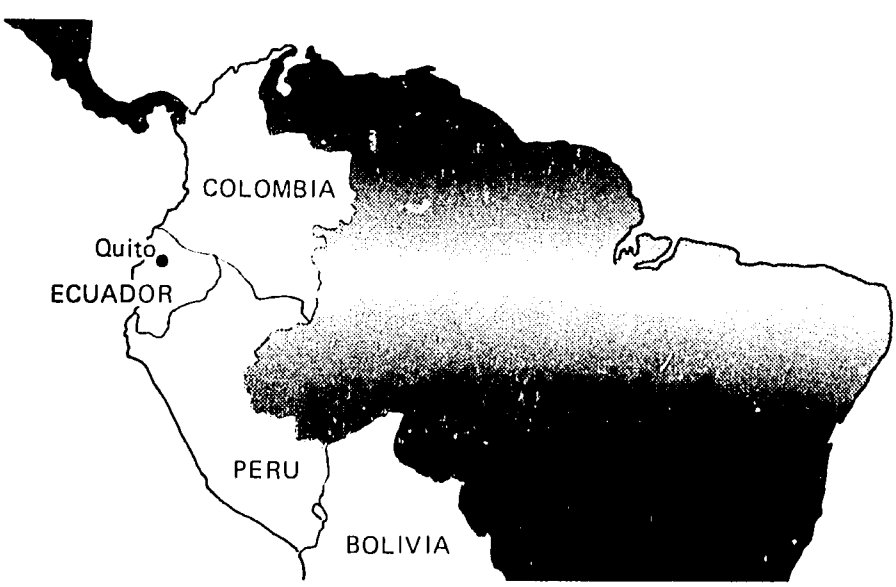
Program Objectives

Regional staff are pursuing several major objectives, one of which is to help national research programs produce germplasm with high yield potential, disease resistance, and adaptation to the agroclimatic areas of the region. Another objective is to train personnel in germplasm management to achieve these ends. Yield potential *per se* is not a major limiting factor in the region, but the importance of disease resistance can be appreciated from the fact that in Ecuador three resistant barley varieties have raised yields to where they were before the 1976-77 PSH epidemic (Table 1). The economic benefit of these three varieties, selected by the National Institute of Agricultural Research (INIAP), is approximately US$ 1.4 million per year, or 27% of the total INIAP budget.

Another major objective of the program staff is to train scientists in agronomy and agronomic research procedures aimed at developing viable recommendations for cereal growers.

Germplasm Development

A total of 157 nurseries from CIMMYT Mexico were received in the region for 1984 seedings; over half were bread wheat. The Latin American Disease and Observation nurseries (VEOLAs) comprise the most promising advanced lines of bread wheat and barley from the national programs. The 8th Wheat VEOLA and 7th Barley VEOLA were prepared at the regional base in Ecuador, and 45 sets were distributed among 11 countries within the region and elsewhere. Recently the nurseries were expanded to include segregating materials from Andean breeders. No new varieties were released in the Andean Region in 1984.



Colombia

Observations in June at the Tibaitatá Experiment Station near Bogotá showed that the newly released ICA-Susatá (Ald 'S') was susceptible to a low frequency *P. striiformis tritici* (PST) race virulent on Yr 9 (R.W. Stubbs, unpublished). By the end of the year, the frequency of the virulent strain had increased dramatically in the second cropping cycle and ICA-Susatá was completely susceptible to leaf and spike infection. The 1B/1R translocation possessing Yr 9 is contained in Ald 'S', and apparently was the only effective gene for PST resistance in ICA-Susatá. This variety was also highly susceptible to *Gaeumannomyces graminis*, confirming observations made in Ecuador. Severe *P. recondita* infection as well as moderate levels of *G. graminis* infection were noted in ICATA 76. The susceptibility of these two varieties stresses the need for wheat breeding programs to emphasize disease resistance when developing varieties for the traditional wheat-growing areas of Colombia.

In 1983, the Colombian Agricultural and Livestock Institute (ICA) expressed interest in growing wheat in the Llanos, a low-lying plain (200 m elevation) with high temperatures (mean minimum 22.9°C) and acid soils, where soluble aluminum can limit crop production. The availability of material for this area was examined in 1984, when several nurseries from CIMMYT

Mexico and some Colombian segregating material were sown. It appeared that temperature was the greatest constraint to wheat adaptation in the Llanos; most of the lines that germinated did not produce spikes, although numerous small tillers were produced. Presumably, high temperatures kill the apical meristem. Diseases were also present: *Helminthosporium sativum* and *Fusarium equiseti* were identified from plant samples (L.I. Gilchrist, unpublished). Further screening and more detailed studies will be conducted in 1985.

Ecuador

Bread wheat varieties INIAP-Altar and INIAP-Tungurahua continued to perform well and remained resistant to major diseases in 1984. Chimborazo was increasingly affected by PST; in some cases, spike infections reached 60%. Trap nursery field data indicated that no changes in the PST races occurred. Clement, which contains Yr 9, was very resistant in the trap nursery, but preliminary evidence suggests that Clement may also contain an additional resistance gene for PST.

Inoculation of breeder nurseries produced severe PST epidemics on susceptible materials and permitted good screening for resistance. Inoculation and screening have played a vital role in producing relatively stable resistance to PST in germplasm for the Andean zone and in incorporating effective resistance genes into many varieties worldwide. Ecuador was formerly considered a "hot spot" for this disease. Other diseases recorded in the nurseries were *F. nivale*, *Septoria tritici*, *S. nodorum*, *G. graminis*, Nariño Dwarf, and BYD, with *H. tritici-repentis* causing severe foliar blight in material in one on-farm trial.

The incorporation of leaf rust (*P. hordei*) resistance into barley continues to be another major objective of the program, and in 1984, cooperation between INIAP and the CIMMYT-based ICARDA breeder was strengthened to overcome leaf rust and other factors limiting barley production. Breeding nurseries were successfully inoculated with *Rhyncosporium secalis*, using infected leaves, and good resistance data were obtained. Infections of BYD and the "spot form" of *H. teres* were noted in barley nurseries. The PSH virulence genes remain unchanged from last year — race 24 predominates, but without the "Mazurka" or "Varunda" variants.

Peru

With the consolidation of several isolated breeding programs in the Peruvian "Sierra" into one program based in Cuzco, a coordinated germplasm development program for the Andean areas of Peru was initiated. The wheat varieties Ollanta and Cahuide are still somewhat resistant to the major

Dr. P. Wall, agronomist (right), and Dr. J. Dubin, pathologist, CIMMYT outreach staff posted to the Andean region.

diseases prevalent in the Sierra, and emphasis was placed on reconstituting these varieties, since no basic seed had been produced for many years. Farmers' fields contained up to 50% mixture, but the mixtures are often susceptible to rusts, primarily PST. At the same time, production of basic seed of Gavilan (Pavon 'S') and Inia-C102 (CC - Inia x Bb) was started.

Trials of advanced material from all previous breeding programs were sown throughout the Sierra. Decisions on variety release will thus take into account adaptability and general disease resistance.

No unique pathology problems were seen in Peru in 1984, but *Xanthomonas translucens*, *S. nodorum*, *S. tritici*, and *F. nivale* occurred commonly in the National Institute of Agricultural Research and Extension (INIPA) breeding nurseries at Andenes (Cuzco). Barley yellow dwarf was also observed in both the Andenes and Taray stations, and good infections of stem rust (*P. graminis tritici*) occurred in Taray.

The National Agrarian University (UNA) and INIPA continue to work with winter wheats for the high plateau (3800 m elevation) of Puno and other very high areas. In the UNA nurseries in Huancayo, where the climate is not as extreme as in Puno, yields of up to 8 t/ha were obtained from several selections of facultative types. Interest in winter wheats is growing in Peru and it is vital to test the most advanced material in the harsher conditions of the Puno plateau.

Bolivia

In Bolivia, attention is increasingly focused on the Department of Santa Cruz, where, with appropriate incentives, wheat could be produced on a large area. In the area north of Santa Cruz, where 8500 ha were planted to wheat in 1984, helminthosporium diseases have been the major biological constraint. Selection strategies of the Tropical Agricultural Research Center (CIAT), Bolivia, are aimed at overcoming these diseases. However, 1984 was a dry year and there was little development of helminthosporium, resulting in poor selection pressure.

Leaf rust (*P. recondita*) is not normally a disease of major importance in this area, but in 1984 there were severe infections north of Santa Cruz and at the Abapo-Izozog project in the Bolivian Chaco. Trap nursery data indicated that the higher incidence of this disease was not due to a race change, but rather to an increase in the inoculum load reaching the area, probably from the southeast. Nacozari 'S' and Cupesi (Bobito 'S'), new varieties of the Abapo-Izozog project, were both very susceptible, as were varieties PAI 3 and PAI 4. A new advanced line, Mistol (Bow 'S') showed good resistance to both *P. recondita* and *P. graminis*, but the variety matures slightly too late for widespread use. Saguayo, the main variety grown north of Santa Cruz, also proved to be highly susceptible to leaf rust.

Collections of a foliar wheat blight from the San Benito Experiment Station, Cochabamba, in 1983, were analyzed and the fungus *H. avenae* was associated with the lesions. This is the first report of the *H. avenae* strain in the Andean region. The Commonwealth Mycological Institute confirmed the identification and has specimens on deposit.

Crop Management

Bolivia—The mountain valleys of Cochabamba had a very wet season after the extreme drought of 1983. In drier areas where wheat is commonly grown in Bolivia, it appears that the fertilizer recommendation could be increased from 40-40-0 to 80-80-0, and the recommendation for barley could be raised from 30-30-0 to 60-80-0. However, it is unlikely that any recommendation will be adopted by the farming population because of the poor economic situation and the uncertain market for the grain produced. The critical economic situation has also made it difficult for the Bolivian Institute of Agriculture and Livestock Technology (IBTA) to carry out as much agronomic work in 1984 as in previous seasons.

In the lowland area of the Department of Santa Cruz, the Abapo-Izozog project, under the Ministry of Defense, is settling farmers on irrigated land. The major wheat production problem in this area is the compaction and low infiltration rate of the sandy clay loam soils, in which the clay fraction is primarily kaolinite. In 1983, it was hypothesized that direct drilling of seed might ameliorate the soil compaction problem by reducing the amount of wheel-traffic over the fields, especially when they were moist, and direct drilling was tried in 1984. Although zero tillage (direct drilling) did not give good results, a minimum tillage treatment (subsoiling to 60 cm with tynes 50 cm apart, and then drilling the seed) gave significantly higher yields (about 0.5 t/ha greater) than the normal practice of subsoiling, plowing, disking, and seeding. This work is to be continued to study the longer-term effects.

Ecuador—Poor soil fertility is the major constraint to improving yields and economic benefits in the Cayambe area of northern Ecuador. In 1984, as in the wet season of 1983, optimum fertilizer applications were markedly different from those found in the drier years prior to 1983. During the dry years before 1983, 80-160-0 (80 kg N/ha and 160 kg P_2O_5/ha) was the most economic fertilizer rate, followed by 80-80-0, but in the 1983 and 1984 seasons there has been far less response to applied phosphorus and more response to applied nitrogen. The optimum fertilizer application in these seasons was between 120-40-0 and 160-40-0.

Covering broadcast seed with a light offset tandem disc harrow, as opposed to the heavy disc harrow normally used by farmers, gave excellent results. Plant populations were good at sites where this

implement was used. In the future, work on banding fertilizer and seed will be an adjunct to research on broadcasting and seed incorporation.

In the Saicedo area on the western Andean range, at elevations between 2800 m and 3400 m, barley is an important food crop grown by most farmers, generally small-scale farmers organized in communes. In previous years, poor fertility was the greatest impediment to wheat production in the area, but trial numbers were insufficient to identify optimum economic fertilizer treatments. In 1984, only one replication of a fertilizer trial was seeded at each site, and therefore results were obtained from a far greater number of farmers' fields.

The optimum fertilizer level encountered was 60-90 kg N/ha and 40-80 kg P_2O_5/ha. There was some evidence of a response to potassium and more research needs to be done on the response to this element. Yields of the unfertilized check varied with the previous crop. Barley sown after fertilized potatoes or grazed, weedy fallow gave far higher yields (about 1.3 t/ha more) than barley sown after barley, horse beans, or peas (all unfertilized). However, the responses to applied fertilizer in this season were similar regardless of the previous crop.

A 'bafile' harrow, developed in Bolivia in a cooperative project with the Swiss government (CIFEMA), was tested this year in the Saicedo area as an alternative method of incorporating broadcast seed and fertilizer. The use of this ox-drawn harrow significantly increased yields at two sites where it was tried, and provoked much interest among cooperating farmers. Compared with the usual methods of using a single-tyne or ox-drawn plow or a hand hoe, the harrow, with its 1.6 m width, reduces the time required to incorporate seed in a field.

Peru—Exploratory trials to identify the most significant factors limiting yields were installed in five departments of the Sierra. Lack of good clean seed is a serious problem for farmers, but contrary to the expectations of researchers, variety *per se* did not prove to be a great constraint in the Sierra. Poor soil fertility was the prime limiting factor found in all areas, though in some locations weeds were extremely important, and the two factors will have to be treated together because of the strong interaction shown between them.

Economics research—The Andean region is the only area in the world where the amount of land devoted to wheat cultivation has declined markedly in the last 15 years and yields have stagnated. To understand the origins of this situation and its implications for future wheat research in Ecuador, the CIMMYT Economics Program conducted a study in Cayambe, Ecuador. Results of this study showed that when national profitability of several crop-livestock activities was calculated, wheat provided the highest returns to land after potatoes. These results imply that a strong wheat research program is justified in Ecuador, and that researchers should plan for possible changes in food policy over the long term. A detailed account of the study is reported in Byerlee (1985).

Training

Agronomy research course—A training course on performing agronomic research under conditions representative of target groups of farmers was organized and conducted in Peru during late 1983 and 1984, with the help of CIMMYT regional and headquarters staff. The course, held in and around Cuzco, was attended by 19 scientists and included research agronomists and extension specialists.

The course was conducted in four parts. The first part took place during 10 days at seeding time, when survey results were analyzed and trials were designed and seeded. The second part of the course was held during a one-week period in mid-season. Treatment responses were judged and notes were taken on diseases and other factors that could influence results. The third session was offered during two weeks at harvest, when trials were harvested and two farmer field days were conducted. At the same time, data were analyzed and participants established priorities for the following season. The last session of the course occurred 3-4 months after harvest. Participants met for three days to present and discuss results from all areas of the Sierra, and plans for 1984-85 were made.

Although a short course can provide only the most essential information, participants judged the course to be very successful. The effectiveness of the course is apparent from the fact that in eight areas of Peru, research is now conducted under the circumstances of small grain producers, whereas before the course such research was done in only one area of the country. Further training of researchers is needed so that they may in turn train the new researchers entering the program.

Barley Workshop—A two-day Andean Barley Workshop was held in Bogotá, Colombia, during June, 1984, with the objective of stimulating cooperation and increasing research coordination among Andean barley breeders. The host institution was Agrofomento, and participants came from Colombia, Ecuador, Peru, Bolivia, Chile (CIMMYT), and ICARDA. After presentations on the status of barley research in their respective countries, participants spent a day

in the field at Agrofomento viewing breeding material and holding informal discussions. Final discussions on increasing cooperation produced two principal conclusions: to include F_2 germplasm in the Andean Barley VEOLA, and to revive the Andean Barley Yield Trial (ERCA).

Training in Mexico—Eight scientists from the region went to Mexico for in-service training in 1984. Three studied breeding, four agronomy, and one station management. Three program scientists and two program directors from the region made brief visits to CIMMYT headquarters.

Program visits—The head of the Ecuadorian barley program and the head of the cereals program at UNA, Peru, made CIMMYT-funded visits to the Chilean barley program to promote the exchange of germplasm and ideas.

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Table 1. Area seeded and yields of wheat and barley in the Andean region, 1984, and changes over 1979-84

Crop	Area (1000 ha) 1984	Area (1000 ha) % Change 1979-84	Yield (t/ha) 1984	Yield (t/ha) % Change 1979-84	Price[a] (US $/t)	Imports (1000 t)
Wheat						
Bolivia	75	0	0.9	0	Fluctuating	300
Colombia	39.8	29.6	1.74	27.0	270	540
Ecuador	20.7	-32.0	1.21	17.0	184	360
Peru	90	5.9	1.1	10.0	170	1000
Barley						
Bolivia	100	0	0.7	0		
Colombia	21.4	-71.0	1.60	-14.5		
Ecuador	24.7	7.4	0.96	47.7		
Peru	120	-22.0	1.4	62.8		

[a] Price in December, 1984; does not necessarily reflect price paid in the 1984 season

Southern Cone Region

M.M. Kohli and M.A. McMahon

Introduction

A satisfactory picture of wheat production in the Southern Cone region emerges from a comparison of the years 1980 and 1984 (Table 1). In all countries except Brazil, increases in the amount of land planted to wheat have been accompanied by higher yields per hectare. As a result of these gains in productivity, approximately 43% more wheat has been harvested in the last five years.

Gains in wheat production during 1984 alone exemplify the potential of the Southern Cone region for raising cereals production. Many factors played an important role in the 1984 increases. In Argentina, poor incentives reduced the wheat area by approximately 15% during 1983, but this reduction was more than compensated for by the high yields obtained under good growing conditions and by the use of nitrogen fertilizer on more than 10% of the area.

In Chile and Paraguay, favorable agricultural policies promoted increases in wheat production and the amount of land under cultivation. Paraguay would have become self-sufficient in wheat during 1984 if a serious frost had not killed one-third of the wheat crop.

Brazilian wheat farmers have been reducing the amount of land under production since 1970, when wheat-soybean rotations began on a large scale. The reasons for this decline are primarily the cost of production (high technology is required) and the cost of financing a good crop. According to an estimate by the Federation of Brazilian Wheat and Soya Cooperatives (FECOTRIGO), 43% of the total cost of wheat production in the state of Rio Grande do Sul is the interest on credits taken for the crop. This situation did not change in 1984. Uruguay has maintained the same wheat area for some years. In the last few years farmers have increased productivity, partly because of good growing conditions and widespread acceptance of new varieties.

Crop Status

Argentina—Heavy rains affected much of Argentina's wheat-growing area. Wheat was seeded in most areas at the optimum time when soil moisture conditions were good, but seeding in the southern parts of Buenos Aires province had to be delayed by as much as two months. There was no water shortage in the Western Pampa region, where one-third of the land devoted to wheat production is located. Fertilizer response (700,000 ha of land were fertilized with nitrogen) was apparent, more so in wheat planted after maize than in wheat planted after soybeans. Serious problems with weed control and widespread herbicide damage occurred in commercial fields. Increased stem rust and leaf blotch infection in commercial crops may require an aggressive campaign to introduce new resistant varieties.

Brazil—Wheat production was fairly poor in Brazil in 1984. Many factors closely related to the cost of financing a wheat crop, which is a large investment for most farmers, discouraged production. The wheat price, fixed at US$ 210.00/t at the beginning of the cycle, was apparently not sufficient to encourage the seeding of more land to wheat. Risk is a major factor of wheat production, and although the recommended technology is well-proven, it is costly. As a result, use of fertilizer is decreasing and soil preparation practices are deteriorating further.

Drought in northern Paraná and severe frost in parts of Paraná and Rio Grande do Sul also limited production in 1984. Other areas had fairly good moisture distribution and low disease pressure.

Chile—Successful marketing of 1983's wheat crop and the maintenance of agricultural policies favorable to local production encouraged farmers to seed 10% more land with wheat in 1984. The attractive local price, which is approximately 85% of the floor price

(US$ 237.00) for imported wheat, helped farmers use more improved, certified seed and fertilizers. Unfortunately, yield potential was reduced significantly because of moisture shortages, resulting in only a minor increase in wheat production over the previous year.

Considering the national average yield of 2.1 t/ha, it is important to note that 98% of the 228 participants in the National Production Contest harvested more than 4.0 t/ha and that the highest reported figures reached 10 t/ha. These figures indicate potential yields that can be obtained with improved technology.

Paraguay—In large part due to consistent government support, the amount of land under wheat cultivation in Paraguay has been increasing in the last five years, reaching 120,000 ha in 1984. Over 90% of this area was fertilized with at least an 18-46-0 NPK formula, and some farmers applied another 40 kg N/ha as top-dressing. Approximately 80% of the seeding was done during the recommended period. Because seed of the new varieties was unavailable, about 80% of the area was seeded to Itapua I (60%-65%) and 281/60 (15%-20%). Cordillera-3 (Veery No.3), a new high-yielding variety, covered approximately 8,000 ha in 1984, and the amount of land seeded to this variety should increase dramatically in the future.

The wheat harvest was predicted to meet national demand (180,000 t), but a severe frost during the grain-filling period killed about 30% of the crop. Despite this misfortune, some farmers harvested as much as 4.3 t/ha (almost three times the national average), and a new record for national wheat production (140,000 t) was set in 1984.

Uruguay—Early rains allowed only 10% of the farmers to seed wheat in May. Most farmers seeded in mid-July, soon after the rains, and the crop suffered a little from a lack of moisture. Slightly higher than normal temperatures brought severe infections of leaf rust and scab. Leaf blotch infection was moderate to high and stem rust, which came rather late, also reached moderate levels. Overall, it was an excellent year for disease screening, but thanks to the spread of new varieties (E. Hornero on 50% of the land), farmers did not suffer the heavy disease damage that was anticipated.

Many commercial crops looked excellent, with yields of approximately 3 t/ha. However, an increasing number of fields had poor weed control and this is lowering the national average yield.

Germplasm Development

Bread wheat—Climatic conditions allowed good crop development throughout most of the region. Several advanced lines, compared with the commercially grown check varieties, were identified for superior yield potential.

Dr. M. McMahon (far left), CIMMYT scientist based in the Southern Cone region, with (left to right) Dr. J. Dubin, Dr. N. Borlaug, and two national program researchers.

Temperatures over 30°C during the early growth period severely affected the wheat crop in parts of Paraná, Brazil. However, based on crop establishment, tillering capacity, and delayed initiation of stem elongation, valuable new germplasm that may be better suited to the tropical wheat regions was identified (Table 2). The performance of this material was equal to or better than such locally adapted varieties as Anahuac, Cocoraque, and Maringa. In northern Paraná, where drought was very severe (over 80 dry days after crop emergence in a 110-day crop cycle), the lines listed in Table 3 appeared promising.

Further south in the state of Rio Grande do Sul, Brazil, where newer germplasm developed through the shuttle breeding program is giving good results, a group of advanced lines was selected for aluminium tolerance (Table 4). Additional germplasm was evaluated for adaptation and yield potential throughout the region; the Veery selections generally showed superb performance at most locations. Advanced lines selected from the 17th IBWSN for wide adaptation throughout the region are presented in Table 5.

Durum wheat—A guaranteed price that was 12.5% higher than that for bread wheat, combined with purchase agreements by millers, encouraged Chilean farmers to increase the amount of land under durum wheat cultivation. The national production of approximately 29,000 t in 1984 nevertheless met only 30% of the total demand, and production is likely to go up in 1985. Because of this interest in the crop, the National Wheat Program released two new varieties Aromo INIA and Chagual INIA, to supplement the current commercial varieties, Quilafen and SNA-3. Durum yields in the central valley of Chile averaged approximately 5 t/ha, and some farmers harvested over 8 t/ha. Considering these yield levels, Chile should be self-sufficient in durum wheat production if approximately 20,000 ha of land are seeded.

The amount of land on which durum wheat is cultivated continues to decrease in Argentina. Even the 1982 release of the new variety, Buck Candisur, has not been able to reverse this trend. To some extent, the problem is related to the seed quality of the durums grown and to export market needs. Serious efforts are being directed at developing high-yielding varieties with large vitreous kernels. Germplasm from CIMMYT is regarded as a source of variability for high yield and disease resistance. A group of promising lines selected from the 15th IDSN is presented in Table 6.

Triticale—Official support of triticale cultivation in Brazil encouraged farmers to seed approximately 1500 ha in 1984. Most of this land was in the state of Rio Grande do Sul, and was seeded to two varieties, PFT 766 and TCEP 77138. A severe frost during the heading period emphasized the problem of early heading in these varieties and the recommendation that they should be seeded later. Later maturing germplasm with high test weights must be identified for normal seeding periods. Those farmers whose crops did not suffer from frost harvested as much as 3.5 t/ha.

Most triticale germplasm does not have serious disease problems before heading. After heading, it is susceptible to several diseases, especially scab, glume blotch, and spot blotch. Pre-harvest sprouting and low test weight remain the most important factors limiting triticale production, but newer germplasm selected from the 15th ITSN provides additional variability for these characters (Table 7).

Southern Cone Advanced Lines Nursery (LACOS)—The 4th LACOS was organized under the auspices of the Interamerican Institute of Agricultural Sciences (IICA) Cono Sur/Interamerican Development Bank (BID) program, and coordinated by the INIA-CIMMYT wheat program in Chile. The nursery consisted of the most advanced 308 entries from 18 wheat-breeding stations in the region. The objective of the nursery is to speed the wide exchange of advanced local germplasm. Forty sets of the 4th LACOS were distributed to cooperators within and outside of the region. The most significant aspect of the nursery is that approximately 75% of the advanced lines entering the trial are products of local breeding programs. This is an important difference between the LACOS and other international nurseries. Results of the 2nd LACOS have been published and those of 3rd LACOS are being analyzed. There is a strong indication that national research programs are using LACOS materials more each year for their disease resistance and adaptation requirements.

New Releases

A list of wheat varieties released in the region during 1984 is given in Table 8.

Disease Screening

The most serious aspect of disease screening in 1984 was increased stem rust infection in Argentina. The new race, which attacks material with a Sonora 64 background, built up slowly over the past two years and finally appeared on a large scale in commercial fields. The most widely grown commercial varieties are susceptible, including Marcos Juarez INTA, Victoria INTA, and Klein Chamaco. Although cooler temperatures generally kept the severity of infection in commercial fields low (± 20S)[1], some fields had much higher levels of infection (± 60S). This may well be the point at which new resistant varieties must come into widespread use.

For the first time, the stem rust gene Sr 27 from WRT 238.5 showed a 40MS-S reaction in Chile. Even though stem rust infections have rarely been serious in Chile (except for a small area in the north), this new susceptibility may need to be monitored closely over the next few years.

Leaf rust infection was moderate to severe over the entire region, and thus good screening conditions prevailed.

Early heat and humidity in parts of Brazil favored the development of spot blotch (*Helminthosporium sativum*). The advanced lines listed in Table 9 showed a moderate degree of resistance to this disease.

The climate was also favorable for septoria leaf blotch (*Septoria tritici*) infection, which was severe at several locations. The outstanding selections for resistance to *S. tritici* in the region are presented in Table 10. Severe glume blotch infection (*S. nodorum*) was observed in Passo Fundo, Brazil, where none of the materials included in the International Septoria Observation Nursery (ISEPTON) showed any resistance. It is urgent that good sources of resistance to glume blotch be identified, especially for the warmer wheat regions.

Ing. Martha Diaz, Uruguay, has quite successfully employed artificial inoculation to identify scab-resistant germplasm in the field. Her results confirm the low susceptibility of La Paz INTA, Las Rosas INTA, and the following two advanced lines:

Nad//Bb/Inia
CM 7161-9M-1Y-8M-2Y-0Y
F3.71/Trm
SWM 5704-10Y-1M-3Y-3M-3Y-0B-1PTZ-0Y

Bacterial leaf blight (*Pseudomonas syringe*) has been on the increase in Argentina, especially in the Pergamino area. Severe bacterial infection (*Xanthomonas campestris*) in durum wheats was also observed in the southern parts of Buenos Aires province. Lines from the 17th IBWSN selected at Pergamino for low levels of bacterial leaf blight are listed in Table 11.

Although an increase in the aphid population in Chile early in the season forced many farmers to use insecticide for the first time in several years, the aphids, which are a vector of barley yellow dwarf virus (BYDV), did not cause a high level of BYDV infection in commercial fields.

Agronomy

This section presents reports on agronomic work in two countries of the Southern Cone region — Chile and Argentina. In Chile, research on weed control, nitrogen and phosphorus was conducted to determine appropriate recommendations for wheat farmers, and a wheat-pasture rotation using naturalized *Medicago* spp. was evaluated as well. Trials in Argentina measured the response of wheat to nitrogen and phosphorus, and demonstration plots were established to extend research results and support Argentina's fertilizer campaign. The effect of repeated phosphorus applications on the availability of phosphorus to the wheat crop was studied, as was the performance of early and late sown varieties.

Chile

Most of Chile's wheat is produced under rainfed conditions in such areas as the Secano Interior, which is located on the east side of the coastal mountain range and receives no maritime influence. Longitudinally, the Secano Interior lies between the Fifth and Eighth Regions of the country (Figure 1). Although much wheat was once grown in the area, lack of adequate technology has reduced wheat production and the region is now considered depressed. The research summarized here was conducted in the Seventh and Eighth Regions of Chile, and the data, with slight modifications, can be extrapolated to the rest of the Secano Interior.

In the Seventh and Eighth Regions, 158,855 ha are suitable for wheat production; this amounts to 15% of the total area of the Secano Interior (Table 12). The coldest months are June and July, with average temperatures of 8°-9°C and occasional frosts; the hottest months have average temperatures of 20°-21°C. Seventy to eighty percent of total rainfall occurs between May and August. The dry period extends from October through April, and soil moisture reserves are inadequate for plant growth (Figure 2).

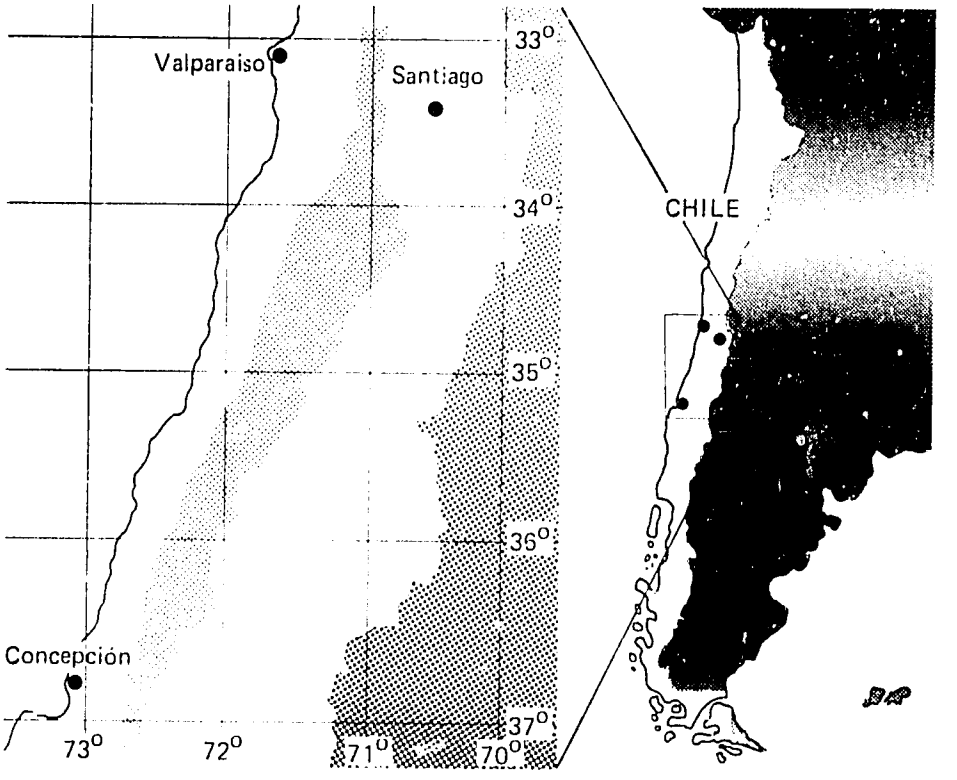


Figure 1. Secano Interior, Chile.

The soils, derived from granite, range from slightly sloping to slopes of more than 20%. The topsoils are sandy clay loam, and the subsoils are sandy clay. Because the land has been cultivated and subjected to poor management for generations, it is generally highly eroded and soil fertility has been lost. Soil analysis done by INIA-Quilamapu shows NO_3-N levels ranging from 2 to 8 ppm, phosphorus levels (Bray 1 method) from 3 to 5 ppm, and exchangeable potassium from 40 to 120 ppm. Organic matter fluctuates between 1% and 3%, depending on the intensity of the cropping, and pH is generally in the range of 5.8 to 6.0.

Current wheat yields vary from 500 to 700 kg/ha; the higher yields are usually obtained when spring rainfall is high. This low level of productivity was the stimulus to start a production research program in farmers' fields in 1981.

Farm survey—A preliminary farm survey was done in 1981 to gather information about wheat production in the region. Most wheat was grown under a sharecropping system in plots of 3 ha or less, and all power for land preparation and sowing was supplied by horses and bullocks. Planting started after the rains in May; sowing at a later date was impossible because soils became saturated. Because seed was sown broadcast and covered with a plow, it was distributed at uneven depths. The seeding rate varied from 110 to 140 kg/ha. Farmers used treated seed, but they never used certified seed and only 15% selected their seed. Furthermore, they were not aware of new varieties released by experiment stations and about 93% of the farmers interviewed used varieties that matured too late for conditions in the region.

Fifty-three percent of the farmers did not apply fertilizer, and the remainder applied nitrogen only at tillering and in very small quantities (less than 20 kg N/ha). Phosphorus was not used. Of the farmers interviewed, 65% had never used herbicide, and the rest applied it late, when the weeds were in flower.

Seventy-five percent of the farmers surveyed produced enough wheat to meet their own consumption needs, but the remainder had to buy wheat. Seed grain from the previous harvest was usually kept or exchanged with neighbors.

Production trials—Trials were conducted in farmers' fields to determine which technological factors limited yields. The factors examined were weed control, nitrogen, and phosphorus; other factors, including soil preparation, variety, and date and method of sowing, were managed by the farmer. The objectives of these trials were to:

- Determine the maximum yield potential;
- Determine the gap between actual and potential yields;
- Determine the contribution of each technological factor to potential yield;
- Set priorities within the technological package and determine the interactions involved; and,
- If the potential yield was satisfactory, to determine the technological package for extension to the farmer.

Each factor was applied at the check level and at the level recommended for maximum yields. Trial results are shown in Figure 3, in which two varieties are compared. At the check level (0 nitrogen and phosphorus applied), there was a difference of 500 kg/ha between the varieties, and when nitrogen and phosphorus were applied, there was a 220% difference in favor of the improved variety.

Varieties—Table 13 compares the performance of three varieties over two years, and confirms the availability of high-yielding varieties adapted to the Secano Interior. Although the 1983-84 crop cycle was dry, and 1984-85 was wet, in both cycles the improved varieties were superior. The early maturing variety, Onda, was best in the dry year, whereas the intermediate maturing variety, Lucero, was superior in the wet year.

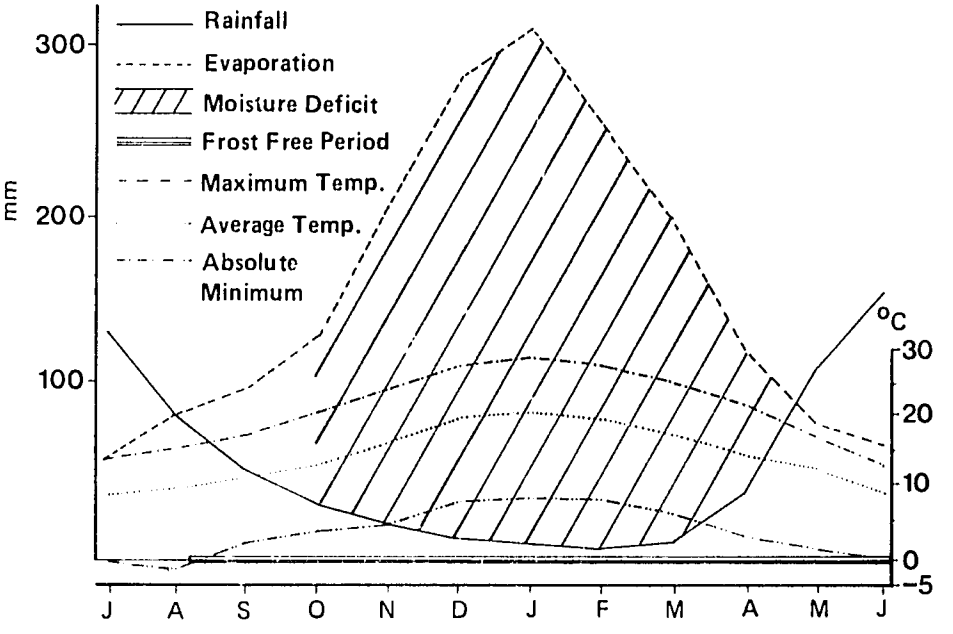


Figure 2. Climodiagram, Cauquenes, Chile (25 years).

Fertilizer response—The response to fertilizer on soils in this part of the Secano Interior is shown in Table 14. There was a good response to nitrogen alone; an application of 120 kg N/ha gave a yield of 5130 kg/ha. The response to phosphorus alone was not significant, but a very strong nitrogen x phosphorus interaction was found: the maximum yield, 6430 kg/ha, was obtained with an application of 120 kg N plus 30 kg P_2O_5. The efficiency of applied phosphorus in these soils is quite high, and small quantities are enough to produce maximum yields, once nitrogen levels are sufficient. Research on potassium and sulfur responses continues.

Weed control—When traditional methods of wheat cultivation are used, weeds are not a problem because the fallow period is long and soil fertility is naturally low. Once fertilizer is applied, weeds compete more strongly with the crop. Broadleaf weeds — mainly Cruciferae, Leguminosae, and Geraniacea — are the most important, and are usually controlled by MCPA plus dicamba on MCPA plus cynazine. Grassy weeds (*Avena*, *Lolium*, and *Hordeum* spp.) are also present, but are not numerous enough to reduce yields.

Technology transfer—During the past few years, the program has encouraged the use of new varieties by giving the varieties to certain farmers for multiplication. In 1984-85, eight farmers were selected to multiply seed and they obtained yields far above the average for the area (Table 15). Because of these efforts, new varieties have come to predominate in the area over the past five years.

Attendance at field days by farmers, technical personnel, and government officials has also increased. Although field days attracted only 9 persons in 1981, the total for 1984 was 159.

Wheat-medicago system—Because of the low productivity of the present system of wheat-native pasture rotation (Table 16), a wheat-pasture rotation using naturalized *Medicago* spp. has been proposed. There are at least two naturalized *Medicago* species in Chile: *Medicago hispida Gaertn* and *Medicago polimorpha*, which are found on the coastal terrace from Quintero to Chanco and in the Fifth to the Eighth Regions of the Secano Interior.

In 1983-84, an experiment to measure the production of a wheat-medicago system was initiated. A medicago pasture degraded by grass species because of the nitrogen fixation of the *Medicago* spp. was selected for the experiment. In the first year (1983-84), wheat (cv. Lucero) sown after the *Medicago* spp. yielded 3500 kg/ha. The degraded pasture, fertilized with 30 kg P_2O_5, produced far more dry matter than the best natural or artificial pastures recommended for the area (Table 17). In 1984-85, wheat (cv. Onda) yielded 4500 kg/ha, and the renewed medicago pasture, one year after having been sown to wheat, yielded 5500 kg/ha dry matter (Table 17). The most interesting part of these trials was the recuperation of the medicago pasture after wheat; almost all weeds were eliminated.

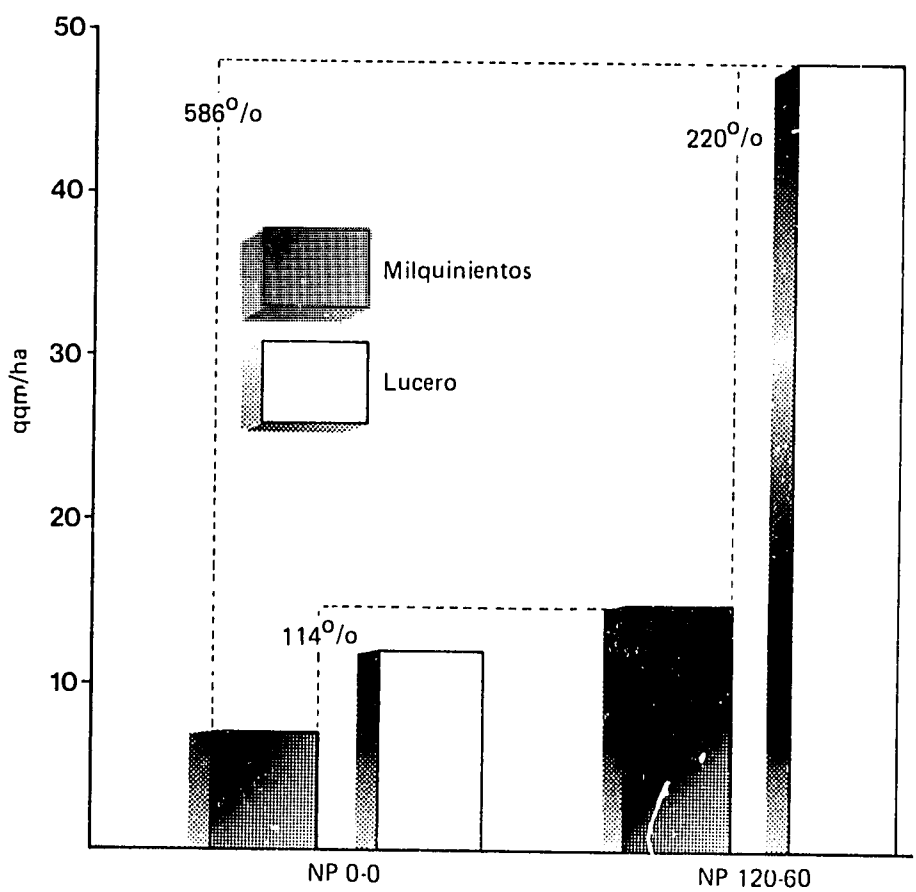


Figure 3. Yield of two varieties, Milquinientos (unimproved) and Lucero (improved), at different levels of inputs, San Nicolás, Chile, 1982-83.

Argentina

Fertilizer response—Six years ago, a network of trials was started at INTA's Pergamino station to measure the response of wheat to nitrogen and phosphorus; this work is described in the *CIMMYT Report on Wheat Improvement, 1983*. As a result of research at Pergamino and

other stations, the government launched a fertilizer program to promote the use of fertilizer with wheat crops. INTA-Pergamino has given strong research and extension support to this program over the past year. Trials were carried out at four sites representative of the wheat area, which in this zone amounts to one million hectares. These trials gave the same results as in former years, and fertilizer recommendations were not changed (Table 18).

As part of INTA's extension efforts, demonstration plots were planted in various locations. Information was received from 43 sites; soil analysis was done at each site prior to sowing. Using this parameter, along with other agronomic criteria, it was possible to make a fertilizer recommendation for every site. Soil phosphorus values (Bray 1) at 82% of the sites were lower than the critical level of 13 ppm, and 52% were below 8 ppm.

The average yield of check plots was 2273 kg/ha, whereas plots with the recommended fertilizer level gave an average yield of 3025 kg/ha. These results indicate an average response of 752 kg/ha or an efficiency level of 12.3 kg wheat for every kilogram of fertilizer applied.

This research and extension work, combined with the government's reduction of the relative price of fertilizer, has had a positive effect on fertilizer use. Of 967,365 ha of land sown with wheat in the area of the INTA Pergamino station, 302,000 ha (32% of the area) were fertilized.

Residual effect of phosphorus fertilization—Since many of the soils of Argentina's Pampa Humeda are deficient in phosphorus, it is imporant to determine phosphorus availability to the crop as affected by repeated applications of phosphorus fertilizer. To measure this effect, a trial was started in 1981 and now has four main treatments:

1 = 4 years of phosphorus application (1981-84)

2 = 3 years of phosphorus application (1982-84)

3 = 2 years of phosphorus application (1983-84)

4 = 1 year of phosphorus application (1984)

Each main treatment was subdivided into three subtreatments of 0, 30, and 60 kg P_2O_5/ha. The effect of these treatments on levels of available phosphorus (Bray 1) in the soil is shown in Table 19; samples were taken after the 1984 harvest.

In moderately deficient soils, available phosphorus rose quickly to desirable levels. These results indicate that in this type of soil, phosphorus deficiency can be eliminated easily, and that a sufficiency level can be maintained with smaller subsequent applications. This research will be continued to determine longer-term strategies for fertilization.

Fertilizer reponse—To support the national fertilizer campaign, INTA-Marcos Juarez carried out various demonstrations on fertilizer use. Only nitrogen is recommended in this area, as phosphorus deficiency has not been detected.

In each demonstration site, six varieties were sown with two levels of fertilizer (check or zero level, and the recommended level for each site). Each plot measured 100 m x 15 m. The demonstration was effective and the response over all sites averaged 12.3 kg/ha of yield response for every kilogram of nutrient nitrogen applied.

On-farm tests of varieties and advanced lines—At INTA-Marcos Juarez, advanced lines are tested in large plots in farmers' fields in different ecological zones before release. In 1984, two trials of this kind were conducted. The first was planted in a Casilda series soil, which is characterized by a pronounced Bt horizon and found in the wetter area. The second trial was in the drier area on a Marcos Juarez series soil that had a moderate Bt horizon.

The trials included two varieties and three advanced lines of intermediate wheats (sown in June), and three varieties and five advanced lines of late wheats (sown in July). Each variety was tested at 0 and 100 kg N/ha. The experimental design was a split plot with three replications; the main plot was sown with the variety and the subplot was fertilized. The size of each subplot was 3 m x 40 m.

Results are presented in Tables 20 and 21. At the Marcos Juarez site, there were no differences among the materials sown early. Among the late sown materials, LAJ 2532, a new line that will be released as the variety Don Ernesto, was by far the highest yielding line. The fertilizer x variety interaction was only significant for LAJ 2514. At the Casilda site, very significant differences were found among early sown varieties, and the best yielding line was LAJ 2484. There were also significant differences within the late sown group, and as at the Marcos Juarez site, line LAJ 2532 was superior. At both sites, early sown varieties and lines were superior to those sown later.

Training, Seminars, and Workshops

Six visiting scientists and one pathology trainee visited Mexico to participate in bilateral activities or exchange programs. These visits are always helpful, not only because they develop closer ties among personnel from different institutions, but also because they provide a better understanding of the region's most serious problems.

CIMMYT assisted and participated in the organization of a wheat seminar at the Carillanca Experiment Station of INIA in Chile. The seminar, organized to celebrate the twenty-fifth anniversary of the station, dealt with several aspects of Chilean wheat research and production.

Table 1. Changes in wheat production in the Southern Cone region, 1980-84

Country	Area (1000 ha) 1980	Area (1000 ha) 1984	Yield (kg/ha) 1980	Yield (kg/ha) 1984	Production (1000 t) 1980	Production (1000 t) 1984
Argentina	5023	6120	1549	2140	7780	13,200
Brazil	3122	1736	865	1054	2702	1830
Chile	432	509	1587	2063	686	1050
Paraguay	47	120[a]	915	1165[a]	43	140
Uruguay	227	270	1349	1667	307	450
Total	8,851	8,918			11,518	16,440

[a] Only 90,000 ha of wheat harvested due to frost damage; average yield was 1555 kg/ha

Table 2. Germplasm selected for heat tolerance, Brazil, 1984

Lira 'S'
CM43903-II-4Y-1M-3Y-2M-1Y-1M-0Y
Lira 'S'
CM43903-II-2Y-1M-6Y-2M-1Y-0B
Yaco 'S'
CM41195-A-13M-1Y-2M-1Y-0M-1P-0P
* Fln-Acc x Ana
SWM4578-56M-3Y-3M-1Y-0M
* Fln-Acc x Ana
SWM4578-56M-3Y-3M-0Y
* Fln-Acc x Ana
SWM4578-56M-3Y-3M-2Y-0Y
* Jup - Bjy
CM39992-8M-7Y-0M
* Kea 'S'
CM21335-C-9Y-3M-1Y-1Y-1Y-0B
Car 853-Coc 75 x Vee 'S'
CM47556-EE-1M-1Y-2M-1Y-0Y-3PTZ-0Y
Mrs - Coc
SWM4127-1Y-1M-4Y-2M-1Y-0M
F 12.71-Coc
SWM5784-17Y-1M-5Y-1M-1Y-0B
Kvz - Trm
SWM3879-9Y-13M-3Y-1M-0Y
Kvz - K4500 LA4
SWO176-3M-1Y-10Y-1Y-1M-0Y-0PTZ
Au - P301
SWM485-500Y-0D-501Y-5M-1B-501Y-501M
Chat 'S'
CM33090-N-1M-1Y-0M-59Y-0B-1PTZ-0Y
Jup-Zp x Coc
CM37614-B-14Y-4M-1Y-0M
PF 70354-Ald 'S'
CM47090-14M-1Y-1F-703Y-10F-705Y-3F-0Y
KlFt-CNT7xAld
B19815-G-504M-600PR-1T-0T
Veery No. 3

Checks: Anahuac, Cocoraque

* Excellent vigor

Table 3. Bread wheat lines that performed well under drought conditions in northern Paraná, Brazil, 1984

NS 732—Pima
SWM 6976-9Y-1Y-2Y-0Y
NS 732—Pima
SWM 6976-9Y-1Y-2Y-3Y-0Y
Klat—Sis 'S'
SWM 7388-8Y-1Y-2Y-1Y-0Y
[Rmy(Wa4767/391.58D.81-1453 x 10.15.6410)]Blt 'S'
SWM 7651-8Y-1Y-2Y-3Y-0Y
Nor-Ymh2 x Trm
SWM 7651-8Y-1Y-2Y-3Y-0Y
63.189.66.7- Hys 'S' x Fury
SWM 6739-16Y-2Y-1Y-1Y-2Y-0Y

Table 4. Best aluminum-tolerant lines from 2nd Aluminum Screening Nursery (ALSN) in Cascavel, Passo Fundo, and Cruz Alta, Brazil, 1984

Cross and pedigree	Reaction to aluminum toxicity[a]
PF70354-Ald 'S' CM47090-14M-1Y-1F-703Y-10F-705Y-2F-0Y	MR
PF70354-Mus 'S' CM47091-7M-1Y-3F-1Y-0Y	R
PF70354-Mus 'S' CM47091-7M-1Y-3F-2Y-0Y	R
IAS58 (Kal-Bb x Cj 'S'/Ald 'S') CM50464-12Y-6F-1Y-1Y-8M-4Y-0M	MR
Maringa (check)	R
(IAS58-IAS55 x Ald 'S'/Mrng)Ald 'S'-IAS58.103 x Ald 'S' CM55517-B-1F-701Y-1F-707Y-2F-0Y	R
PF70354-Ald'S' x Mes 'S' CM57597-CC-2Y-1Y-4M-0Y	R
[Mrng(Nad-Tor x Pch/Blt 'S'-Mes 'S')]Pat72195^2-Zp 'S' x Ald 'S'- Emu 'S' CM57616-A-3Y-1Y-1M-2Y-2M-4Y-0M	R
Bnq'S'-CNT 8 x Ald 'S'-IAS58 CM58323-K-1Y-2Y-0M-3Y-3M-0Y	R
Thb 'S' F11915-A-502M-1Y-3F-702Y-4F-0Y	MRR
Ald 'S'-BIII146^2 F12298-C-1M-1Y-1Y-1M-4Y-0M	MRR

[a] R = Resistant, MR = Moderately resistant, and MRR = Moderately resistant to resistant

Table 5. Advanced bread wheat lines from the 17th International Bread Wheat Screening Nursery (IBWSN) selected for wide regional adaptation

Row no.	Cross and pedigree
12	Kea 'S' CM21335-C-9Y-3M-1Y-1Y-1Y-0B-2KE-0Y
13	Kea 'S' CM21335-C-9Y-3M-1Y-1Y-1Y-0B-6KE-0Y
16	Vee 'S' CM33027-F-1M-9Y-0M-97Y-0B
17	Vee No.8 CM33027-F-12M-1Y-1M-1Y-1M-0Y
21	Vee 'S' CM33027-F-12M-1Y-6M-0Y-83B-0Y
22	Vee 'S' CM33027-F-12M-1Y-12M-1Y-1M-0Y
27	Vee 'S' CM33027-F-15M-500Y-0M-75B-0Y
28	Vee 'S' CM33027-F-15M-500Y-0M-76B-0Y
29	Vee 'S' CM33027-F-15M-500Y-0M-78B-0Y
34	Chat 'S' CM33090-N-1M-1Y-0M-121Y-0B
35	Bow 'S' CM33203-M-8M-8Y-1M-1Y-1M-0Y-1PTZ-0Y
43	Snb 'S' CM34630-D-5M-2Y-1M-1Y-2M-2Y-0M
49	Bjy 'S'-Jup CM40035-6M-4Y-2M-1Y-2M-1Y-0B
77	(Tob x Ce-Pato/Bb-Gll)Nac CM49624-14Y-5M-1Y-1Y-2M-2Y-0M
78	Buc 'S'-Bjy 'S' CM49641-9Y-1M-1Y-1Y-0M
79	Buc 'S'-Bjy 'S' CM49641-9Y-1M-1Y-5Y-0M

(continued)

Table 5 (continued)

Row no.	Cross and pedigree
106	Buc 'S'-Emu 'S' CM52324-22M-1Y-2Y-2M-2Y-1M-0Y
110	Buc 'S'-Pvn 'S' CM52359-12M-2Y-2B-2Y-1M-0Y
111	Buc 'S'-Chre 'S' CM52421-26Y-3Y-3M-1Y-1M-0Y
116	(IAS58-IAS55 x Ald 'S'/Mrng)Ald 'S'- IAS58.103A x Ald 'S' CM55517-B-1F-701Y-1F-707Y-1F-0Y
150	Bow 'S'-Pvn CM61830-13Y-1M-3[illegible]-2M-5Y-0M
188	Kea 'S'-Buc 'S' CM67354-14Y-2M-3Y-0M
203	Gen 81
206	Seri 82

Note: Locations observed:
Argentina: Paraná, Marcos Juárez, Pergamino, Buck's Seed, Balcarce
Brazil: Cruz Alta, Palotina, Londrina
Chile: Santiago, Chillán, Temuco
Paraguay: Capitán Miranda
Uruguay: La Estanzuela

Table 6. Promising lines selected from the 15th International Durum Screening Nursery (IDSN) in Argentina and Chile, 1984

Row no.	Cross and pedigree	Row no.	Cross and pedigree
1	Guil 'S' CM14646-C-1Y-1M-1Y-4AU-0Y	128	Ren 'S'-Gdov 2584 CD38814-9B-1Y-2M-0Y
17	Chto 'S' CD16913-B-2M-2Y-3M-4Y-0M	131*	Yav 'S'-Sapi 'S' CD38909-8B-1Y-1M-0Y
25	Shwa 'S'-Gre 'S' CD23156-1Y-1M-2Y-1Y-2M-0Y	132	Yav 'S'-Cndo CD38074-4M-1Y-3M-1Y-0M
27	Care 'S' CD24831-E-3Y-5M-1Y-0Y	188	R143-Ruff 'S' x Stil 'S' CD41500-A-1M-1Y-1M-0Y
33	Gfn-Aa 'S' x Gta 'S'-Pg 'S'/Boy 'S' CD25241-A-2Y-3M-1Y-1Y-0M	189	R143-Ruff 'S' x Stil 'S' CD41500-A-1M-1Y-2M-0Y
44	Shwa 'S'-Yav 'S' CD26406-3B-2Y-7Y-0M-8Y-0B	236	(Shwa 'S' x Magh 72 'S'-Yav 'S'/ Rok 'S')Guil 'S' CD44101-B-2Y-2M-1Y-0M
45	Shwa 'S'-Yav 'S' CD26406-3B-2Y-7Y-0M-18Y-0B	237	[(Kif 'S' x RSS-BB-1419/ Mexi 'S'-CP)Waha 'S']Yav 'S' CD44110-A-1Y-1M-1Y-0M
46	Shwa 'S'-Yav 'S' CD26406-3B-2Y-7Y-0M-24Y-0B	247	Gediz 'S'-Bar 'S'/ Ege x Ruff 'S'-Fg 'S' CD44552-B-1Y-1M-1Y-0M
47	Shwa 'S'-Yav 'S' CD26406-3B-2Y-5Y-0M-1Y-0B	286	(J Jusram-Gll'S' x F3Tun/ Cr 'S'-Gs 'S')Stil 'S' CD39931-10B-2Y-2M-1Y-0M
50	Shwa 'S'-Yav 'S' CD26406-3B-2Y-7Y-0M-16Y-0B	287	(J Jusram-Gll 'S' x F3Tun/ Cr 'S'-Gs 'S')Stil 'S' CD39931-10B-2Y-3M-1Y-0M
65	Cll x Gta 'S'-Pg 'S' CD29069-1Y-3Y-1M-1Y-2M-1Y-0M	288	(J Jusram-Gll 'S' x F3Tun/ Cr 'S'-Gs 'S')Stil 'S' CD39931-10B-6Y-1M-2Y-0M
77	Dack 'S'-Rabi 'S' x Yav 'S' CD34027-11Y-3M-3Y-1M-0Y		
78	Dack 'S'-Rabi 'S' x Rok 'S' CD34028-2Y-2M-1Y-1M-1Y-0M		
87	(56.3-56.112 x Ch 67/Fg 'S')Ru 'S' CD34604-D-1Y-2M-1Y-0M		

Note: Locations observed:
Argentina: Paraná, Balcarce, Barrow
Chile: La Platina

* Excellent vigor

Table 7. Promising lines selected from the 15th International Triticale Screening Nursery (ITSN) in Brazil and Chile, 1984

Note: Locations observed:
Brazil: Passo Fundo, Cruz Alta, Londrina
Chile: La Platina

* Excellent vigor and good agronomic type

Row no.	Cross and pedigree	Row no.	Cross and pedigree
1	Cananea 79	70	Ptr 'S'-M_2A^2 X-44650-12M-1Y-1Y-2M-1Y-1M-0Y
2	Beagle	88*	Olt 'S'-Lnc 'S' X-51800-6Y-2M-1Y-3M-0Y
3	Caborca 79	89*	Olt 'S'-Lnc 'S' X-51800-6Y-2M-2Y-1M-0Y
4*	Chiva 'S'	93*	Pnd 'S'-Ye75 x Mpe 'S' X-59862-3M-2Y-1M-0Y
16	Bto 'S'-Ptr 'S' X-49509-3Y-2Y-1M-2Y-2M-0Y	105	Octo-Bulk31-Cin 'R' x Caborca 79 X-52650-19Y-1M-3Y-1M-0Y
17	Bto 'S'-Ptr 'S' X-49509-6Y-1Y-2M-1Y-2M-0Y	109	Spd 'S'-Pvn76 X-54268-7Y-1M-1Y-1M-0Y
23	Ptr 'S' x Cml-FS1377/IA x Cin-FS658 X-51038-D-4Y-3Y-5M-1Y-1M-0Y	121	Bgl 'S'-Ram 'S' X-44265-4KE-1Y-500B-0Y
24	Ptr 'S' x Cml-FS1377/IA x Cin-FS658 X-51038-D-4Y-3Y-5M-1Y-3M-0Y	122	Topo x Puppy-Bgl 'S' B-3361-0Y-33
29	Ptr 'S'-Gzl 'S' x Pnd 'S'-Abn 'S' X-61083-3M-2Y-1M-0Y	135	Lmg 'S' X-33208-I-500Y-500M-503B-503Y-0Y
37	Rm 'S'-Ptr 'S' x Rat 'S'/ Lmg 'S' x Msf 'S'-IRA X-63735-B-1Y-2M-0Y	159	Ptr 'S' x M_2A-IRA/Ram 'S' x IRA-Cal X-53782-D-2Y-3M-1Y-0B
39	Rm 'S'-Ptr 'S' x Rat 'S'/ Lmg 'S' x Msf 'S'-IRA X-63735-F-3Y-3M-0Y	164	Mula 'S' X-18330-3M-2Y-2M-1Y-2M-0Y
62	Echidna 'S' x M_2A-Za75 X-61039-6M-1Y-1M-0Y	167*	Mus 'S'(2) B-2670-7190-0Y
64	Echidna 'S' x Pnd 'S'-Rm 'S' X-61079-4M-1Y-1M-0Y	168	Zebra79 B-2672-7191-0Y
		169	Mus 'S'-Lynx 'S' B-3023-7251-0Y

Table 8. Wheat varieties released in the Southern Cone region, 1984

* CIMMYT origin

Variety or cross and pedigree	Institution
Argentina	
Retacon INTA (LAP 878) = Jar-Chr x Cno 67 H 2138-12P-1B2P-1P-0P	INTA
Pampa INTA (LAP 889) = Jar-Chr x CC-Jar H 2139-1P-4B-2P-1P-0P	INTA
* Cochico INTA (Bv 9400/82) = Ktz M12-Pato (B)/B Man-7C x Cdl CM 24166-L-7M-1Y-3Y-0YQ-0P-1BV	INTA
* Norkin Irupe = Cno-Gll x ND 81-Tzpp CM 23166-5A-1G-1G-0A-0G	Northrup King
* Norkin Cabure = Ji x Cno-Pj CM 21343-3A-2G-2G-0A-0G	Northrup King

(continued)

Table 8 (continued)

Variety or cross and pedigree	Institution
Norkin Churrinche = Era-Polk x Tob N 7568-9A-1G-1G-0A-0G	Northrup King
Norkin Lider = Tob-B Man x Bb/Klft MJ 1433-14B-6G-1G-1G-1G-1A-0P	Northrup King
Klein Criollo = B Nam x Kl Puma	Klein Seeds
Klein Salado = Kl Puma- O A x Cno	Klein Seeds
* Buck Ombu = Cno 'S'-Gll/Tob-B_2 Man x Bb Tzpp-Sn 64 x Tzpp-An CM 26339-E-4Y-1Y-2Y-1M-15Y-3LD	Buck Seeds
Brazil	
* Br 11 = Guarani (MS 7810) = 8156 x Tob - Cno	EMBRAPA
* OCEPAR 7 = Batuira (IOC 813) = Kea 'S' CM 21335-C-9Y-3M-1Y-1Y-1Y-0B	OCEPAR
* OCEPAR 8 = Macuco (OC 812) = IAS 64 - Aldan 'S' CM 47207-6MJ-103 PR-2T-0T	OCEPAR
* OCEPAR 9 = Perdiz (OC 8112) = IAS 58-Bjy 'S' x Bnq CM 47971-A-4M-105 PR-2T-0T	OCEPAR
* OCEPAR 10 = Garça (OC 8123) = IAC 5 - Aldan 'S' CM 46961-16M-109 PR-1T-0T	OCEPAR
* OCEPAR 11 = Juriti (OC 8148) = IAC 5- Aldan 'S' CM 46961-16M-113 PR-1T-0T	OCEPAR
R S 1 = Fenix (S 8010) = PF 70100 - J 15157-69	IPAGRO
R S 2 = Santa Maria (S 8018) = S 45 - Kvz	IPAGRO
R S 3 = Palmeira (S 8020) = S 45 - Kvz	IPAGRO
R S 4 = Ibiraiaras (C 7924) = IAC 5 - S 76	IPAGRO
CEP 11 (CEP 7778) = PF 6968^2-Hadden B 11950-4Z-1A-1A-0A	FECOTRIGO

(continued)

* CIMMYT origin

* CIMMYT origin

Table 8 (continued)

Variety or cross and pedigree	Institution
Chile	
* Sauce INIA = Tanager 'S' CM 30617-2Y-1M-7Y-3M-1Y-0M	INIA
* Chagual INIA (Durum) = 21563-Aa 'S' x Fg 'S' CM 9799-126M-1M-5Y-0M	INIA
Aromo INIA (Durum) = Stw 63-Gll x Aa 'S' A 13979-3P-2P-3P	INIA
* Ovacion INIA = Bobwhite 'S' CM 33203-H-11M-5Y-0M	INIA
* Cisne INIA = Kvz - Cj 71 SWM 1430-4Y-3Y-0M	INIA
Lautaro INIA (Q 1 - 81) = Bezo 1 - NS 646 x Au = NS 2699	INIA
Patagua INIA (H-1) = (Pato Arg./Tzpp-Sn 64 x Nor) Leda T 6001-T-T-1T-500H-500H	INIA
Quillay INIA (H-2) = Az 67 - Leda T 5996-T-T-3T-500H-500H	INIA
Canelo INIA (H-3) = 7 C - Rabe T 3044-1T-4T-12T-500H-500H	INIA
Astro Baer = HB 11418-KL. Tol x Weihenstephan-H38 TI 115-B-614-GOR69/79	Semilla Baer
Paraguay	
Cordillera 4 = Aepoglom - II 64-27 (MN72131)	INIA

Table 9. Advanced wheat lines that showed a moderate degree of resistance to *Helminthosporium sativum*, Brazil, 1984

F12.71-Coc SWM5784-17Y-1M-4Y-5M-1Y-0B	Bobwhite 'S' CM33203-K-10M-7Y-3M-2Y-1M-0Y
Sunbird 'S' CM34630-D-5M-2Y-1M-2M-2Y-0M	Bon-Yr/F35.70 x Kal-Bb CM41860-A-5Y-2Y-3M-1Y-1M-1Y-0B
Kvz-K4500 La 4 SWM176-3M-1Y-10Y-2Y-2M-0Y-0PTZ-0Y	Broadbill 'S' CM43381-D-1Y-4M-3Y-4M-3Y-0B-3M-0Y
Kvz-K4500 La 4 SWM176-3M-1Y-10Y-1Y-1M-0Y-0PTZ	Car 853-Coc x Vee 'S' CM47556-Q-1M-2Y-6M-0Y-2PTZ-0Y
Chat 'S' CM33090-N-1M-1Y-0M-121Y-0B	Oreg F1.158-Fdl x Kal-Bb/Nor CM47634-I-2M-3Y-1M-2Y-1Y-1M-0Y
Kea 'S' CM21335-C-94-3M-1Y-1Y-0B	Oreg F1.158-Fld x Kal-Bb/Nor CM47634-I-2M-3Y-1M-2Y-1Y-2M-0Y
F3.71-Trm SWM5704-10Y-1M-3Y-3M-3Y-0B-1PTZ-0Y	

Table 10. Leaf blotch resistant lines selected from the 14th International Septoria Observation Nursery (ISEPTON)

Row no.	Cross and pedigree	Average[a] infection
1	Kvz-7C SWM-4064-6Y-4M-3Y-1M-1Y-3M-0Y-0PTZ-0Y-0PTZ-1PTZ	6/3
6	Kvz-K4500-LA4 SWO-176-3M-1Y-10Y-1Y-8M-0Y-0PTZ-0Y-1PTZ	6/4
23	Bow 'S' CM33202-K-9M-2Y-1M-1Y-2M-0Y-1PTZ	6/4
25	Bow 'S' CM33203-K-9M-9Y-4M-4Y-1M-0Y-1PTZ	6/4
30	Snb 'S' CM34630-D-5M-2Y-1M-1Y-0M-0PTZ	7/3
32	Snb 'S' CM34630-D-5M-2Y-3M-3Y-0M-0PTZ	7/3
74	F6.74-Bun 'S' x Sis 'S' CM60042-M-1Y-2M-2Y-1M-0Y-1PTZ	6/4
86	IAS20-H567.71 CMH76.480-13Y-5B-1Y-1B-1Y1B-0Y-0PTZ	6/4
96	IAS20-H567.71 x IAS20(5) CMH78A.544-7B-1Y-1B1Y-1B-0Y-1PTZ	7/4
99	CMH74A.754-Pel Atr2 CMH79.236-2Y-5B-2Y-1B-0Y-1PTZ	7/4
106	Thornbird 'S' F11915-A-502M-1Y-1F-701Y-3F-0Y-1PT	7/4
111	Kvz-K4500.L.A.4 -0PTZ	6/4

Note: Scores taken on 00/99 scale; average of eight locations (Marcos Juárez and Pergamino, Argentina; Cruz Alta, Brazil; Chillán, Hidango, and Santo Domingo, Chile; and La Estanzuela, Uruguay)

Table 11. Lines selected from the 17th International Bread Wheat Screening Nursery (IBWSN) for low levels of bacterial leaf blight, Pergamino, Argentina, 1983

Entry no.	Cross and pedigree	Entry no.	Cross and pedigree
42	Sunbird 'S' CM34630-D-5M-2Y-1M-1Y-1M-1Y-0M	111	Buc 'S' - Chrc 'S' CM52421-26Y-3Y-3M-1Y-1M-0Y
43	Sunbird 'S' CM34630-D-5M-2Y-1M-1Y-2M-2Y-0M	149	Bow 'S' - Pvn CM61830-13Y-1M-3Y-2M-4Y-0M
77	(Tob x Ce-Pato/Bb-Gll)Nac CM49624-14Y-5M-1Y-1Y-2M-2Y-0M	150	Bow 'S' - Pvn CM61830-13Y-1M-3Y-2M-5Y-0M

Table 12. Area (ha) classified according to use capacity in the seventh and eighth regions of Chile

Source: *Plan de Desarrollo Agropecuario*, 1965-1980

Use capacity	Area (ha)	Percent total
II, III, IV	158,855	14.94
V	599	0.06
VI	192,895	18.14
VII	682,267	64.17
VIII	28,580	2.69
Total	1,063,196	100.00

Table 13. Yield of old and new varieties, San Nicolas, Chile, 1983-84 and 1984-85

Variety	Maturity class	Yield (kg/ha) 1983-84	Yield (kg/ha) 1984-85
New			
Onda	Early	4640	5204
Lucero	Intermediate	4050	5330
Old			
Milquinientos	Late	3450	3960

Table 14. Effect of nitrogen and phosphorous fertilizer on the yield of wheat (cv. Onda), San Nicolas, Chile, 1984-85

P_2O_5 (kg/ha)	N (kg/ha) 0	30	60	90	120
0	2610		3540		5130
15		3370		5110	
30	2470		4630		6430
45		4340		5510	
60	2710		5510		6100

Soil analysis:
N = 17.4 ppm
P = 7.3 ppm
K_2O = 205 ppm
MO = 2.2%
pH = 5.6

Table 15. Yield of seed multiplications, San Nicolas, Chile, 1984-85

Farmer	Variety	Yield (kg/ha)
E. Riffo	Lucero	5900
N. Fuentealba	Lucero	5000
A. Diaz	Lucero	4300
V. Toro	Onda	3900
J. Fuentes	Onda	3800
S. Sandoval	Lucero	3500
L. Lillo	Onda	3300
L. Riquelme	Onda	2800

Area = 1.25 ha
Fertilizer applied = 100-50
Weed control = MCPA + Banvel D.

Table 16. Yield of different pastures, Secano Interior, Chile

Pasture	Yield[a] without fertilizer (t/ha)	Fertilization	Yield[a] with fertilizer (t/ha)
Phalaris	2.1	50-75-50-S-B	3.0
Subterranean clover	2.0	32-100-50-S-B	3.3
Phalaris + subterranean clover + ryegrass	2.9	32-100-50-S-B	2.9
Successional	0.9	90-75-0	1.8
Native	1.4	50-75-0	2.4

Source: Contreras, D., Caviedes, E., and Ovalle, C., *Informe Tecnico Area de Produccion Animal, E.E. Quilamapu*

[a] Average values over five years (1979-83)

Soil analysis (1983-84):
N = 13.2 ppm
P = 12.0 ppm
K = 226.2 ppm
MO = 1.6%
pH = 6.2

[a] Dry matter

[b] First year after wheat

Table 17. Yields of wheat and *Medicago* spp., Cauquenes, Chile, 1983-84 and 1984-85

Cycle and crop	Cultivar	Yield (kg/ha)	Fertilization
1983-84			
Wheat	Lucero	3500	30-30-0
	Qu. 1475	3000	30-30-0
Medicago spp.	Native	4000 DM[a]	0-30-0
1984-85			
Wheat	Onda	4500	30-30-0
	Millaleu	4000	30-30-0
Medicago spp.[b]	Native	5500 DM	0-30-0

Source: National Institute of Agricultural Research and Extension (INTA), Pergamino

Table 18. Yields of wheat under different nitrogen and phosphorus treatments at four locations, Argentina, 1984

Treatments (kg/ha)		Yield (kg/ha)			
N	P_2O_5	La Chispa	M. Ocampo	Junin	9 de Julio
0	0	2074	2773	3585	3204
0	40	1971	2570	4449	3723
0	80	1967	2774	4673	3951
30	20	3032	4119	4608	3495
30	60	3181	4259	4576	3736
60	0	3123	4031	4253	3389
60	40	3204	4406	4386	3717
60	80	3254	4129	4496	3857
90	20	3401	4448	4598	3605
90	60	3423	4430	4631	3754
120	0	3189	4178	4251	3613
120	40	3405	4495	4592	3414
120	80	3332	4537	4589	3556
150	80	3559	4816	4570	3765
CV%		5.41	3.68	5.92	5.66

Table 19. Effects of different levels of applied phosphorus fertilizer on the level of available soil phosphorus, 9 de Julio (soil type Hapludoll), Argentina, 1984

	Treatment[a]							
	1		2		3		4	
Kg P_2O_5 applied per year	Total P_2O_5 applied	P ppm	Total P_2O_5 applied	P ppm	Total P_2O_5 applied	P ppm	Total P_2O_5 applied	P ppm
0	0	9.63	0	11.16	0	13.00	0	8.05
30	120	20.63	90	21.10	60	18.80	30	18.30
60	240	27.63	180	22.13	120	29.06	60	17.73

[a] Treatment 1 = 4 years fertilizer; 2 = 3 years fertilizer; 3 = 2 years fertilizer; 4 = 1 year fertilizer
Soil phosphorus levels determined by the Bray 1 method

Table 20. Yield of varieties and advanced lines at 0 and 100 kg N/ha, National Institute of Agricultural Research and Extension (INTA), Marcos Juarez (soil series Casilda), Argentina, 1984

Date of sowing	Varieties	Nitrogen rate (kg/ha) 0	100	$\bar{x}$	Statistical significance
Intermediate June sowing	Las Rosas INTA	2026	2195	2111 c	NS
	Chaqueño INTA	2056	2402	2229 bc	NS
	LAJ 2514	2320	2598	2459 b	NS
	LAJ 2484	2640	2903	2772 a	NS
	LAJ 2537	1987	2278	2132 c	NS
	$\bar{x}$	2206	2475	2340	**
Late sowing July	Victoria INTA	1932 ab	2237 a	2084	**
	M. Juarez INTA	2070 ab	2333 a	2202	**
	Klein Rendidor	1958 ab	2085 ab	2023	NS
	LAJ 2532	2208 a	2305 a	2257	NS
	LAJ 2522	1667 b	1708 ab	1687	NS
	LAJ 2519	2182 a	2250 a	2216	NS
	LAJ 2533	1903 ab	2235 a	2009	**
	PAR 80/5134	2097 a	2000 ab	2048	NS
	$\bar{x}$	2002	2144	2073	

CV = 4.81% ** = Significant difference 1% NS = Not significant

Table 21. Yield of varieties and advanced lines at 0 and 100 kg N/ha, National Institute of Agricultural Research and Extension (INTA), Marcos Juarez (soil series Marcos Juarez), Argentina, 1984

Date of sowing	Varieties	Nitrogen rate (kg/ha) 0	100	$\bar{x}$	Statistical significance
Intermediate June sowing	LAJ 2484	3805 a	4167 a	3985	NS
	LAJ 2537	3710 a	3487 a	3598	NS
	Las Rosas INTA	3583 a	3570 a	3577	NS
	Chaqueño INTA	3487 a	3485 a	3486	NS
	LAJ 2514	3138 a	3653 a	3396	**
	$\bar{x}$	3545	3672	3609	
Late sowing July	LAJ 2532	3542	3540	3541 a	
	Victoria INTA	3153	3597	3375 a	
	LAJ 2519	3083	3153	3118 ab	
	PAR 80/5134	2903	3098	3000 ab	
	LAJ 2533	2958	2890	2924 ab	
	M. Juarez INTA	2555	2963	2759 ab	
	Klein Rendidor	2567	2667	2617 b	
	LAJ 2522	2223	2583	2403 b	
	$\bar{x}$	2873	3061	2967	

CV = 6.9% ** = Significant at 1% level NS = Not significant

North and West Africa and the Iberian Peninsula Region

S. Fuentes F.

Introduction

CIMMYT's regional program for North and West Africa and the Iberian Peninsula provides a link between national cereal programs and the research and training units at CIMMYT in Mexico. Regional staff visit wheat programs in Tunisia, Algeria, and Morocco every year, sometimes after the wheat is planted, and always at the grain-filling stage of the crop. The wheat programs of Portugal (the program's host country) and southern Spain are visited more than others in the region during the cropping season.

During 1983-84, as in previous seasons, North African weather conditions were unfavorable for producing cereal crops. Heavy rains delayed planting until December and mid-January, and a severe drought from January to April hindered plant development, reduced yields, and resulted in a poor harvest. In the plateaus of western Algeria, late frosts compounded problems caused by drought, limiting production on many commercial fields. Rains near harvest in Morocco caused grain to sprout in the field. In the Iberian Peninsula, better rainfall distribution was the decisive factor contributing to higher total production.

Significant gains in yield per hectare were obtained in 1983-84 over the previous season. Good agronomic practices and the use of high-yielding cultivars also contributed to the increase in production. The variety Anza covered 53% of the land under wheat cultivation in Portugal. In the province of Andalusia in Spain, Anza (along with Cajeme and Yecora) was grown on about 420,000 ha (90% of the land planted to wheat). Additional details of cereal production in Morocco, Portugal, and Spain are provided in Table 1.

Germplasm Evaluation

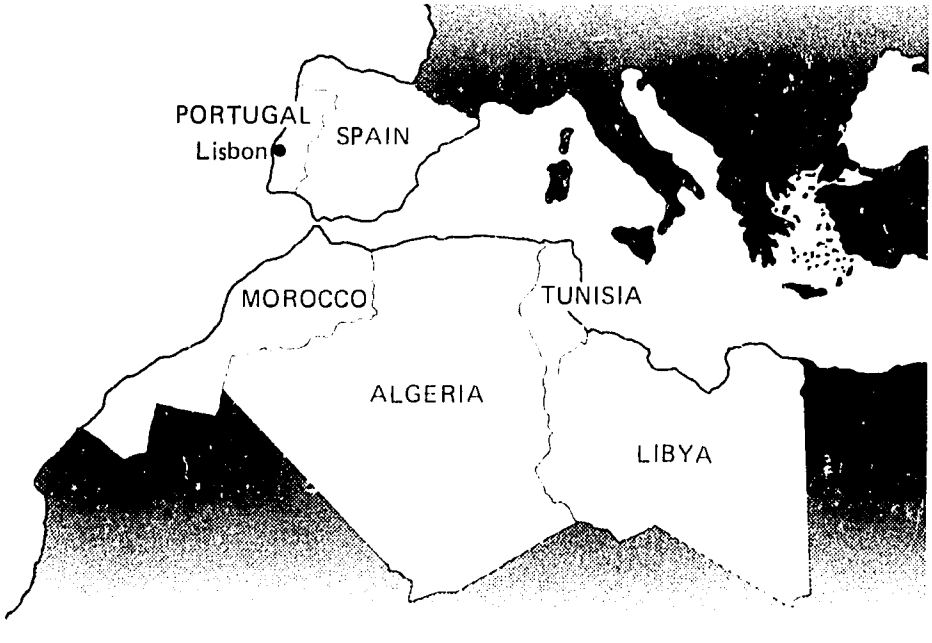
Leaf rust virulence—Collaborators in several countries collected samples of *Puccinia recondita*, and the virulence of the pathogen was analyzed in the greenhouse and laboratory facilities of the National Plant Breeding Station (ENMP) at Elvas, Portugal (the collaboration of Agr. Ing. Maria Júlia Gonçalves and the pathology group at ENMP is gratefully aknowledged). Seedlings of the international set of 27 Lr-isogenic lines were used in the test, as well as 12 hexaploid lines selected from CIMMYT's international nurseries for low coefficients of infection. Both sets of materials were obtained from CIMMYT pathologists in Mexico. Thatcher and Morocco were used as susceptible checks.

Although the data obtained do not represent a thorough survey of leaf rust in each country participating in the study, they do reflect the characteristics of rust samples received at Elvas. The exception to this statement is Portugal, where numerous samples were collected from most areas where wheat is grown. Individual genes or the probable combination of genes for resistance in the host, and corresponding genes for virulence in the pathogen, are given in Table 2.

In the Iberian Peninsula, leaf and stem rust were seen during the late growth stages of the commercial crops. Disease screening at the ENMP in Elvas, Portugal, is achieved by spraying field plots weekly with spores of the three rusts and *Septoria tritici* to induce artificial epidemics. At the end of April and May, excellent epidemics of stripe rust and septoria leaf blotch were recorded in all screening nurseries. Leaf and stem rust developed to a lesser extent than the other diseases. Table 3 lists the most resistant genotypes that also had good plant type; these materials were selected at Jerez and Seville in Spain.

Other diseases—Environmental conditions in North Africa were not conducive to the development of foliar diseases in commercial crops. A dry root rot was observed in Tunisia and attributed to a soil fungi complex composed primarily of *Fusarium* and *Helminthosporium* spp. Barley stripe, caused by *H. gramineum*, was found occasionally in older varieties in Algeria and Morocco; net blotch (*H. teres*) was severe on susceptible barleys in experimental plots.

Hessian fly—Hessian fly is a problem of increasing concern in Morocco. The insect causes severe



stunting and prevents tillering in wheat, triticale, and barley. At research stations in Guich, Merchouch, and Cidera, material is being tested for sources of resistance and to assess the virulence of the insect populations.

Varietal Situation

Several advanced lines of bread wheat, durum wheat, and triticale with good yield potential and acceptable levels of disease resistance have been registered in the varietal catalogs of their respective countries, or are candidates for release (Table 4).

Some of these cultivars originated in local crosses, but most are local selections of materials distributed by CIMMYT through the international nurseries program. Promising bread wheat lines listed frequently in the international nurseries over the past 3-4 years include Veery 'S' (cross CM33027) and the older crosses Kal-Bb and $Y50_E$—Kal^3 (cross 35188). The durum wheats Yavaros 'S' (cross CM9799) and Shwa 'S' (cross CD20626) have given excellent yields in southern Spain; Inia—Arm 'S' is a promising triticale genotype. Lines selected from CIMMYT international screening nurseries for good agronomic characteristics and disease resistance are listed in Table 3.

Dr. S. Fuentes, CIMMYT scientist in the North and West Africa region.

Training

One of CIMMYT's most important functions is to train research personnel from national cereal programs. National program scientists may participate in 4-7 month training courses on different aspects of research, or they may make short visits to the research units at CIMMYT headquarters. In 1984, two scientists from Morocco and Portugal completed the breeding training course in Mexico.

Other scientists from national programs in the region attended a travelling workshop organized annually by regional staff to observe nurseries in different environments. In April 1984, 12 breeders and pathologists from Tunisia, Morocco, Spain, and Portugal visited experiment stations in Guich, Cidera, Merchouch, and Annoneeur in Morocco, and Carmona and Cordoba in Spain. They were accompanied by CIMMYT and ICARDA staff members. The trip provided an opportunity for personnel of different national and international programs to assess wheat and barley genotypes in the field, as well as to exchange and discuss ideas and experiences.

a Mostly bread wheat; about 7%-10% of the area was planted to durum wheat.
b 686 t of certified seed distributed to farmers for planting.
c Estimated data for Cadiz Province only; no records of production available.

Table 1. Wheat, barley, and triticale production in Morocco, Portugal, and Spain, 1983 and 1984

	1982-83			1983-84		
	Area (1000 ha)	Production (1000 t)	Yield (t/ha)	Area (1000 ha)	Production (1000 t)	Yield (t/ha)
Morocco						
Bread wheat	690	732	1.06	724	759	1.05
Durum wheat	1,286	1,239	0.96	1,095	976	0.89
Barley	2,151	1,228	0.57	2,078	1,198	0.58
Portugal						
Wheat	331	327	0.98	309[a]	466	1.50
Barley	88	54	0.61	81	91	1.12
Triticale					0.7[b]	
Spain						
Bread wheat	2,477	4,097	1.65	2,142	5,618	2.62
Durum wheat	138	233	1.69	125	426	3.41
Barley	3,634	6,570	1.81	3,944	10,695	2.71
Triticale					6[c]	

Table 2. Seedling reaction on Lr-isogenic lines and selected hexaploid wheats from CIMMYT's breeding program to mono-uredial isolates of *Puccinia recondita* from various countries, ENMP, Elvas, 1984

Country and no. of isolates		Genes in the Lr-set							CIMMYT bread wheats[a]								
		2a	3	3Ka	17	19	20	24	1	2	3	4	5	6	7	8	9
Portugal	(88)	-	-	F	F	+	+	+	-	F	+	F	+	+	+	+	+
Spain	(19)	+	-	F	+	+	+	+	+	+	+	+	+	+	+	+	+
Italy	(23)	F	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Turkey	(7)	F	-	-	F	+	+	F	+	+	+	+	+	+	+	+	+
Saudi Arabia	(14)	-	-	F	+	+	+	-	+	-	+	-	+	+	+	+	+
Tanzania	(25)	+	-	F	F	+	+	+	F	F	F	-	+	+	+	+	+
Kenya	(7)	-	+	-	+	+	+	-	+	+	+	+	+	+	+	+	+
Zimbabwe	(6)	-	+	F	+	+	+	-	+	+	+	+	+	+	+	+	+

Note: Effective genes indicated by (+), frequently effective genes by (F), and noneffective genes (overcome by the virulence of the pathogen) by (-).

a

1. (Tob-BMan x Bb/Cdl)Sx — CM8972-F-9M-1Y-1M-1Y-0M
2. AnE-My74 x Ti71 — CM15928-3M-1Y-500M-0Y
3. KtzM12-UP 301/BMan-7C x Cdl — CM24160-GG-1M-1Y-1Y-1Y-3M-0Y-1PTZ-0Y
4. Maya 'S'-Moncho 'S' — CM29251-3M-17Y-1M-1Y-1B-0Y
5. Bobwhite 'S' — CM33203-K-9M-2Y-1M-1Y-1M-0Y
6. Sunbird 'S' — CM34630-D-5M-2Y-1M-1Y-2M-2Y-0M
7. Chiroca 'S'-Anahuac 'S' — CM40111-19M-500Y-500M-502Y-500B-0Y
8. HD2205-Alondra 'S' — CM40629-500M-500Y-505M-500Y-0M
9. Clement-Mo73 x Torim 73 — CM43381-D-1Y-1M-3Y-0M

Table 3. Genotypes selected from two CIMMYT international screening nurseries for good agronomic characteristics and high resistance to the three rusts and *Septoria tritici*, Elvas, Portugal, 1985

Nursery and entry no.	Variety or cross and pedigree
17th IBWSN[a]	
13	Kea 'S' CM21335-C-9Y-3M-1Y-1Y-1Y-0B-6KE-0Y
26**	Veery 'S' CM33027-F-15M-500Y-0M-66B-0Y
27**	Veery 'S' CM33027-F-15M-500Y-0M-75B-0Y
29*	Veery 'S' CM33027-F-15M-500Y-0M-98B-0Y
36	Bobwhite 'S' CM33203-K-10M-7Y-3M-2Y-1M-0Y
57	Fink 'S' CM41560-A-5M-24-3M-14-1M-1Y-0B-0PTZ
65*	Lira 'S' CM43903-H-4Y-1M-1Y-3M-1Y-0B
96*	Pat10-Ald 'S' x Pat 72300/Pvn 'S' CM49922-1M-2Y-1Y-1M-2Y-0M
98*	Pat10-Ald 'S' x Pat 72300/Pvn 'S' CM49922-1M-2Y-2Y-1M-1Y-0M
165	ND-Vg 9144 x Kal-Bb/Yaco 'S' CM62661-D-1M-1Y-3M-2Y-0M
15th IDSN[b]	
41*	Memo—Goo 'S' CD26136-1M-1Y-1Y-1Y-1M-0Y
43**	Shwa 'S'—Yav 'S' CD26406-1B-1Y-2Y-0M-9Y-0B
44*	Shwa 'S'—Yav 'S' CD26406-3B-2Y-7Y-0M-8Y-0B
51*	Shwa 'S'—Yav 'S' CD26406-3B-2Y-7Y-0M-21Y-0B
52**	Shwa 'S'—Yav 'S' CD26406-3B-2Y-9Y-0M-1Y-0B
73	Yel 'S'-Bar 'S' (Ovi 65-CP x Fg 'S'/ Ruff 'S'—Fg 'S') CD33857-1B-8Y-3M-1Y-3M-0Y
132*	Yav 'S'—Cndo CD38974-4M-1Y-3M-1Y-0M
146*	Shwa 'S'—Ren 'S' x Yav 'S' CD40159-3B-4Y-2M-0Y
154	Bdv—Ru 'S' x Yav 'S' CD40500-C-2M-0Y
251	Nile ICD74117-1L-1AP-0AP

a International Bread Wheat Screening Nursery

b International Durum Wheat Screening Nursery (material in this nursery also screened for resistance to barley yellow dwarf virus)

* Good phenotype

** Excellent phenotype

(continued)

c International Triticale Screening Nursery
* Good phenotype
** Excellent phenotype

Table 3 (continued)

Nursery and entry no.	Variety or cross and pedigree
15th ITSNc	
45	Ptr 'S'/Rm 'S'—IRA x FS477 x 48675-7Y-3Y-3M-1Y-4M-0Y
69**	Bgl 'S'-M_1A x Mlsl-IA x 53641-A-502Y-504Y-500Y-500B-0Y
87*	Bsn 'S' x Cin-FS 658/IA-M_2A x 50234-F-4Y-2Y-3M-1Y-1M-0Y
106	Bsn 'S'—Maya 74 x 58439-9Y-2M-2Y-3M-0Y
139	Tesmo 'S' x 39860-7Y-1M-1Y-3Y-1M-1Y-0B
130	Tesmo 'S' x 39860-7Y-1M-1Y-5Y-1M-1Y-0B
145	Dingo 'S' x 41047-A-1Y-2M-1Y-1Y-2M-0Y
158*	Pnd 'S'—Mpe 'S' x Gpr 'S'—Yak 'S' x 50408-B-5Y-2Y-1M-1Y-0B

Table 4. Bread wheat, durum wheat, and triticale cultivars that were either registered in the varietal catalog or candidates for varietal release in three countries in 1984

Variety	Cross and pedigree	Status	Country
Bread wheat			
Caia	Azteca—Mucaba	Registered	Portugal
Mira	$Y50_E$—Kal^3 35188-5M(Fl)-39Y-0M-24M-0Y	Registered	Portugal
Almansor 1	E4870-C30xM5392666.5/BbxCC-Inia CM22099	Candidate	Portugal
Vouga	Napo-Cdl x Zbz CM8935-D-5M-3Y-3M-2Y-0M	Candidate	Portugal
Lima 1	Veery No.3 = Kvz-Buho 'S' x Kal—Bb CM33027-F-12M-1Y-6M-0Y	Candidate	Portugal
Jouda	Kal—Bb	Registered	Morocco
Merchouch	Nesma x CIMMYT line	Registered	Morocco
Durum wheat			
Celta	Ple 'S'-Ruff 'S' x Gta 'S'-Rtte CM17904-B-3M-1Y-0M	Candidate	Portugal
Nuño	Yavaros 'S' = Jo 'S'—Aa 'S' x Fg 'S' Fg 'S' CM9799	Approved and released	Spain
Cazalla	Mallard 'S' = Mexi 'S' xCh67—Jo 'S' Ch67—Jo 'S' CD1894-3Y-1Y-0M-1B	Candidate	Spain
Trebujena	Shwa 'S'—Yav 'S' CD20626-5M-2Y-1M-0Y	Candidate	Spain
Peñaflor	Rokel 'S' x Mexi 'S'—Fg 'S' CD1895-12Y-1Y-8B-0Y	Candidate	Spain
Marzak	E12 = BD113	Registered	Morocco
Acsad 65	Stork 'S' = Gdo VZ469/Jo 'S' x 61.130-Lds CM470	Registered	Morocco
Triticale			
Borba 1	Bgl 'S' x M_2A-Cin X15673-A-1Y-2Y-1M-0Y	Candidate	Portugal
Avis	Inia-Arm 'S' X1648-9N-0M	Candidate	Portugal
Tentudia	Tigre 'S' = M_2A-M_1A X27947-22M-1Y-0M	Candidate	Spain

Eastern, Central, and Southern Africa Region

E. Torres and D. Danial

Introduction

The aim of CIMMYT's regional wheat program in Eastern, Central, and Southern Africa is to foster the development of institutions and individuals involved in wheat research and production. Taking into account the specific needs of national programs, CIMMYT provides technical assistance and advice, sponsors visits of national scientists to wheat programs in the region and abroad, and shares the products of its screening program in Kenya. In 1984, considerable progress was achieved in screening international wheat nurseries in Kenya. National programs also made advances in developing germplasm suitable for the region.

Current screening strategies take into account diverse stress factors operating against wheat grown at high elevations thoughout the region. A viable wheat cultivar combines the following characteristics in a good plant type: earliness for dryland farming; tolerance to the acidic or aluminum toxic soils found in vast expanses of potential farmland in Zambia, Tanzania, Kenya, Rwanda, Ethiopia, and Burundi; superior resistance to stem rust, which occurs throughout the region; and resistance to other diseases (stripe rust, spot blotch, tan spot, septoria blotches, fusarium head scab) wherever they are of economic importance. The program has identifed lines with acceptable overall performance for immediate use in production. Lines with specific traits that enable them to withstand the stresses listed above are continually sought for use in the hybridization programs.

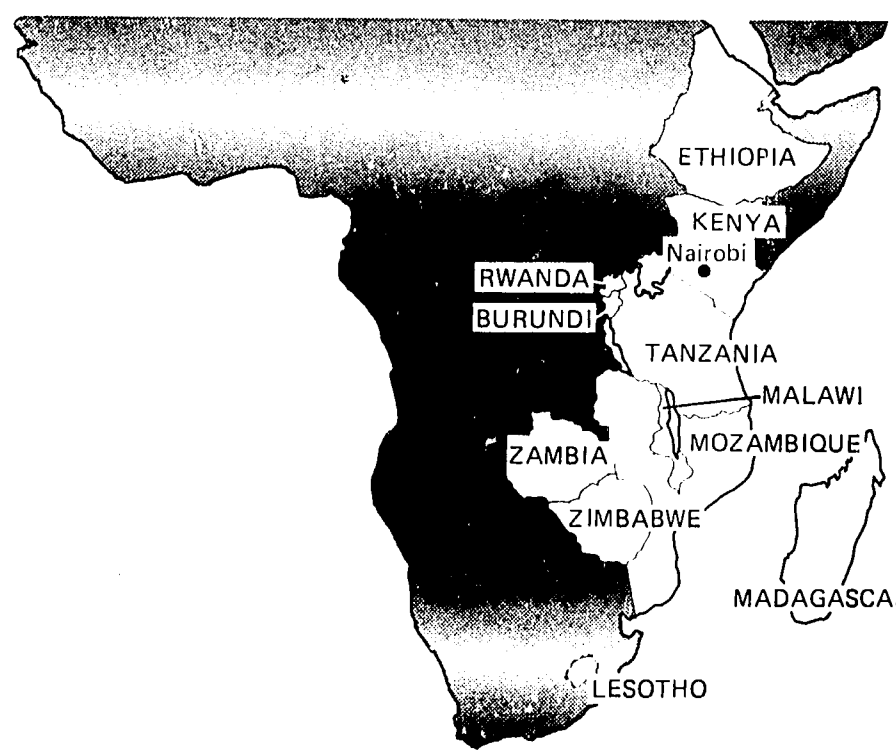
Kenya

Multilocational testing—Most nurseries are first screened during the long rainy season at the National Plant Breeding Station (NPBS), Njoro. Entries are drilled in 2-row, 2 m plots at all sites (3-row, 2 m plots are used for F_2s). Specialized nurseries are planted at sites where specific stress factors are likely to occur with sufficient intensity. Materials intended for dryland areas are planted at Ngorengore and screened for earliness, whereas aluminum-tolerant lines or F_2 populations are planted at Eldoret where acid soils are common. Nurseries containing lines with probable resistance to septoria, helminthosporium blotches, or stripe rust are planted in Molo, where low temperatures and high rainfall are often conducive to natural epidemics.

Germplasm promotion—Lines selected at Njoro are promoted to one of two nurseries, Selections from International Nurseries (SIN), or Preliminary Observation for Parental Collections (Pre-OPC). These nurseries are planted during the off-season and receive supplementary irrigation. The SIN nursery includes entries of superior agronomic type that range from resistant to moderately resistant against stem rust, and are also resistant against low to moderate infections of stripe rust. The Pre-OPC nursery is composed of lines with acceptable agronomic type and very high levels of resistance to stem rust, stripe rust, or both. Entries with poor plant type or medium to high levels of stem rust and stripe rust infection are discarded at Njoro.

Selections from Ngorengore enter the Pre-OPC as a subgroup. At Njoro they are further evaluated to confirm their earliness, and to assess plant type and disease resistance. Selections from Eldoret and Molo are harvested too late to be included in off-season planting at Njoro, and are observed during the following main season in the Observation for Parental Collections (OPC) for plant type and stem rust resistance.

Lines in the SIN are tested under intense disease pressure during the off-season. Those lines that maintain superior performance enter the Multiplication Plots (MPS) for the Screening Nursery for the African Cooperative Wheat Yield Trial (SNACWYT) in the main season. Lines with mediocre plant type but outstanding resistance to stem rust or stripe rust are transferred to the OPC for main-season planting at Njoro, Ngorengore, and Eldoret. Lines in the Pre-OPC that express



superior plant type are promoted to the MPS. Pre-OPC lines retaining the feature for which they were selected (rust resistance or earliness) enter the OPC.

Usually there is a lower rate of attrition from the SNACWYT because lines have already been tested in the MPS or OPC. Lines from the MPS enter that year's SNACWYT, a regionally distributed nursery. Lines from the OPC enter the Parental Collection (PC), a comprehensive set for which a descriptive catalog of valuable traits will be issued annually.

Screening international nurseries—Table 1 shows the progressive diminution of nurseries received in 1983 as less-adapted lines were discarded during 1983-84. The remaining 32 lines entered the 8th SNACWYT, distributed in 1984 (Table 2). Disease pressure was more intense in 1984, and inoculation efforts increased, as can be seen from Table 3. About 10% of the lines were selected, with a higher frequency of selection for earliness and aluminum tolerance.

Parental Collections—The Yellow Rust Parental Collection (YRPC) has been further refined after two severe field tests in 1984. At the end of the main season in 1984, the collection consisted of 53 lines with acceptable plant type. These lines have withstood yellow rust (i.e., stripe rust) attacks for over six years.

The program examined 15 stem rust-resistant lines with resistance genes from Agatha and RL 6040, derived from backcrosses made in Mexico by the germplasm development program. These lines remained resistant to stem rust over two seasons when tested with bulk inoculum from Kenya, but they are unfortunately very susceptible to stripe rust.

Segregating populations—Individual plant selections within each line were bulked, and F_2 populations planted in the 1983 main season were advanced to F_3 in the 1983-84 off-season, and to F_4 in the 1984 main season. Beginning with F_5 in the 1984-85 off-season, individual selections will be planted separately, and full pedigree selections will be followed thereafter. Eleven bread wheat lines and one triticale line are represented in the F_5 nursery (Table 4).

Table 5 shows the handling of the F_2 populations planted in the 1984 main season. One population, F_2 SxS Aluminum, appears particularly promising, with plants selected from 83 of 127 lines.

International yield trials—Four CIMMYT international yield trials were conducted at Njoro during 1984. These were the 20th ISWYN, the 5th ESWYT, the 15th ITYN, and the 15th IDYN (Table 6). There were

Dr. E. Torres (second from left), head of CIMMYT's Eastern, Central, and Southern Africa office, based in Nairobi, Kenya.

dramatic differences between the ISWYN and ESWYT, apparently caused by differences in soil fertility. The ESWYT had good yields for the local check, K. Kulungu, and other high-yielding material. The difference between Veery 'S' and the local check was significant at 1% probability. The ITYN also gave meaningful results; high-yielding Merino 'S'/Jlo 'S' performed significantly better than the local check, T65. Results from the 15th IDYN reflect durum wheat's lack of adaptation at Njoro.

Yield performance and low disease incidence were the selection criteria under which 16 lines were chosen to be submitted to the station for preliminary yield trials in the 1985 main season (Table 7).

National Programs

Burundi—In Burundi, national program scientists simultaneously assessed crop development under conditions of low fertility and high fertility, as well as at different levels of disease severity. When the 7th SNACWYT, the 2nd Aluminum Screening Nursery (ALSN) and the Aluminum Resistant Material (ARM) were tested with this dual system, a number of lines appeared promising.

The best lines were 6106-9 (from Holetta Research Station, Ethiopia), and selections from IAS 64/Aldan 'S' (CM47049, entry 1 in the ALSN; CM47202, entry 24 in the ARM), Aldan 'S'/IAS 58 (CM53481, entries 32-35 in the ALSN), and Cqt// H499.71A/*4 Jup 73/3/Cqt (CMH79A.35S, entries 69-71 in the ARM).

Madagascar—The Malagasy, starting with the F_2 Masa Aluminum Tolerant Nursery (F_2 MATN) in 1980, have reached the stage of final yield testing and eventual release of varieties. A particularly outstanding family is a set of lines derived from PF 70354/Vee 'S' (CM65063), with yields in excess of 4 t/ha for all entries in a replicated irrigated yield trial, and top yields of 5.8 t/ha (Table 8).

Zambia—Zambia's wheat program, with assistance from one Belgian scientist and a team funded by Canada, has identified PF 7748 as a viable cultivar for rainfed conditions and released it as "Whydah." For irrigated conditions, local selections of Chat 'S'/Kavco (cross CM56774), starting with F_2s, have reached a stage where several lines are likely to be considered for release.

Zimbabwe—Zimbabwe possesses optimal growing conditions for wheat, and CIMMYT germplasm expresses its yield potential both in farmers' fields and on experiment stations. In the 1984 Advanced Variety Trial (AVT), conducted by the national wheat team at 10 sites, Rusape (= Veery 'S') was the highest-yielding entry among seven standard varieties. Rusape yielded an overall mean of 7726 kg/ha; local yields ranged from 5948 kg/ha at Matopos (a cold site, 1338 m elevation) to 10,343 kg/ha at Harare (1506 m elevation). When all 20 lines in the trial were considered, line SA 79014-9-11 (= Za/Zp) performed better than Rusape, giving an overall mean of 7897 kg/ha, with local yields varying from 5631 kg/ha at Beitbridge (570 m elevation) to 10,381 kg/ha at Harare. This line has also yielded best in the past two years' AVTs (source: *Report on Wheat Advanced Variety Trials*, Crop Breeding Institute, Department of Research and Specialist Services (DRSS), Harare, Zimbabwe).

Regional Nurseries

Nursery results—An incomplete return of results from the Seventh African Cooperative Wheat Yield Trial (ACWYT) and 7th SNACWYT permits only fragmentary analysis of these nurseries. The 24 entries of the ACWYT were ranked for yield at each reporting site. No entry ranked among the top 10 across all sites. Two entries ranked among the top 5 at 5 sites, and 4 more entries were in the top 5 at 4 sites (Table 9). The ample dispersion of rankings reflects the diversity of growing conditions encountered in East Africa.

Distinguishing regional needs—Results from regional nurseries suggest the advantage of combining sites or areas in which groups of germplasm perform in similar ways. Table 9 illustrates the close similarity between Burundi and Madagascar, which share four of their five best-yielding lines or varieties. Although these countries are geographically distant, both have acid soils, which probably account for the high performance of triticale in these areas.

Results from the 7th SNACWYT also help distinguish different needs across the region. The seven best entries in Burundi are either triticales or wheat crosses involving Brazilian progenitors (Mga/Aldan = CM46961-12M-1Y-1M-604Y-1PTZ-0Y; Kvz//An/My/3/Pf 70354 = B13977-A-1Z-5A-0A-1PTZ-0Y), or varieties developed within the region (K.Popo, ET 6106-9). In contrast, the five best entries in Zimbabwe were three Veery lines, Cmt/Yr//Mon (CM43405-A-2Y-1M-1Y-1M-1Y-0B), and BSV 50/Can 'S'//Vee 'S' (CM47768-A-1M-1Y-4M-2Y-0Y). Analogous sets for Malawi and Tanzania are composed of regional varieties, high-yielding Mexican-type wheats, and triticale entries.

A practical conclusion, and one that should determine the future course of action in the region, is that screening efforts in Kenya should aim at specific groups of locations and stresses in Kenya and elsewhere.

Acknowledgements

Our sincere thanks are given to scientists in national and provincial wheat programs in the region for letting us participate in their research endeavors. Special appreciation is due to NPBS, Njoro, for the assistance provided to our screening program through its introductions section.

Table 1. Reduction in number of lines from international wheat nurseries received in 1983 after successive seasons of selection at Njoro, Kenya

Crop	Main season 1983 (Int'l Nurs)	Off-season 1983-84 (SIN-83)[a]	Main season 1984 (8th MPS)[b]	Off-season 1984-85 (8th SNACWYT)[c]
Bread wheat	2000	74	26	20
Durum wheat	800	26	6	5
Triticale	800	25	14	7

a SIN = Selections from International Nurseries
b MPS = Multiplication Plots
c SNACWYT = Screening Nursery for African Cooperative Wheat Yield Trial

Table 2. Entries selected from the 1983 wheat international nurseries for the 8th Screening Nursery for the African Cooperative Wheat Yield Trial (SNACWYT)

Entry no.	Variety or cross and pedigree
1	Ata 81
2	Ures 81
3	Veery No. 8
4	Veery No. 5
5	Veery No. 5 'S' (75B)
6	Veery No. 5 'S' (Seri 'S')
7	Veery No. 5 'S' (115B)
8	Bow 'S' CM33203-K-10M-7Y-3M-2Y-1M-0Y-Oke
9	Hahn 'S' CM33682-L-IY-IY-IM-3Y-100B-503Y-500B-0Y-Oke
10	Hahn 'S' CM33682-L-1Y-1Y-4M-4Y-100B-502Y-0M-Oke
11	MN 72131/Pvn CM42402-30Y-1M-1Y-1M-2Y-0B-Oke
12	*T. aest*/Mo//Nac CM43367-E-3Y-1M-4Y-1M-1Y-0Y-Oke
13	Cmt/Yr//Mon 'S' CM43405-A-5Y-2M-2Y-6M-2Y-1M-0Y-Oke
14	Lira 'S' CM43903-H-2Y-1M-5Y-1M-1Y-1M-0Y-Oke
15	Mon 'S'/Ald 'S' CM53460-4M-1Y-2Y-3M-1Y-2M-Oke
16	Mon'S'/Ald'S' CM53460-4M-1Y-6Y-2M-1Y-0M-Oke
17	Bnq 'S'/CNT8//Ald 'S'/IAS 58 CM58323-E-1Y-2Y-5M-1Y-2M-Oke
18	Spinetail 'S' CM58478/B-2Y-1Y-1M-1Y-0M-Oke

(continued)

Table 2 (continued)

Entry no.	Variety or cross and pedigree
19	Fink 'S' CM41860-A-5M-2Y-2M-1Y-0M-Oke
20	Burgas*2/Sort 12.13//Kal/Bb SWM3115-2M-4Y-1M-1Y-0M-Oke
21	Shov 'S' CD10569-C-10M-1Y-0M-Oke
22	CH 67/Jo 'S'//Cr 'S'/3/Fg 'S' CD20692-1M-3Y-2M-1Y-3Y-1M-0Y-Oke
23	Somo 'S' CD32038-B-1Y-4Y-3M-0Y-Oke
24	Yav 'S'/AA 'S' CD32617-1B-3Y-1M-0Y-Oke
25	Snipe 'S'/Rabi 'S' ICD74121-3L-IAP-OAP-Oke
26	Bgl/M_2A X15733-2Ke-Oke
27	Drira//M_2A X15839
28	M_2A*2/IRA//M_2A/Ti71 X49274-5Y-1Y-1M-1Y-2M-0Y-Oke
29	Ita*2/IGA//Bta/3/Ptr 'S' X50872-C-3Y-4Y-2M-2Y-4M-0Y-Oke
30	Pnd 'S'/*2IRA//Mpe (R) X50973-B-12Y-1Y-1M-1Y-2M-0Y-Oke
31	Masa Mex/Kenya Acc 3833-59.Y 11Ke-Oke
32	Drira/Kgr//IRA/Bgl B2674-OAP-Oke

Table 3. Effect of one season's selection in Kenya upon the frequency of retention of lines from 1984 international nurseries

Site and selection criteria	Crop[a]	Main Season 1984 (Int'l Nurs)	Off-season 1985 SIN 1984[b]	Off-season 1985 Pre-OPC 1985[c]	Total	%
Njoro						
Plant type, stem rust and stripe rust resistance	BW	1171	28	118	146	12.5
	DW	336	2	7	9	2.6
	TCL	646	43	24	67	10.4
Molo						
Stripe rust resistance	BW	1675	-	112	112	6.7
Ngorengore						
Earliness	BW	189	-	83	83	50.6
Ol Joro Orok						
Crop development	BW	600	-	3	3	0.5
	DW	20	-	7	7	35.5
Eldoret						
Aluminum tolerance	BW	352	-	62	62	53.1
Total		4989	73	416	489	9.8

a BW = bread wheat
DW = durum wheat
TCL = triticale

b SIN = Selections from International Nurseries

c Pre-OPC = Preliminary Observation for Parental Collections

Table 4. Composition of F_5 nursery at Njoro at the beginning of offseason, 1984-85

Parents and cross number	Number of plants in F_5
Sdy/Cndr 'S'//Jup/Bjy 'S'	
SWM12325-	1
Pvn/Vee 'S'	
SWM12377-	1
Krasnodarky Karlik/Odk 51//Vee 'S'	
SWM12769	6
Odk 16/Pdga//Au/Jitrospvrwuw/179/MJI	
SWM12781-	1
Pew 'S'/Vee 'S'	
CM69825-	6
Gen 81//Br 74.72/Coc 75	
CM72428-	2
Gh 'S'/Dodo 'S'	
CM72445-	4
Pew 'S'/Glen 81	
CM73976-	4
Snb 'S'/Kea 'S'	
CM73978-	5
Bb/Gallo//Cj71/3/F35.70//Kal/Bb/4/Dodo 'S'	
CM74045-	5
Bow 'S'/Gh 'S'	
CM74416-	3
Mizar/5/IA/Kla//Cal/3/Bgl/4/IRA/Bgl	
CT3875-	2

Table 5. Selections made in F_2 populations planted at different sites in Kenya, main season, 1984

Crop and population	Site	Total entries	Lines selected	No. of plants
Bread wheat				
F_2 bulk SxS	Njoro	460	99	362
F_2 bulk aluminum	Eldoret	127	83	243
F_2 bulk helminthosporium	Molo	72	9	(Bulk)
Triticale				
F_2 bulk early	Ngorengore	62	27	(Bulk)
F_2 bulk	Eldoret	234	41	(Bulk)

Table 6. Results from CIMMYT international yield trials and nurseries conducted at the National Plant Breeding Station (NPBS), Njoro, Kenya, main season, 1984

Trial or nursery[a]	Mean	Yield of selected entries (kg/ha)			Percentage difference between highest entry and check	Significance level[b] (%)
		Lowest yielding entry	Highest yielding entry	Local check		
20th ISWYN	1470	174 (NS 5128)	2641 Ciano 79	1666 (K. Kulungu)	58	5
5th ESWYT	2930	545 (Sap'S'/Mon'S')	5391 Vee 'S' (entry 19)	3247 (K. Kulungu)	66	1
15th ITYN	2720	1087 (NIAB.T.183)	3746 Merino 'S'/Jlo 'S'	2334 (T65)	60	1
15th IDYN	1230	715 (DT 411)	1779 Entry 24	1316 (K. Njiwa)	35	NS

a ISWYN = International Spring Wheat Yield Nursery
ESWYT = Elite Selection Wheat Yield Trial
ITYN = International Triticale Yield Nursery
IDYN = International Durum Yield Nursery

b Test of significance using Duncan's Multiple Range Test (DMRT); NS = Not significant

Table 7. Wheat and triticale entries submitted by the CIMMYT East, Central, and Southern Africa regional program to the Kenyan Wheat Program for evaluation in the 1985 Preliminary Yield Trials

Crop and cross or variety and pedigree	Origin 1983-84[a]	Rust reaction[b]		Yield (kg/ha)
		Stem	Stripe	
Triticale				
Drira/M2A X15893-OAP	MPS-29	0	10R	-
M2A(2)/IRA//Ti71 X49274-5Y-1Y-1M-1Y-2M-0Y	MPS-41	0	20R	-
Pad 'S'/IRA(2)//Mpe (R) X50975-B-12Y-1Y-1M-1Y-2M-0Y	MPS-43	0	5R	-
Masa Mex/Kenya Acc 383.59 4	MPS-45	0	5R	-
Bread wheat				
Mus 'S'/Ptm//Maya/Ald 'S'	5th ESWYT-16	5S	TMS	3953
Tyrant 'S'	5th ESWYT-18	TMS	TMS	3953
Tyrant 'S'	20th ISWYN-8	-	10MRMS	2484
Veery No.9	5th ESWYT-11	0	10MR	3970
Veery 'S'	5th ESWYT-19	0	10MS	5391

(continued)

Table 7 (continued)

Crop and cross or variety and pedigree	Origin 1983-84[a]	Rust reaction[b] Stem	Rust reaction[b] Stripe	Yield (kg/ha)
Veery 'S' CM33027-F-12Y-1Y-12M-1Y-2M-0Y	SIN-16	0	5RMR	-
Maya/Mon//Kvz/Trm CM44083-N-2Y-2M-1Y-1M-1Y-2M-0Y	SIN-34	0	TR	-
Koel 'S' CM34574-F-1M-5M-1M-1Y-0M	SIN-123	0	0	-
Fink 'S' CM41860-A-5M-2Y-1Y-0M	SIN-124	0	0	-
Ciano 79	20th ISWYN-39	-	5MSMR	2641
Almaasor	20th ISWYN-50	-	10MS	2492
Hyslop/Pavon	20th ISWYN-18	-	10MRMS	2361

a MPS = Multiplication Plots
ESWYT = Elite Selection Wheat Yield Trial
ISWYN = International Spring Wheat Yield Nursery
SIN = Selections from International Nurseries

b S = Susceptible, T = Trace, R = Resistant, M = Moderately resistant; numbers are percentages

Table 8. Best-yielding entries in a replicated bread wheat yield trial, FIFAMANOR, Madagascar, 1984

Cross and number	Pedigree in Madagascar	Yield (kg/ha)	Days to heading	Days to maturity	Disease score: Septoria	Disease score: Helminthosporium
PF 70354/Vee 'S' CM65063	2.1.2	5855	79	137	3	2
Huac/TJB 788.1038 CM5342	—	5735	70	127	3	3
PF 70354/Vee 'S' CM65063	2.2.2.1	5715	73	126	5	4
PF 70354/Vee 'S' CM65063	2.1.1.1	5445	74	137	3	3
PF 70100//Kvz/HD2009 CM65031	3.2.1.2	5435	71	129	2	5
PF 70100//Kvz/HD2009 CM65031	5.3.2.1	5411	74	129	3	3
Ald 'S'//7C/Ald 'S' CM64294	1.1.3	5370	72	137	4	4
Tif 72.55/Imu CM65270	2.2.1.1	5275	77	137	5	6
Mga/Pew 'S' CM59372	1.1.2	5115	71	137	2	4
Pat//On/Maya 'S'/3/Ald'S' CM59825	6.1.2	5100	67	129	6	5

Source: Research Department, FIFAMANOR

a Disease development evaluated using a 0-9 scale; 0 = Free from infection; 1-3 = Resistant; 4 = Moderately resistant; 5-6 = Moderately susceptible; 7-8 = Susceptible; and 9 = Very susceptible.

Table 9. Entries among the top five in four or more of the nine reporting sites in the 7th African Cooperative Wheat Yield Trial (ACWYT)

Sites	Entry number[a] and ranking					
	23	15	22	18	17	10
Toluca, MEXICO	6	16	12	3	10	2
Arusha, TANZANIA	10	1	7	6	2	4
Mbeya, TANZANIA	19	2	12	9	16	3
Kabale, UGANDA	16	2	8	18	4	7
Tsangano, MALAWI	3	10	4	6	16	5
Malkerns, SWAZILAND	1	6	13	11	4	15
Antsirabe, MADAGASCAR	1	5	4	3	13	6
Matama, MOZAMBIQUE	2	7	1	5	4	7
Kizosi, BURUNDI	4	5	1	2	19	23

a 23 = Juanillo 207 (triticale)
15 = T-65 (triticale)
22 = Coqui/4/IA/M2A//Pj/3/Bgl (triticale)
18 = Bgl derivative (triticale)
17 = Veery 'S' CM33027-F12M-1Y-2M-1Y-2M-0Y
10 = Bb/Gll/Cj/3/F.35.70//Kal/Bb CM34555-B-1M-4Y-1M-1Y-2M-0Y

South and Southeast Asia Region

E.E. Saari, D.A. Saunders, and C.E. Mann

Introduction

Presently, four countries within the South and Southeast Asia region receive priority: Burma, Indonesia, the Philippines, and Thailand. These countries are at different stages of wheat production and organizational development, and all of them, with the exception of Burma, have little or no history of growing wheat.

The temperature regimes, soil conditions, and disease problems of this new wheat-growing region differ from areas where wheat is a traditional crop. Little solid data is available yet to permit confident predictions of the outcome of any particular wheat production practice. However, through careful surveys of field sowings and through coordinated research projects, interim "technology packages" are being refined rapidly.

Burma

Production—Although wheat cultivation in Burma decreased markedly during the late 1960s and early 1970s, since 1974 the area sown with wheat has expanded. Approximately 100,000 ha are currently seeded; this area is nearly as large as that used for wheat production in Burma before the mid-1960s.

The expansion in wheat cultivation is as dramatic as the change in national mean wheat yields, which rose from 0.45 t/ha in 1974 to the current estimate of 1.2 t/ha. Although improved yields may be attributed partly to the introduction of higher yielding varieties from Pakistan in 1980, the increase was produced primarily through more irrigation facilities, greater use of fertilizer, and improved management practices. The government of Burma is actively promoting the expansion of wheat and barley production throughout the country, including the more tropical southern delta.

Wheat is grown in the cool, dry season, principally without irrigation. There is little rainfall and the crop is essentially grown on residual moisture. Experiments indicate that mid-November is the optimal sowing period for the present varieties, a finding confirmed in farmers' fields. Some rainfall usually occurs in late November, helping to establish the crop, and December is essentially rain-free. In the 1983-84 cropping season, rainfall in November was greater than normal in the northern areas and crop establishment and development were good.

Breeding—The next generation of promising lines is being tested in a national trial consisting of released varieties and a number of Veery selections, of which Veery No.2 and Veery No.5 look particularly good.

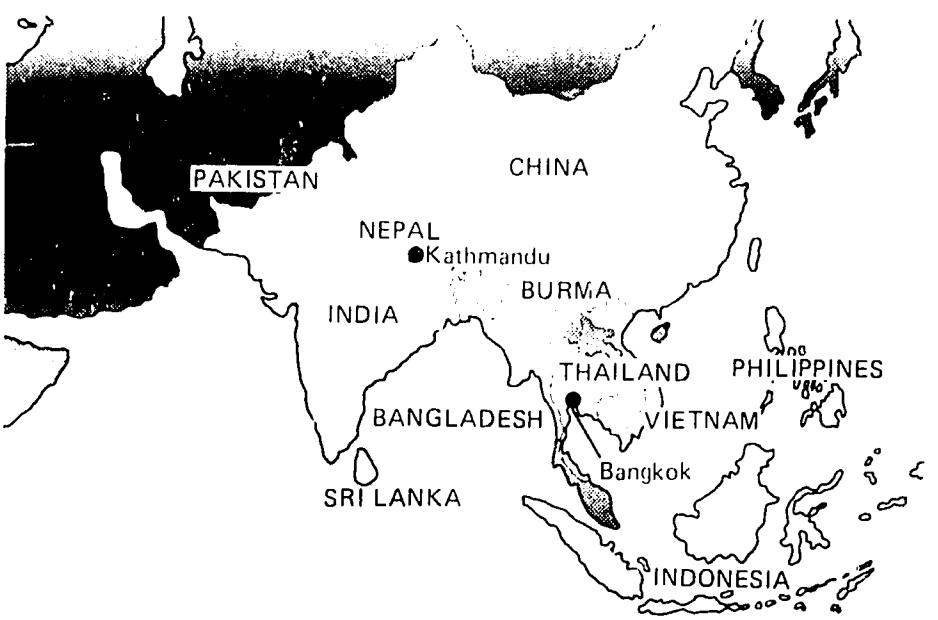
Small-scale crossing programs were initiated at two locations, Yezin and Zaloke; the program at Zaloke was started by FAO. Excellent F_1s indicate the potential gains to be obtained from breeding work, and the necessity of having experienced national staff available to make the best use of these crosses.

International nurseries were grown at Yezin, Ye U, and Heho (barley). The Pankon Agricultural Research Farm at Ye U, which opened in 1983, was recommended as the main station for wheat introductions, since Yezin does not represent the present wheat-growing areas adequately.

Considerable progress can be expected from variety improvement in Burma. The variety Monywa white (= IP4) is still dominating in the Sagaing and Monywa divisions, but seed production and distribution is underway for the newly released varieties from Pakistan, Lyallpur 73 and Punjab 81. In the higher elevations of Shan State, older, tall varieties such as Lerma 50 and W.C. 4 (an introduction from Canada) are gradually being replaced by LU 26 and Punjab 81.

Barley is grown commercially in Shan State, but accurate production statistics are unavailable. The main variety is Morex; Clipper and Golden Valley are of secondary importance.

Disease—Leaf and stem rusts are the most serious wheat diseases in the country, but no major epidemic occurred in 1984. The race structure in Burma is reported to be different from the race structure of rusts on the subcontinent, and this difference, along with the increasing occurrence of leaf rust in Northern Thailand, should be studied.



Seedbed preparation—Seedbed preparation for wheat after the monsoon crop appears to be a major constraint to increased yield. When traditional bullock-drawn equipment is used, the initial plowing produces large clods that dry quickly and become very difficult and time-consuming to break down. Up to 10 harrowings are performed. Inspections of farmers' fields indicated a positive relationship between stand density (and plant development) with fineness of tilth of the topsoil. A partial solution to this problem would be to reduce the depth of primary tillage. Less secondary tillage would then be required and moisture loss from the soil profile prior to seeding would be decreased.

In comparisons between farms within individual villages, it was found that tractor-cultivated fields produced higher yields than fields prepared by traditional means. Mechanization in other crops, particularly rice, is proceeding quite rapidly, and so the problem of decreasing the turnaround time may ultimately be solved by this means.

Seed rate and fertilizer use—Other factors that require investigation are seeding rate and fertilizer technology. Research stations use a seeding rate of 100 kg/ha, but some farmers use a rate as low as 60 kg/ha (very poor stands may also indicate poor seed viability). Fertilizer is not used on wheat in some parts of the country, although most farmers fertilize the main (monsoon) crop. Where fertilizer is used and the crop is grown on residual moisture, the practice of splitting nitrogen applications would not seem to be technically well-founded.

Indonesia

Production—Indonesia's wheat imports increased to nearly two million metric tons in 1984, and constantly rising import bills for this commodity prompted the government of Indonesia to investigate the possibility of domestic wheat production. In the government's new five-year development plan, increased production of carbohydrate crops, including wheat, is a high priority.

Although small quantities of wheat are grown for home consumption in isolated highland areas, the regional program seeks to establish wheat at lower elevations of 600 m or less. A substation at Kuningan (550 m elevation) is being used as a primary breeding and selection site, because it is an acceptable compromise between the environmental extremes that exist in Indonesia.

Breeding—Introductions have come from three sources: a collection of Indian and Pakistani lines and varieties introduced before 1980; recent CIMMYT nurseries; and a number of lines from the Institute of Plant Breeding program in the Philippines. Broadly adapted lines tested at several locations over more than two years are Swati and IWP 72; SA 75, Lyallpur 73, and Punjab 81 consistently rank among the higher-yielding lines. Of the

Dr. E.E. Saari (left), pathologist based in Thailand, makes periodic visits to wheat programs throughout the South and Southeast Asia region.

more recent introductions, UP 262, Cno 79, Tyrart 'S', C 220-4, C 169-6, C 212-59, C 213-13, and Trigo 2 seem to have potential. Lines from all three sources have been combined for a four-station trial on Sumatra and Java (results are not yet available). So far, no varieties have been released.

Table 1 lists CIMMYT nursery lines that performed well in the acid soils of Sumatra.

Java—Target areas for wheat are difficult to define accurately in Indonesia, since one can find almost any type of climate and crop competition is often intense. Defining target areas is particularly challenging for the densely populated island of Java, where the principal flour mills are situated. One promising area, situated near the Sukamandi Experimental Station some 120 km east of Jakarta, covers approximately 250,000 ha. Irrigation is available for about nine months of the year, and two rice crops are grown between December and July-August. From August to December much of the land is vacant. During this period some rainfall occurs, which, combined with residual moisture in the soil, is enough to produce a crop of 1-1.5 t/ha if certain problems can be solved.

The overriding problem is *Sclerotium rolfsii*, an organism that can eliminate up to 50% of the seedlings and continues to weaken plants until they mature. A research program for controlling this organism has begun. Grassy weeds (*Echinochloa* and *Cynodon* spp.) also require attention. Despite these difficulties, excellent individual plant development indicates that wheat may have potential as a commercial crop in this area. Fortunately, high temperatures (21°C at night, 32°C during the day) do not greatly restrict plant development of the lines currently being tested, which are mainly of Indian and Pakistani origin. Initial on-farm experiments carried out on land at 600 m elevation demonstrated that yields of 1.5 t/ha may be achieved with farmers' management.

Sumatra—There is much interest in wheat cultivation in Sumatra, and research efforts are currently based at Sukarami Field Crops Research Station, near Padang. These areas on the western mountain chain have podzolic and lateritic soils, and fertility research is necessary to determine how to increase yields. Yields of 25 lines from the University of the Philippines at Los Baños (UPLB) and from CIMMYT were studied at elevations of 650-1250 m. The highest individual yield was 3.3 t/ha, and mean yield was highest at 1000 m and declined either above or below that elevation. Research at this location has also focused on establishing the optimum seeding date for wheat. Preliminary evidence suggests that wheat should be sown in May for harvest in August, the driest month (rainfall is approximately 100 mm).

Fusarium head scab is a significant problem when temperatures and humidity are high. Although the intensity of this disease is reduced by the recommended May seeding date, additional research on fusarium is needed.

The largest potential area for wheat cultivation on Sumatra appears to be the transmigration zones to the east of the western mountains. This extremely large area is being developed. Soils are acidic, with high levels of aluminum, and the government has sponsored a project to lime the soils progressively. Temperatures are essentially stable throughout the year (minumum 22°C, maximum 33°C) and August is the driest month. Research for this zone will be initiated in 1985 at the Sitiung substation, located southeast of Sukarami at 100 m elevation. Other stations will be included in research activities following observations at Sitiung.

The Philippines

Production—In the Philippines, annual wheat imports are currently between 850,000 and 900,000 t. Per capita wheat consumption has risen from 8 kg in 1977 to 10 kg in 1982, a 21% increase in six years. Attempts to partially substitute sorghum flour and flour from some root crops for wheat flour have proven unsuccessful, partly because Filipinos have acquired a preference for a particular quality of the local bread.

Breeding—A wheat breeding program has existed at UPLB for about 15 years. From this program the two current varieties, Trigo 1 and Trigo 2, were derived. Both varieties are rather late maturing and only moderately resistant to helminthosporium; Trigo 2 has a tendency to lodge. The national testing system has identified lines that are better than Trigo 1 and Trigo 2 with regard to yield, earliness, and lodging resistance, but these lines do not necessarily possess improved helminthosporium resistance. Table 2 shows results of five lines from UPLB (C numbers) and two BPI selections (PL numbers) from CIMMYT nurseries, compared to the check varieties, Trigo 1 and 2. Two lines will be submitted for varietal release in 1985 after the required amount of seed is produced.

The breeding program at UPLB now has crosses between old material (which came from introductions in the 1960s) and Mexican material, as well as selections from CIMMYT segregating populations in advanced generations. This germplasm should help broaden the genetic base and should lead to the release of heat-tolerant varieties with improved resistance to helminthosporium and the rusts. (The rusts are not severe in the Philippines, but lack of resistance makes Filipino lines unsuitable for breeding programs outside the country.)

Breeding materials at the Bureau of Plant Industry (BPI) are almost exclusively from CIMMYT. The station at San Mateo, Isabella, has attempted a second generation breeding cycle during the summer months with some success.

Helminthosporium leaf blight remains the main wheat disease; heavy epidemics occur every year. Since the economic situation may make chemicals not only too

expensive, but unavailable, breeding for resistance to this disease is extremely urgent.

National Wheat Pilot Project—The National Wheat Pilot Project was established on Luzon in 1982 to investigate the commercial potential for wheat. This project is coordinated by the Philippine Council for Agriculture Resources, Research and Development (PCARRD), which, with the National Food Authority (NFA), supervises the pilot production areas.

To define problems and constraints limiting increased yields, the project has undertaken on-farm research trials. When a solution to a particular problem is available, changes are made in the technological package recommended to farmers. If no solution is known, PCARRD selects the appropriate cooperating agency from among the universities or the BPI, then funds and directs the research. This system permits the efficient use of personnel and resources for particular areas of study, with little duplication of effort. Research studies currently in progress include control of helminthosporium and sclerotium diseases by chemicals, insect control, fertilizer technology, weed control, and harvesting methods.

Wheat production in pilot project areas—In 1983-84, the sowing of 47 ha of wheat was supervised and financed by the National Wheat Pilot Project. Prior to the cropping season, 110 potential farmer cooperators were trained in Ilocos Norte, Ilocos Sur, Isabela, and Nueva Ecija at seminars that introduced them to important management factors involved in wheat production, and fully explained the technological package. Ninety-four farmers from seven provinces on Luzon eventually participated in the project.

Pilot project areas were generally sown later than planned because the rice harvest was quite late. A number of significant features were observed in the pilot sowings. The effect of seeding depth greatly influenced the development of the crop. Seeding at 5-8 cm produced plants with more tillers and more "normal" development than seeding at shallower depths. This effect was pronounced even in well-watered fields, and so is presumably distinct from soil moisture aspects usually associated with deeper seeding. Effects of seeding too deeply were also noted.

Another significant feature of the pilot sowings was that the farmers made a number of alterations in the technological package. Several farmers space-planted the wheat by hand, seeding very carefully into furrows or using a dibbling stick. Because of the care taken, these fields were among the most impressive, having very even stands with excellent tillering (up to seven tillers per plant). Other farmers sowed in rows up to 60 cm wide to enable weeding using a buffalo and plow or bamboo harrow. Some farmers used a rice-straw mulch to conserve moisture, and their crops also had strong tillering.

Weed control was generally good. Crops were weeded mechanically or by hand during the first three or four weeks, an amount of weeding that appears sufficient because crop competition against weeds is good after that stage. Later cultivation damages the crop.

Weed, disease, and pest control—Seedling blight and root rot caused by *Sclerotium rolfsii* were a widespread problem in pilot plots. No chemical for seed treatment was available in the market at the time of sowing.

Helminthosporium was serious in all crops except those sown very late. By early grain-filling, some crops that had received two applications of mancozeb had severely infected flag leaves and heads. Wide row-spacing reduced the severity of the disease presumably by reducing the relative humidity within the crop canopy. Stem-borer damage was also observed, but in many cases the amount of insecticide applied (up to four times) was probably not justified.

Pilot project results and future research—During the last year, improvements in agrotechnique for growing wheat in the Philippines increased greatly. Only one pilot project field had obvious waterlogging damage (a major problem in 1982-83), and the wheat crop in one other field had poor emergence because of excessive seeding depth. Most fields had adequate plant populations and in the absence of disease would have yielded 1.5-3.0 t/ha; the highest yield obtained was 1.9 t/ha. Mean yield over all sites was 692 kg/ha, in comparison to 400 kg/ha in 1982-83.

Disease control methods or resistant varieties need to be developed and early disease recognition must improve if farmers are to obtain reliable high yields. The farmer seminars in late 1984 emphasized disease recognition and control procedures. About 250 ha of wheat will be sown in the next cropping cycle, and all seed will be treated against sclerotium with thiram or captan, depending on availability.

Thailand

Production and breeding—Thailand is seriously studying substituting a portion of its annual wheat imports (200,000 t/yr) with locally produced wheat. Varieties are being developed through the close cooperation of three institutions: the Department of Agriculture, Kasetsart University, and Chiang Mai University. Since 1980, a system of country-wide nurseries has been developed, to which all breeding institutions submit entries (Table 3).

Approximately 50% of the data returned from these nurseries proved useful. This percentage is acceptable because the nurseries have two additional functions. First, they are a means of exploring new sites that may be suitable for wheat and barley cultivation; second, they serve to familiarize research staff of new stations with wheat. For this latter purpose, a two-day workshop was held in October for technicians from all experiment stations where wheat was grown. The workshop dealt with all aspects of nursery

handling, from field preparation to data recording, and included a practice sowing with different equipment.

The highest-yielding lines in the Wheat and Barley Thai Yield Nurseries (1983-84) were compared to the released varieties used as checks (Tables 4 and 5). Before the final candidates for release are selected, some of the promising lines will be grown in small plots under farmers' conditions during the 1984-85 growing season.

In 1983-84, approximately 4 t of Inia 66 and Sonora 64 seed were produced by the Department of Agriculture at two northern stations. In 1984-85, the seed increase program will still include these two varieties, but emphasis will be placed on multiplying the most promising lines (Table 4).

Disease—*Sclerotium rolfsii* is the main wheat disease in Thailand. Good control is achieved if there is no excess water after sowing, and seed for 1984-85 nurseries will be treated with carboxin. Although leaf rust incidence is still low, the spectrum of races appears to be expanding slowly. Barley is increasingly susceptible to sclerotium and is threatened by *H. sativum* every year. Because much barley breeding work seems to be done for *H. teres* resistance, few introduced lines are sufficiently resistant to *H. sativum*. Trials for chemical control started in the 1984-85 season.

Weed control experiments—This year, a wider range of chemicals was tested on wheat in Thailand. The tests demonstrated that a mixture of diclofop-methyl and chlorsulfuron will control the weed spectrum adequately, with the possible exception of *Digitaria* spp., when applied 7-10 days post-emergence. Volunteer maize and rice are controlled by diclofop-methyl, although the control of rice may depend on soil moisture conditions after application.

Target areas for commercial wheat production—Two broad categories of land suited to future commercial production of wheat in Thailand have been identified. The first category consists of upland areas of low to medium elevation, where no crop is grown following the harvest of maize in September and upland rice in October. The wheat crop should be seeded into soil with a full moisture profile, and some additional rainfall must be received during November to ensure acceptable yields.

The second broad land category is lowland areas, where sufficient water is not available in the irrigation system to grow rice during the entire dry, cool season. Wheat, because of its relative drought tolerance, can survive this situation, and in 1983-84, wheat yields of 2.4 t/ha were obtained in experiments in which crops received only two irrigations during the juvenile plant phase (up to 30 days after emergence).

Dr. C.E. Mann (left), inspecting barley trials in Thailand.

Although the lowlands represent a large potential wheat-producing area, unsolved technical problems, mostly related to the tendency of the heavy, infertile soils to become waterlogged, preclude the area's immediate use. Research is nevertheless proceeding on seedbed preparation and seeding methods (including zero/minimum tillage), water control and management, fertility, and weed control.

Research in upland areas—Since the lowland areas are problematic, the emphasis in wheat extension is on rainfed upland areas (where, during the past 10-15 years, some farmers have been growing wheat for a local specialty market), and on some free-draining sites where some possibility of irrigation exists.

In 1983-84, 27 sites, ranging from 0.2-1.0 ha, were sown by farmers. Yields were generally low, less than 800 kg/ha, mainly because of farmers' inexperience with the crop. Seeding was usually too late (mid-October appears to be the optimal date for seeding rainfed wheat), and seed was planted at too shallow a depth, which affected crop establishment and development. Fertilizers were rarely used. Data indicate a universal response to nitrogen, but phosphorus and potassium requirements are unclear. Data on the potassium response of wheat suggest that economic responses to potassium may be rare. For phosphorus, soil analyses mainly suggest deficiency levels (5-10 ppm), but responses have been few and inconsistent. High phosphorus absorption capacities have been indicated

Weeds are also a problem. Predominant grassy weeds affecting wheat were various species of *Eragrostis*, *Eleusine*, *Echinochloa* and *Digitaria*, whereas broadleaf weeds include *Amaranthus* spp. and *Portulaca oleracea*.

Low wheat yields currently attained under rainfed conditions preclude intensive weed control measures. Where some supplementary irrigation is available, increased yield potential should encourage better weed control. Data suggest that the first five weeks is the critical period during which weeds should be controlled. Mechanical aids to weeding (rotary hand weeders, hinged hand hoes, shallow plows, and harrow weeders) are being promoted, but a more satisfactory result may be obtained in the future through chemical weed control.

Some commercially available herbicides (e.g., Butachlor, Alachlor, Oxadiazon, Isoproturon) have been tested experimentally with acceptable results. However, in practice, phytotoxicity problems, related to the level of soil moisture following application and to seeding depth, have been experienced.

Local wheat utilization program—The adoption of wheat is promoted among farmers through a "local utilization" program. In this program farm families are shown the uses of wheat and instructed in the preparation of wheat products. Interested farmers can apply for seed and are informed of the management practices required to grow the crop. The program has proven successful and is only limited by the restricted supply of seed. The program's next objective is to create "local markets" for farmers' wheat, such as village mills, noodle factories, or bakeries.

Training

Training in wheat breeding, pathology, and production continues to be one of the regional program's major objectives, and six candidates have been identified for in-service training in Mexico in 1985.

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a International Triticale Screening Nursery
b Helminthosporium Screening Nursery
c Aluminum Screening Nursery

Table 1. Lines with outstanding performance in acid soils, Sumatra, 1984

Nursery and entry no.	Variety or cross and pedigree
15th ITSN[a]	
83	Castor 'S' x M_2A - Arm 'S' X44621-4Y 2Y-1M-1Y-5M-0Y
84	Castor 'S' x M_2A—Arm 'S' X44621-4Y-3Y-1M-1Y-1M-0Y
104	Cin-F5579 x FS1897/Trr 'S' X52471-11Y-1M-1Y-6M-0Y
187	Spd 'S' - Pvn X54268-7Y-1M-1Y-6M-0Y
2nd HSN[b]	
35	Mlt 'S' CM47634-I-2M-3Y-1M-2Y-1Y-1M-0Y
108	[Jup (7C-Pato(B)/LR64-Inia x Inia-Bb)]Ana CM37760-C-21Y-2M-1Y-3M-9Y-0M
109	Kvz-Bon [(21931-CH53 x An/Gb56) Pj]Soty Yr Resel(B) CM33729-A-1M-4Y-3M-1Y-0Y
114	Baya 'S' CM42374-1Y-1M-1Y-2M-1Y-0B
2nd ALSN[c]	
21	Mrng

Table 2. Lines that yielded well in trials at three sites in the Philippines, 1984

Line	Yield (kg/ha)	Yield of highest check of respective trial (kg/ha)	Check	Relative yield (% of check)
C 169-6	1862	1535	Trigo 1	121
C 152-7	1727	1535	Trigo 1	113
C 749-2	1710	1509	Trigo 2	113
C 220-5	1902	1711	Trigo 1	111
C 719-1	1663	1509	Trigo 2	110
PL 132	1603	1535	Trigo 1	104
PL 136	1539	1535	Trigo 1	104

Table 3. Development of national nurseries in Thailand, and number of stations reporting usable results

Year	Wheat Thailand Observation Nursery	Wheat Thailand Yield Nursery	Barley Thailand Observation Nursery	Barley Thailand Yield Nursery
1980-81	5			
1981-82	9	5	8	
1982-83	10	5	6	4
1983-84	10	6	5	4

Table 4. Best lines across six locations in Wheat Thailand Yield Nursery, 1984

Rank	Name	Pedigree	Average yield (kg/ha)
1	No. 144	Pi62-Fr x Pi62-Mz/Mxp	2064
2	SW 29	Quimori 79	2001
3	UP 262		1971
4	CMU 26	Bb-Cno x Inia66-Soty	1885
5	CMU 245	Chat 'S'	1876
6	CMU 20	Jup-12300 x LR64-8156/Nor	1838
7	SW 23	Buc 'S' (No.41)	1868
.			
.			
.			
11	Inia 66	Check	1774
15	Sonora 64	Check	1708

Table 5. Best lines across four locations in Barley Thailand Yield Nursery, 1984

Rank	Name	Average yield (kg/ha)
1	FNBL 7701	1592
2	FNBL 7704	1525
3	FNBL 7702	1451
4	Jyoti	1361
5	Ibon 118 (check)	1257
6	Ibon 47 (check)	1185

Peru

G. Vázquez G.

Introduction

The production of wheat and barley has declined in Peru over the past few years; total wheat production in 1983 was 100,000 t, down from 117,000 t in 1981, and barley production fell from 170,000 t in 1970 to 130,000 t in 1980. To resolve this problem and foster small grain cereals production, the National Cereals Program (PNC) of the National Institute for Agricultural Research and Extension (INIPA) was created in 1983. The program concentrates on five crops: wheat, barley, oats, triticale, and rye (in descending order of importance). The main objectives of the PNC are to:

- Develop widely adapted, improved germplasm for Peru's three small grain cereal-producing zones: the mountains, the coast, and the cold, high plateau;
- Develop improved cultural practices;
- Promote the application of appropriate technology;
- Train technical personnel; and
- Increase production of cereals, particularly wheat, which is a basic component of the Peruvian diet.

CIMMYT was invited to participate in this program by the Peruvian government, and cooperates with the PNC in several ways. A small grains breeder was assigned to Peru by CIMMYT to facilitate the exchange of germplasm and information between the two organizations, to help evaluate and improve agronomic practices limiting cereals production, and to join in the selection and screening of germplasm. CIMMYT also takes part in training technical personnel, both within and outside of Peru.

Plant breeding

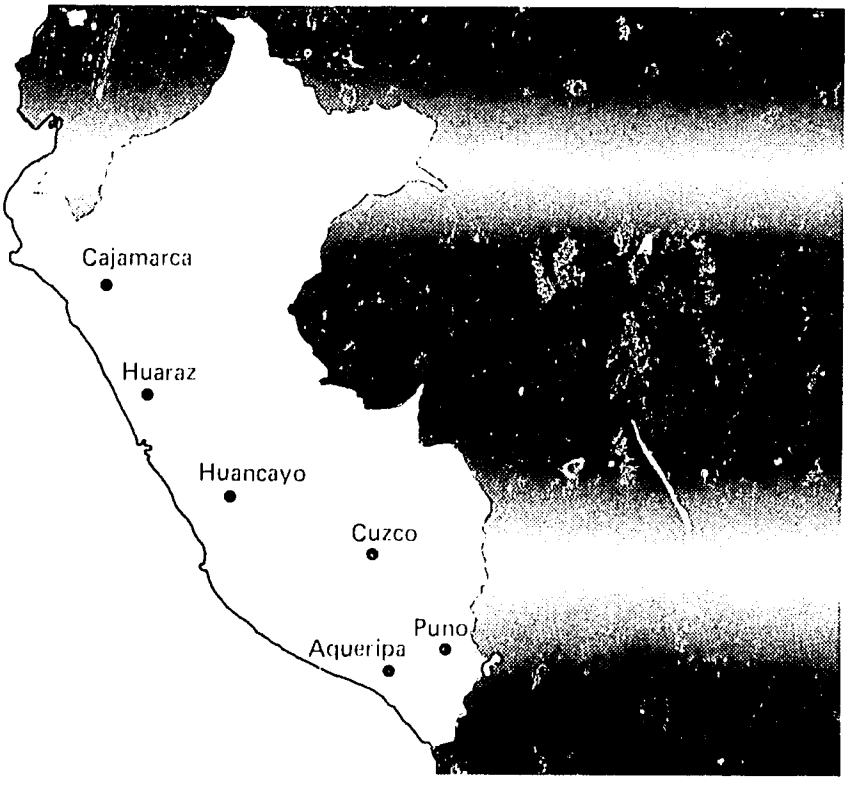
Yield trials—In the 1982-83 cycle, advanced materials were tested in a series of uniform yield trials; intermediate and preliminary yield trials were conducted as well. Lines that performed well during the 1982-83 cycle are listed in Table 1.

Preliminary, intermediate, and advanced yield trials for bread and durum wheat, triticale, and barley were also planted in the 1983-84 cycle. These trials, based on agronomic, disease, and yield data obtained from tests at various sites throughout Peru during 1982-83, were replicated at several sites. Altogether, 47 nurseries were distributed to the main cereal-producing regions of the country, and promising lines with the potential to become commercial varieties were identified. The 12 yield trials of spring wheat materials for the mountainous region included 360 advanced and preliminary lines and check varieties.

Winter wheat trials in the cold, high plateau near Puno were severely affected by frost during different growth stages, and by hail near harvest. Grain yields from some trials were reduced to barely 130 kg/ha. At sites better protected from the cold (for instance, Salcedo Experiment Station near Lake Titicaca), certain wheat lines yielded up to 8470 kg/ha.

Since severe weather conditions prevented the initial objectives of many cereal trials from being realized, the production of fresh and dry forage from trial plots was measured instead. Yields of up to 36 t/ha fresh forage and 16 t/ha dry matter were obtained from some promising materials. These results suggest that the potential dual purpose of these crops as forage and/or grain should be considered when planning cereals research in the high plateau area.

Disease resistance—The wheat varieties most widely grown in Peru (Florence Aurore, Huanca, and Ollanta bread wheats; Barba Negra, Estaquilla, and Chumpi durum wheats) are plagued by susceptibility to numerous diseases. These include stripe rust (*Puccinia striiformis*); stem rust (*Puccinia graminis*); septoria leaf blotch and other less prevalent foliar diseases (*Fusarium nivale*, *Alternaria*



triticina); bacterial diseases (*Xanthomonas translucens*); and root rot caused by *Ophiobolus graminis* and *Fusarium* spp. With the exception of Ollanta, which is of intermediate height and susceptible to stem rust, these varieties are also susceptible to lodging, which limits their potential to benefit from more advanced crop management technologies.

Inia CJ-102 and Gavilán, the new semidwarf varieties derived from CIMMYT germplasm, possess good resistance to rust and moderate resistance to foliar diseases, but are not yet widely used. It is uncertain whether these new varieties will easily replace the taller cultivars, which are planted on sloping land and receive few or no technological inputs.

Future breeding work—The PNC program will continue developing improved lines of wheat and other small grain cereals that are well adapted, high yielding, and possess adequate resistance to the most prevalent diseases. These lines should also have plant types suitable for the areas and conditions where they will be grown; such areas include the uneven, rainfed terrain of the mountains, and the irrigated, high-input environment of the coast. Finally, given the increased interest in winter wheats in Peru, the program should develop winter varieties for human consumption and/or animal feed to be grown in the high plateau of Puno.

Promising materials for each of the cereals within the mandate of the PNC are at various stages of development, and some of these have the potential to become commercial varieties. The PNC will continue to request germplasm from national and international organizations for use in the breeding program.

Production

Training course—The production program was initiated with a three-stage training course designed to instruct crop specialists on various aspects of wheat production. Recommendation domains, priorities, and experimental design were discussed, and CIMMYT staff gave lectures on crop management and the diagnosis of problems in rainfed wheat. Pilot trials on fertilization, weed control, varieties, and seeding rate were established and evaluated by course participants. Preliminary data gathered from these trials were dramatic: trials that received no technological inputs produced yields ranging from 153 to 1443 kg/ha, and trials that received recommended technological inputs yielded from 2503 to 5346 kg/ha. Final results of this research will be reported at the Third Annual Cereals Conference in September, 1986.

Production constraints—Preliminary observations and results from the trials mentioned above show that one of the greatest constraints to wheat production in Peru, especially in the mountain region, is the lack of fertilizer. The use of fertilizer could perhaps double or triple present yields. Observations at several sites indicated that weed control, particularly of *Avena fatua* and *A. sterilis*, might also significantly raise wheat yields. Research directed at eliminating these production constraints should continue, taking into account results of the 1983-84 on-farm trials.

The varieties and seeding rates presently used in the mountain region appear to be adequate; it is recommended that multiplication and purification of seed of preferred varieties be continued. This action, along with appropriate recommendations for planting, should satisfy current demands for seed and improved technologies.

Extension

Program staff hosted field days for farmers and other groups in Cuzco and Huaraz. These events had two important functions: 1) to show farmers and others involved in wheat production the advances in cropping systems, and 2) to demonstrate to extension agents the importance of improved technology

Dr. G. Vázquez (left), CIMMYT breeder working with the National Cereals Program (PNC) in Peru.

and the need for close collaboration with farmers and researchers. Extension workers were encouraged to use diverse methods of communicating research results to farmers, and to relay to researchers the farmers' needs for better alternatives to technologies already in use.

Field days were also held to discuss spring wheat, barley, and winter wheat production trials planted at several sites on the high plateau near Puno. Additional extension efforts included the planting of demonstration plots in farmers' fields in Huancayo, Huaraz, and Cajamarca, and two demonstrations for producers in the Maras area (attended by 31 and 52 farmers, respectively). During the subsequent cropping season, the PNC, working in conjunction with extension personnel, should plant another series of experimental plots in farmers' fields to demonstrate preliminary recommendations formulated from trials conducted during the 1983-84 cycle.

Seed Multiplication

Seed of preferred varieties was multiplied to satisfy the demand for adequate quantities of pure seed. For many years, no seed had been produced, and farmers' fields contained as much as 50% mixture. In three Cuzco substations, multiplication plots were planted with Ollanta, Inia CJ-102, Cholisaca, Gavilán, Huanca, Cahuide, Sinchi, and other bread wheats; Barba Negra durum wheat; and UNA 80, Grignon, La Malvina, and Cebada Criolla barleys. Large-scale multiplication of varieties for the sierra and some multiplication of varieties for the coast were done at coastal experiment stations during winter, 1984. Production from these new seed nurseries is conservatively estimated at 125-150 t of seed for the sierra, and 30 t of the coastal varieties. Seed will be available for spring planting in the sierra in 1984-85, and seed of the coastal variety Participación will be ready for planting in winter, 1985.

Training

Training of technical personnel is essential if a research program is to expand its research capacity and ensure the continuity of its work. CIMMYT assists in the training process by selecting candidates from national programs for training courses at the Center's headquarters in Mexico, and by organizing additional training activities outside Mexico. The Center also arranges for senior researchers to go to CIMMYT headquarters as visiting scientists. In 1984, José Parra Herrera, Juan Salas Miranda, and Jose Cabellos of Peru were sent to CIMMYT for a seven-month training course.

At the PNC, academic training is another aspect of staff development. Three engineers, Gilberto Rodríguez Soto, Graciela Mendoza, and Eduardo Valencia Sánchez, continued to work on master's degrees at the National Agrarian University (UNA) in Lima. René Romero, another engineer, went to Mexico to begin studying for an M.S. degree. In the future, the program plans to give increased priority to training production and extension personnel in addition to training plant breeders.

In 1984, several field days for farmers, extension workers, and researchers were held to discuss trials planted near Puno.

Table 1. Most promising lines and varieties in yield trials, 1982-83 cycle

Variety or Cross	No. of sites	Yield range (kg/ha)
Bread wheat		
Pvn 'S' (Pato R-Cal/7C x Bb-Cno)	4	1520-3300
Forlani—Acc 10 x Ana75	2	1677-3220
MN 7231—Pvn 'S'	1	3250
C.79019 (Costa)	1	6218
Cno 'S'—Jar 'S' x Bb	1	1590
Veery 'S'	1	2916
Sap 'S'—Mon 'S'	1	1640
S.75030	1	5757
Bobito 'S'	1	7237
Tonichi 81	1	2817
Pdgaz x Kal-Bb/Cal x Cno 67	1	2733
Durum wheat		
Yavaros 'S'	3	769-1800
68112—Ward	1	2100
68112—Rugby/Ward	1	3220
Goose 'S'	1	1676
Tassili 77	1	2160
Geier 'S'—USA 0676 x Jo 'S'—Cr 'S'	1	2033
Triticales		
Beagle 'S'—M_2A	2	1350-5000
Coqui (IA-M_2A x Pj62/Bgl 'S')	1	2240
IA-M_2A x Pj62/Bgl 'S'	1	3776
(Drira/M_2A—IA x Ars) Ab 'S'	1	1703
FS.1795—Lne	1	2430
Cin—Cno x Bgl 'S'/Merino 'S'	1	3016
IRA-Drira	1	2005
Barley		
Boy^2—$Surb^3$ x Cl.12225—16d	1	1455
Boy^2—$Surb^3$ x Cl.12917—31d	1	2916
Ben-Tj	1	3500
Api-Cm67 (Hoya-Calt/Hr x Ps/Api	1	4400
C.7509	1	5437
Cl.12971—Cl.12966	1	1474

Pakistan

P.R. Hobbs

Introduction

In 1984, Pakistan produced 10.9 million tons of wheat from 7.2 million hectares, the first decline in production since 1977 (Table 1). The shortfall in production — yields were 17% below the target set for the year — was caused primarily by a record drought (Table 2). Late planting of wheat after cotton, rice, and sugarcane crops, combined with high temperatures during the grain-filling stage, also reduced yields.

These production factors suggest the following research strategies for stabilizing wheat yields in Pakistan:

- Developing wheat lines that are heat tolerant during maturation, and suitable for late planting;
- Basing research on cropping patterns to fit wheat into more intensive cropping systems following rice, cotton, and sugarcane;
- Increasing research on barani wheat; and
- Developing lines with stable disease resistance.

Plant Breeding

New releases—Breeding work was active in 1983, and three new wheat lines from the Ayub Agricultural Research Institute (AARI), Faisalabad, were approved by national and provincial seed boards:

- Faisalabad 83 = (V70391) = Fury//Kal/Bb (CM37138-42-1M-5Y-1M-4VSY-0A)
- Kohinoor 83 = (V79353) = Ore F.158/Fdl//Mexifen 'S'/2*Tiba 63/3/Coc (CM37987-1-1Y-5M-0Y)
- Barani 83 = (K342) = Bb/Gallo /3/Gto/7c//Bb/Cno (CM32347-3M-1M-1Y-1K-0A)

Faisalabad 83 is a substitute for Sonalika for late planting, Kohinoor 83 is recommended for its medium maturity, and Barani 83 is intended for barani areas in the Punjab.

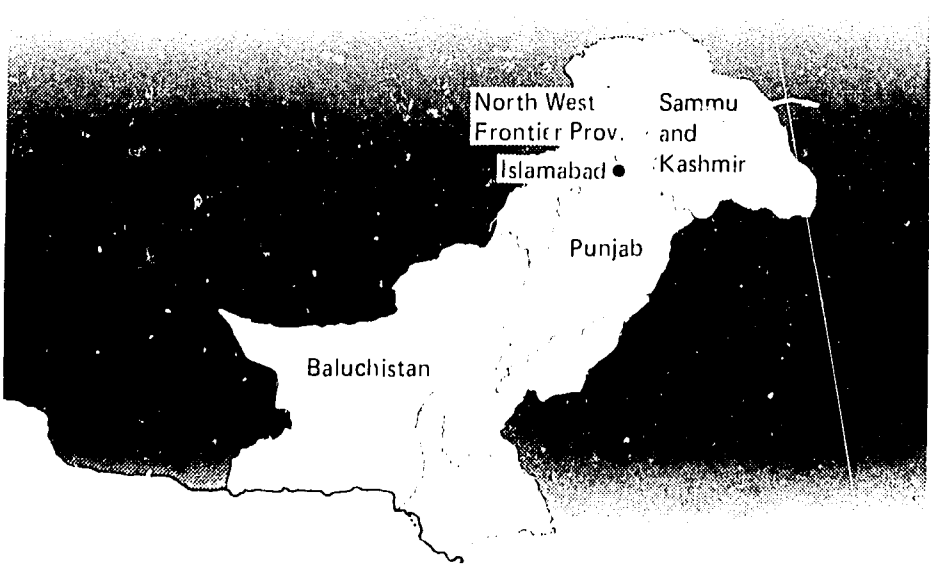
National uniform yield trials—Numerous national yield trials are administered by the national wheat coordinator, and lines to be included in these trials are sent to the national center by provincial breeders. In 1983-84, five different types of trials were prepared and sent out; each type was separated into replicated trials for experiment stations and unreplicated trials for farmers' fields (Table 3). A total of 230 trials were dispatched, and 150 were returned for analysis. The final report on the trials includes information on yield, yield components, and disease data collected throughout Pakistan.

International nurseries—Pakistan received 65 international nurseries from CIMMYT (26 bread wheat, 8 durum, 11 triticale, 10 barley, and 10 others) and 66 from ICARDA (30 bread wheat, 19 durum, 13 barley, and 4 triticale) in 1983-84. These nurseries were distributed to 10 different institutions in the country; most nurseries were planted at provincial research centers. With the exception of results from the F_2 nurseries, all data for CIMMYT nurseries were completed and returned to Mexico for analysis.

Plant Pathology

Diseases were not a problem in 1984, with the exception of loose smut (*Ustilago nuda* f. sp. *tritici*), flag smut (*Urocystis tritici*), and Karnal bunt (*Neovossia indica* or *Tilletia indica*). Loose and flag smuts continued to affect crops in the Punjab, but resistant germplasm is being found, as are various chemicals for controlling the two diseases. Karnal bunt increased in Pakistan, and was found in the Punjab and the Northwest Frontier Province (NWFP). Collaborative research with CIMMYT on this disease will begin in 1985.

The Cereal Disease Research Institute (CDRI) assisted plant breeders with the inoculation and evaluation of cereal diseases. The National Wheat Disease Screening Nursery (NWDSN), containing all commercial varieties, many advanced lines, and much of the segregating material available in Pakistan, was grown at 11 key locations throughout the country. This nursery was inoculated and lines were evaluated for rust susceptibility. The NWDSN was also sent to Kenya, Turkey, and Bangkok for international testing. The



International Disease Trap Nursery (IDTN) was planted and evaluated at six locations in different provinces of Pakistan.

The National Wheat Rust Trap Nursery (NWRTN) was planted and data taken at 16 locations. Laboratory and greenhouse studies continued to identify genes for leaf and stripe rust resistance in local germplasm. The analysis of these data was given to breeders to assist them in their work.

On-farm Research Program

Since most wheat in Pakistan is grown in a double cropping pattern in which the interaction of the two crops is significant, the CIMMYT wheat agronomist developed a site-specific program of on-farm research in Pakistan. This program was carried out with the cooperation of agricultural economists and special attention was given to the farming system at each site.

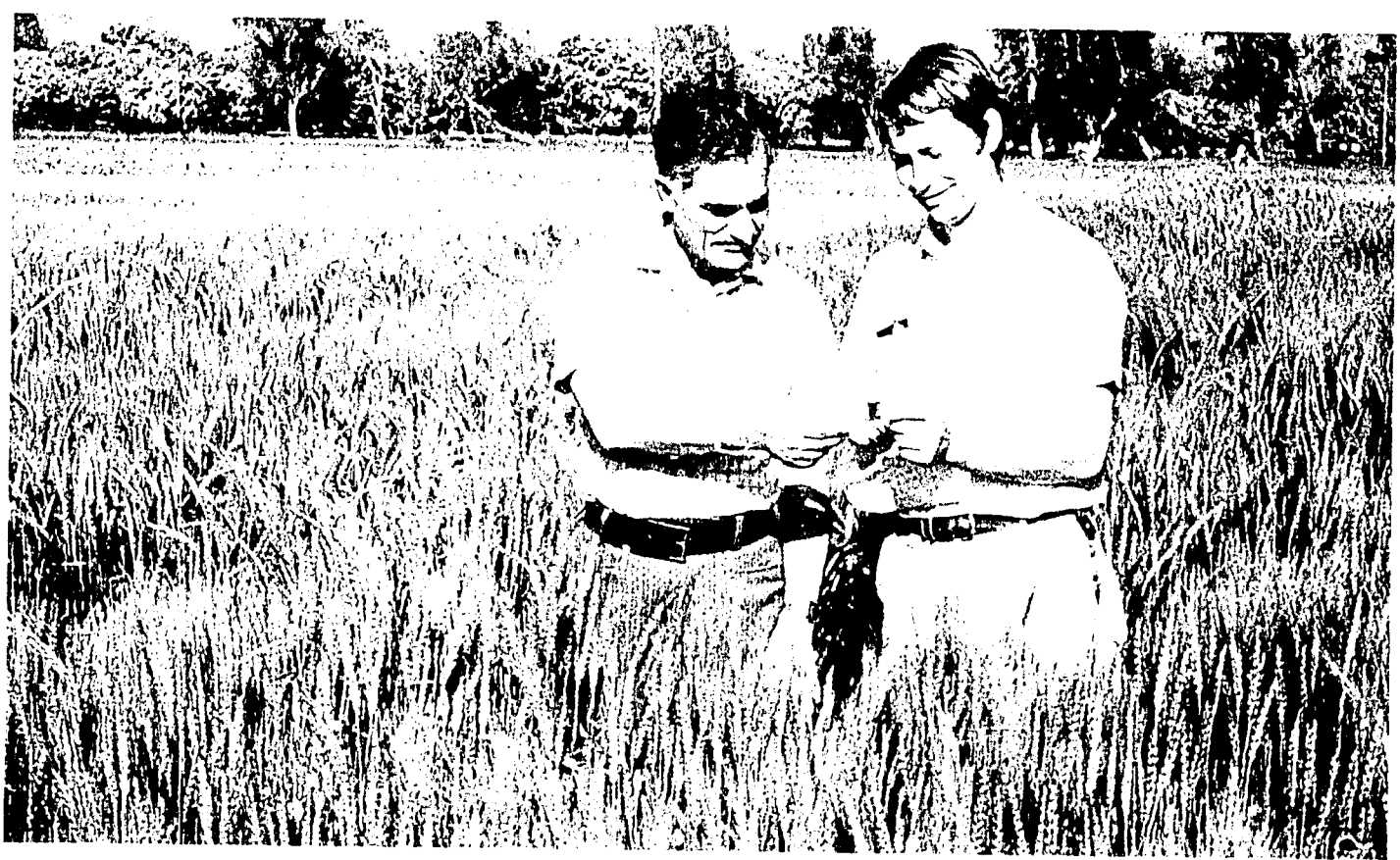
Three steps are involved in the program's on-farm research approach:

- An informal survey is taken in an agro-ecological area where wheat yields have potential for improvement, to identify "recommendation domains," select sites for experiments, and obtain an understanding of the farmers' situation;
- Formal surveys, including yield assessment and crop management surveys, are used to get more specific quantitative data for the area and to identify issues for research; and
- A series of researcher-managed agronomic experiments using recommended techniques for land preparation, stand establishment, fertilization, and weed control is carried out on farms in selected areas to collect quantitative data on potential yields. Farmer-managed plots are also used to obtain information on farmers' yields when improved practices are adopted.

In 1983-84, agronomy research focused on dryland barani and rice-wheat areas in the Punjab, and on maize-wheat areas in NWFP. Most of the work was done by wheat agronomists and social scientists at NARC, with some assistance from provincial research and extension personnel. Preliminary surveys, yield assessments, and crop management studies were conducted in these areas. Agronomic trials on tillage, varieties, fertilizer, and weed control were also undertaken.

Research in Dryland Barani Areas

A yield assessment and crop management study were continued



Dr. P. Hobbs (right), CIMMYT scientist with the bilateral program in Pakistan, examines wheat trials with a colleague at the National Agricultural Research Centre, Islamabad.

and expanded in Rawalpindi and Islamabad districts in 1984. The study consisted of a crop cut survey and interviews with farmers to determine which cultural practices were used in specific plots.

Three locations receiving different amounts of rainfall were included in the study: Islamabad district (high rainfall, more than 895 mm/yr), Daultala (medium rainfall, 640-895 mm/yr), and Chakwal (low rainfall, less than 640 mm). Results for Daultala were compared with the previous year's data: average yields in 1984, a dry year, were 1.77 t/ha, in contrast to 1.9 t/ha in 1983, a wet year. This 7% difference is surprising since the only rainfall in 1984 fell during the booting to flowering growth stages. Despite the dry year, farmers' application of fertilizer increased by 16% for nitrogen (to 44 kg/ha) and 20% for phosphorus (to 37 kg/ha).

Yield is strongly related to rainfall, but is also influenced by management practices, which vary from the low rainfall area of Chakwal to the higher rainfall areas of Islamabad and Daultala. Yields and details of some management practices were obtained from 298 farmers sampled in the 1984 survey (Table 4).

Agronomy trials—Researcher-managed agronomy trials were conducted around Daultala and Islamabad to evaluate fertilizer levels, tillage, variety, and weed control. The biggest factor found to be limiting yields was tillage.

Figure 1 shows average yield responses to different tillage treatments from three locations. The 1.3 t/ha (52%) increase in yield using the moldboard plow is economically very beneficial, because although the cost of each pass with the moldboard is higher than the cost of each pass with the cultivator, fewer plowings are needed following the deeper moldboard plowing. Farmers using the cultivator (which is the traditional implement) frequently plow fields seven to eight times before planting.

A closer look at the treatments indicated that the major reason for increased yield in plots where the moldboard plow was used was that plants rooted better and nutrients and water were more available. In plots plowed by the cultivator, a thick, compact soil layer below the 4 inch plowed surface greatly reduced rooting depth. Weeds and root rot diseases decreased in plots where the moldboard plow was used. The main constraint against the adoption of this technique is the unavailability of disc or moldboard plows.

Fertilizer trials—In the fertilizer trials, a significant nitrogen x phosphorus interaction occurred in plots where the moldboard plow was used, but no interaction was observed in plots plowed with the cultivator. The main effects of nitrogen and phosphorus were significant for both tillage treatments. Averaged over all plots, nitrogen and phosphorus were equal in effect in plots where the cultivator was used, and the effect of phosphorus was 7% greater in deeply plowed plots. The best fertilizer levels in the deeply plowed plots were 50 kg N + 70 kg P_2O_5, whereas in the cultivator plots nitrogen responses occurred up to 100 kg N and 70 kg P_2O_5. Longer term experiments are planned to look at possible residual effects of fertilizer in plots where the moldboard plow was used. Potash gave no response in any plot.

Research in Rice-Wheat Areas

Planting wheat after rice is a major cropping pattern in the Punjab. Seedbed preparation and stand establishment are problems when wheat is planted after rice, especially in heavier soils. These problems increase when wheat is planted after Basmati rice because time for land preparation is limited and rice residues are greater.

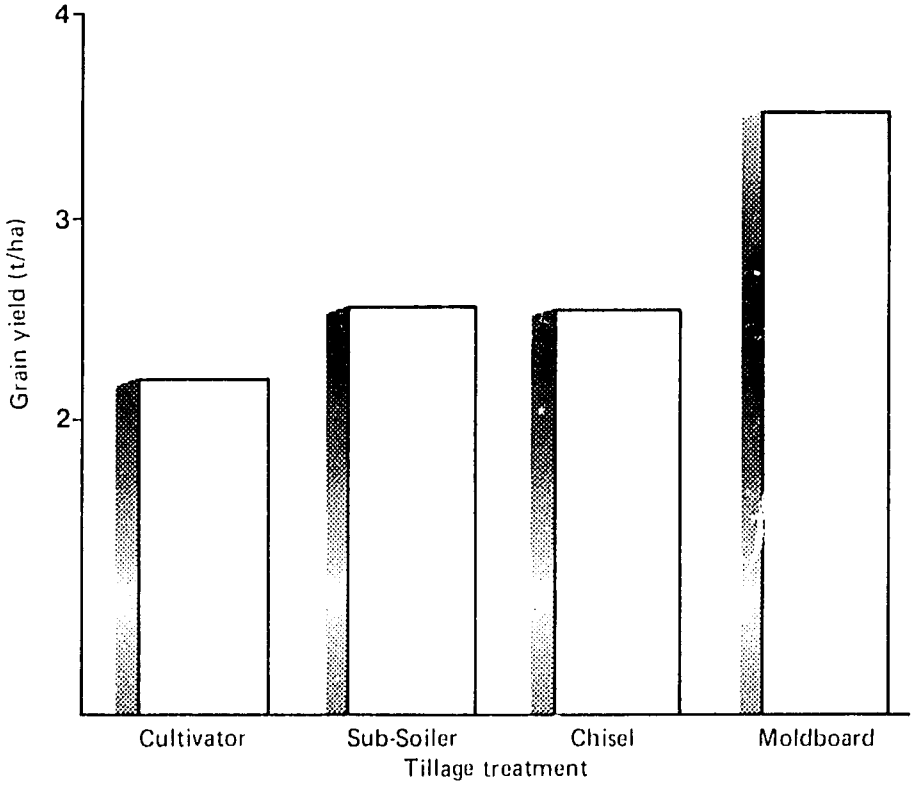


Figure 1. Grain yield x tillage treatment averaged over three sites in Pakistan, 1984.

Varietal use—More than half of the farmers in rice-wheat areas use banned varieties, especially Yecora; only 16% of the farmers use varieties released within the last five years. Since Yecora is susceptible to stripe and leaf rusts, a serious rust epidemic is a real danger.

Yield trials—In the national uniform yield trials, Pak 81 was the highest yielding variety at all sites; it averaged 0.59 t/ha more than the average yield in six variety trials, and performed better than other entries even when planted in December. Since this is the only variety with stripe and leaf rust resistance, it is important to promote Pak 81 in the rice tract.

Weed control—The weed *Phalaris minor* is a serious problem in one fourth of the wheat fields, reducing yields by an average of 25%. The predominant means of controlling *Phalaris minor* is through rotation; farmers grow a fodder crop in weedy wheat fields once every five years. If the herbicides currently available were used at recommended doses to control this weed, a 500 kg/ha increase in grain yield would be necessary to pay for the added cost.

Wheat yields in the rice tract are low and quite variable. The average yield from 152 samples was 1.8 t/ha, but 20% of the fields yielded under 1 t/ha and only 7% yielded over 3 t/ha. Fields where high yields were obtained generally had lighter textured soils, wheat was planted after maize or crops other than rice, the crop was planted earlier and received more irrigations, and 50% more nitrogen was applied. Conversely, fields from which low yields were obtained usually had been planted continuously to wheat for three or more years in the *rabi* (winter) cycle, usually followed basmati rice, and were seriously infested with phalaris. Multiple regression analyses confirmed these observations.

Research in Maize-Wheat Areas

Wheat yields in irrigated maize-wheat areas of the NWFP were higher than in the other two areas. Average yield measured from 150 samples in the survey was 2.8 t/ha. Twenty percent of the fields yielded under 2 t/ha and another twenty percent yielded over 3.5 t/ha. Multiple regression analyses and a comparison of practices in these two yield groups showed that fields from which the best yields were obtained were more often planted after tobacco-maize, received additional land preparation, were planted to Pak 81, and given phosphorous fertilizer. Fields in which yields were low had usually been planted continuously to wheat in the *rabi* cycle and were infested with broadleaf and phalaris weeds.

Agronomy trials—Agronomy trials confirmed the benefits of using Pak 81, phosphorus fertilizer, and herbicides. The best wheat variety averaged over eight sites was Pak 81, producing 563 kg/ha more than Sarhad 82 (Bobwhite 'S'). These two varieties are the only ones resistant to the stripe rust races in Pakistan.

There was a significant effect of nitrogen (57%) and phosphorus (27%) on yield averaged over the nine sites harvested, and a significant nitrogen x phosphorus interaction of 16%. Phosphorus use was very profitable, with a marginal rate of return on capital of 266% for the first 70 kg of P_2O_5 and 169% for an additional 50 kg.

Herbicide trials demonstrated the importance of good weed control. Yield increases from 10% to 16% over the control were found with the phenoxy broadleaf herbicides and from 17% to 22% with the substituted urea compounds that control both broadleaves and grasses. Yield increases for the substituted ureas and phenoxys were 690 kg/ha and 430 kg/ha, respectively.

Kaghan Summer Nursery

Work at the Kaghan Station continued to improve. During 1984, breeders were able to grow, select, advance, and produce seed with resistance to the rusts and to powdery mildew.

Training

Five scientists attended short-term training courses at CIMMYT, and eight others attended conferences or traveled outside Pakistan as visiting scientists.

A three-week weed science training course, attended by 30 participants from Pakistani research and extension programs and universities, was held in Islamabad in January. Consultants and materials came from IPPC (Oregon State University), and USAID supplied funds. The course was made possible through the cooperation of six international and national organizations.

During the fourth annual wheat traveling seminar in March, 28 scientists went from Karachi to Peshawar to evaluate the season's wheat crop. This tour enabled scientists to meet each other, discuss common problems, and evaluate wheat research and wheat in the field.

A four-day Annual Wheat Conference was held in Islamabad in late August. It was attended by scientists from all parts of Pakistan, and papers were presented on all aspects of wheat research.

Table 1. Area, production, and yield of wheat in Pakistan, 1977-1984

Year	Area (1000 ha)	Production (1000 t)	Production (% 1977)	Yield (kg/ha)
1977-78	6360	8367	100	1316
1978-79	6687	9950	119	1488
1979-80	6924	10857	130	1568
1980-81	6984	11475	137	1643
1981-82	6981	11631	139	1666
1982-83	7269	12339	147	1697
1983-84	7325	10936	131	1493

Table 2. Rainfall and temperature data for Pakistan, Islamabad District, 1983-84 and 21 year average

Month	Rainfall: 21 year average (mm)	Rainfall: 1983—84 (mm)	Rainfall: 1983—84 (as % of 21 yrs)	Average temperature (°C) 1982-83	Average temperature (°C) 1983-84
September	72	221	307	n.a.	n.a.
October	25	58	232	n.a.	19.3
November	15	0	0	n.a.	16.1
December	23	1	4	n.a.	11.5
January	50	0	0	9.3	9.1
February	68	106	156	10.6	11.4
March	77	97	126	14.5	18.9
April	60	25	42	18.7	22.0
May	47	17	36	24.6	29.0
Total	443	525	119		

Table 3. National Uniform Yield Trials, Pakistan, 1983-84

Name		No. of sets dispatched	No. of results returned	No. of entries
Normal maturity	A[a]	33	29	19
	B	44	24	19
Early maturity	A	31	26	12
	B	36	19	12
Rainfed	A	16	10	12
	B	19	8	12
Durum/Triticale	A	12	12	10
	B	14	7	10
Barley	A	11	8	10
	B	14	7	10
Total	A	103	85	63
	B	127	65	63

a A = Replicated for experimental stations.
B = Unreplicated for farmers' fields

Table 4. Summary of yield and management practices in the barani areas of Punjab, 1984

Factor	Site			All sites
	Chakwal	Islamabad	Daultala	
Average rainfall (mm)	640	895	640-895	—
No. of samples	63	125	110	298
Yield (t/ha)	0.80	1.93	1.70	1.63
Percentage farmers apply nitrogen	40	83	91	77
Kg N/ha	60	57	50	54
Percentage farmers apply phosphorus	29	63	66	57
Kg P_2O_5/ha	46	44	56	49
Percentage farmers use farmyard manure	44	27	26	31
Percentage farmers use new varieties	37	95	88	80

Bangladesh

L. Butler and M. Guler

Introduction

The Extension Directorate of Bangladesh estimated that in 1983-84, 635,370 ha acres of land were planted with wheat, from which about 1.2 million tons of grain were produced. These yields might have been far lower, because lack of rain in November and much of December, 1983, forced many farmers to plant late. Ordinarily, late planting would mean a shorter growth period and reduced yields, but temperatures at the end of February and beginning of March were cooler than average, effectively extending the cropping season by at least 10 days. During March and April, when there is usually a high risk of violent pre-monsoon storms, the weather was exceedingly dry and ensured the safe harvest of the delayed crop.

Although the dry conditions were favorable for harvesting the wheat crop, they delayed the planting of summer rice (*aus*) and produced water stress in winter rice (*boro*) in many parts of the country. Monsoon rains, beginning in June and lasting through September, caused widespread destruction of crops and property. This crisis, combined with the threat of famine (averted through intensive relief efforts), has focused much attention on the 1984-85 wheat crop in the hope that it will provide grain for persons in areas damaged during the rains.

Breeding

The "favorable date (Nov. 15-30)—late date (Dec. 15-20)" planting and selection system initiated in 1982 was continued, with some modifications, under irrigated and dryland conditions at all regional stations. One of the results of using this system was the reduction of material in advanced trials; material unable to produce as well at late dates of planting as the predominant commercial variety, Sonalika, was eliminated early in the selection process. Only eight lines were included in the most advanced replicated yield trials of 1984-85, compared with twice that number in 1982-83. Since this system permits a rigorous evaluation of material, greater confidence, resulting from stronger supporting data, will accompany applications for a potential variety's release.

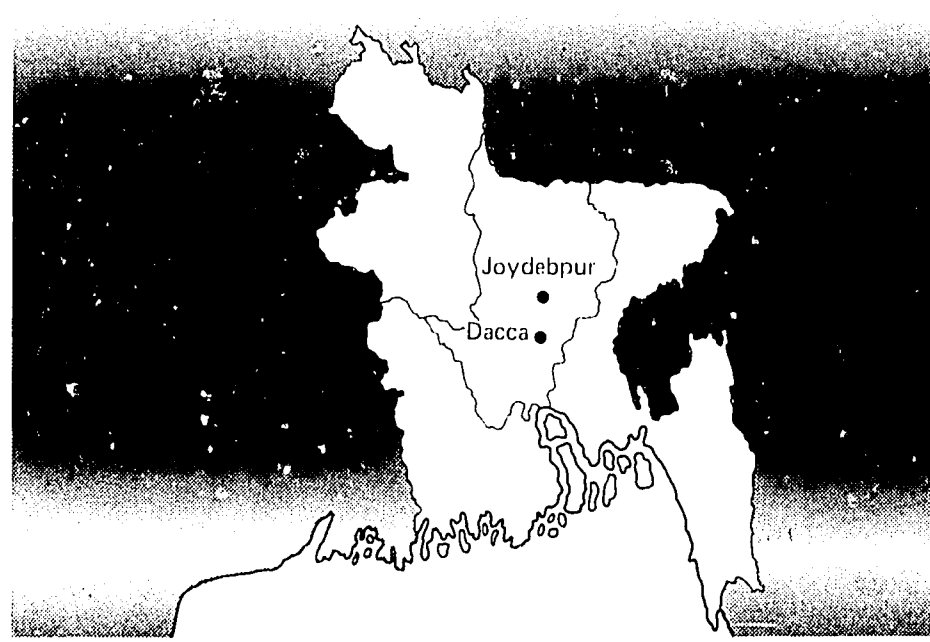
In 1985, the program hopes to release the advanced line Inia/3/Son 64/P4160Z//Son 64 (PK 6841-2A-1A-0A), which has performed extremely well under testing. This line may become the best alternative to Sonalika that the national program has been able to offer (in 1979, Balaka was released, followed by Kanchan, Ananda, Barkat, and Akbar in 1983; Ananda, Barkat, and Akbar are of direct CIMMYT origin). Two other promising lines, Mon/Vul (CM 59062-1Jo-0Jo) and Car//Kal/Bb (Cm 41182-K-9M-1Y-1M-2Y-0Y), are being evaluated in on-farm trials.

Pathology

At the central Bangladesh Agricultural Research Institute (BARI) station at Joydebpur, 1983-84 nurseries were inoculated with leaf rust derived from naturally occurring populations collected and preserved during the previous season. Early and severe infections were observed on susceptible plants in all nurseries as well as in susceptible border rows. The critical need of artificially induced epidemics was indicated by the susceptibility of about 50% of the entries in the advanced yield trials. The consequences of an early natural epidemic on susceptible commercial varieties (the most widely grown varieties, Sonalika and Inia 66, are fully susceptible) were also dramatically illustrated.

Increased emphasis was given to identifying lines resistant to *Helminthosporium sativum*. Reasonable levels of resistance were observed in lines from several nurseries, but the problem of incorporating this resistance into a suitable background remains an obstacle to its use. However, earlier maturing and apparently resistant material from the CIMMYT F_2 Helminthosporium nursery, which included crosses to adapted material, was selected.

The soil-borne pathogen, *Sclerotium rolfsii*, was a potentially severe problem for the 1984-85 season because November and December were warmer than usual. In many trial plots at BARI, Joydebpur, plant populations were significantly



reduced. The Plant Pathology Division reported that a similar situation was observed on farms in many areas. Studies must be undertaken to identify helpful prophylactic measures, but the pathogen is notoriously difficult to control.

Agronomy

Station studies—In station experiments, the effects of six dates of planting on yields of seven varieties of wheat were observed. Varieties developed by the BARI Wheat Centre varietal improvement program were fully competitive with Sonalika even if they were sown late, and could be expected to yield more if planted on more favorable dates. In other experiments, minimum tillage (no plowing) was compared with more traditional tillage practices (3-5 plowings). Although no significant differences in yield were measured between wheat sown on minimally prepared and traditionally prepared land, minimum tillage enables farmers to realize substantial savings in labor and animal energy. Minimum tillage experiments conducted on the station will be performed on farms in cooperation with the Soil Physics Division of BARI.

On-farm studies—Farmers generally maintain that wheat reduces the yield of the summer rice crop. Longer-term fertility experiments were established to study the residual effects of nitrogen, phosphorus, potassium, and sulfur fertilizers applied on a wheat crop followed by an early-maturing summer rice crop. Although summer rice yield results have not yet been received, data on the response of wheat crops to fertilizers are available. The lack of nitrogen, phosphorus, potassium, and sulfur applications resulted, respectively, in 47%, 16%, 11%, and 5% yield reductions (averaged over all sites). These results demonstrate the continuous need of nitrogen and phosphorus fertilizer, particularly nitrogen, and indicate the increasing requirement of

Dr. L. Butler, wheat scientist with the Bangladesh bilateral program, based in Dacca.

potassium and sulfur. These experiments will continue in the 1984-85 cycle.

Extension

Varietal promotion—As described in an earlier report, during the 1982-83 season a varietal promotion program was begun, in which new varieties were distributed in on-farm demonstration kits Kits for the 1983-84 season contained Sonalika and one of four new varieties (500 contained Kanchan, 500 Ananda, 14 Barkat, and 14 Akbar); 1028 kits were planted and managed by extension personnel. The total yield of grain and seed was retained by the farmers, who were encouraged to store a quantity of seed and to sell some to their neighbors if their opinions were favorable. This program is still the most efficient means of introducing and, even more important, disseminating new varieties. Five hundred kits composed of all four varieties plus Sonalika were distributed for the 1984-85 season.

Farmer training—Extension personnel and 30 farmers living near two regional stations took part in one-day training sessions in a pilot training program. Simplified lectures on breeding, pathology, agronomy, and seed storage were given in the morning, and in the afternoon at each respective station participants observed nurseries demonstrating the plant improvement process. The farmers' response was very encouraging; this program will be expanded if possible in 1985.

The project also sponsored a seed-storage training program in the northwest for 900 farmers, and two farmers' field days at regional stations, each attended by nearly 1000 farmers.

Training

In-service training—Four trainees attended courses at CIMMYT, Mexico. Two trainees, Messrs. Hydar Ali Mollah and Md. Anwar Shaheed, both of the BARI Plant Pathology Division, studied breeding and pathology. The other two trainees, Mssrs. Md. Saifuzzaman and Md. Islam, of the Agronomy Division, BARI, took part in the rainfed agronomy course.

Visiting Scientists—Dr. M.H. Mondal, Director (Research), BARI and Mr. Ashraful Islam, Crop Production Specialist, RARS, BARI, Ishurdi, observed CIMMYT Maize and Wheat Programs at El Batan in September. Mr. Islam also attended the Symposium on Wheats for More Tropical Environments sponsored by CIMMYT and held in Mexico.

Graduate Students—Four of seven scholarships provided by the project are in use. At North Dakota State University (USA) in November 1983, Mr. A. Samad began working toward a master's degree in plant breeding, and Mr. Md. Badaruddin began working on a doctorate in agronomy. Mr. A.E.S. Hossain entered Kansas State University (USA) in January to begin studies toward a Ph.D. degree in plant breeding. Mr. Kazi Benozir Alam began to study for a master's degree in plant breeding at the University of Missouri (USA) in January.

Turkey

B. Skovmand

Introduction

The objective of this bilateral program, funded by the United Nations Development Program, is to strengthen the National Cereal Improvement projects in Turkey, through improving and stabilizing grain production in the country. Since wheat is the most important crop in Turkey and is grown in 66 of the 67 provinces, the bilateral program is nationwide and works with 11 research institutes. It should be emphasized that all of CIMMYT's activities are carried out within the realm of the Turkish Cereal Improvement Project.

Crop Research

Germplasm development—The immediate objectives for germplasm development are to:

- Establish an international germplasm exchange and distribution system that will allow Turkey to benefit from improved germplasm developed in other countries, and permit other countries to benefit from materials developed by the Turkish program;
- Develop improved germplasm for the different grain-producing regions of Turkey;
- Increase the understanding of small grain diseases and their role in production; and
- Initiate training for young Turkish scientists in Turkey and at CIMMYT.

During the initial period of the project, from March through December 1984, the establishment of a germplasm exchange system received priority. Aside from international agricultural centers (CIMMYT and ICARDA) and other institutions involved in small grain cereal improvement (e.g., Oregon State University, USA), many programs throughout the world were invited to participate in seed exchanges with the Turkish program. Small samples of commercial varieties and advanced lines were received from almost 100 programs. These materials will be evaluated in the 1984-85 cycle, which started with fall planting in 1984.

Evaluation of foreign germplasm—Foreign bread and durum wheat varieties in the Turkish program were collected and formed into a nursery. This material is planted in Adana and consists of 121 bread wheats and 71 durum wheats. Larger quantities of commercial varieties expected to adapt to Turkish conditions were obtained with the cooperation of breeding programs in Texas (USA) and Bulgaria (Table 1).

These varieties are being evaluated in a replicated yield trial in Ankara, Erzurum, Eskisehir, Edirne, Yesilkoy, and Diyarbakir, and are being studied for disease reaction in Izmir. About 250 foreign introductions, those varieties for which enough seed was available, are being evaluated in the same locations in an unreplicated yield trial.

Nearly 500 introductions, for which less seed was available, are being evaluated in unreplicated trials in Ankara and Izmir. This split should allow identification of winter, spring, and facultative types. A further 500 introductions with very small amounts of seed are planted in Izmir for initial evaluation and seed multiplication.

Nursery distribution—Four types of material were sent out to programs that responded to the Turkish Cereal Improvement Project's request for seed: the winter wheat screening nursery, spring wheat screening nursery, disease resistant material, and sets of commercial varieties.

The winter wheat nursery was sent to CIMMYT, ICARDA, China, Iran, and to Oregon and Texas (USA). The spring material was distributed to Queensland and Western Australia (Australia), and to Quebec and Alberta (Canada). Lines with bunt resistance were sent to Oregon (USA), and sets of rust-resistant lines went to Kenya and Mexico.

Sets of commercial varieties developed by the program were constituted as follows:

- Winter bread wheat: Bolal 2973, Kirac 66, Gerek 79, Haymana 79, and Kirkpinar 79;
- Winter durum wheat: Cakmak 79, Tunca 79, and Kunduru 1149;
- Winter barley: Cumhuriyet 50, Tokak 157/37, Yildirim, Obruk, and Bozuk;

- Spring bread wheat: Cumhuriyet 75, Ata 81, and Gonen;
- Spring durum wheat: Diele 74, Gediz 75, and Gokgol 79,
- Spring barley: Zafer 160, Yesilkoy 387, Kocaoglu 69147, and Yersil.

A total of 153 sets were distributed to 23 countries.

The wheat program received many nurseries during 1984; Table 2 summarizes those received from CIMMYT, Mexico, CIMMYT regional programs and their national collaborators in the Southern Cone region of South America, Ecuador, Kenya, and Pakistan also contributed nurseries to the Turkish program.

Thirty-three additional nurseries (14 durum wheat, 11 bread wheat, and 8 barley nurseries) were received from ICARDA. The Oregon State University program sent 10 nurseries of winter material. These nurseries were shared among appropriate institutions, depending on the growth habit of the materials.

Advanced lines and new releases—The Turkish National Cereal Improvement Project recently released varieties of winter- and spring-type bread wheats, durum wheats, and barley. Advanced lines of all crops have been identified and are being tested nationally in consideration for future release. Some advanced lines from the winter cereal programs are listed in Table 3. Table 4 lists promising spring bread and durum wheat lines developed by the cereal improvement programs.

Wheat Production

Rainfall patterns—Rainfall patterns were abnormal during 1984. Too much rain was received in the coastal spring wheat areas during planting time, so the amount of land sown with wheat decreased because late planting would affect the summer or second crops. In southeastern Turkey, only about half of the normal amount of rainfall was received and this was in the beginning of the cycle. Cereal crops were short of water during the grain-filling period, and both total yield and grain weight were reduced.

Winter cereals received sufficient moisture during the winter but no rain fell after June 2 and test weights were lowered. It is estimated that the wheat harvest in Turkey was 17.2 million tons, an increase of 0.8 million tons over the 1983 harvest, which was severely affected by drought.

Dr. B. Skovmand (right), of the bilateral program in Turkey, with Dr. B.C. Curtis and Dr. S. Rajaram.

In general, cereal crops were not attacked by diseases during the past season, with the exception of high incidence and severity of tan spot (*Helminthosporium tritici-repentis*) in the Western Transitional zone. Durum wheats were especially vulnerable, and the program plans to begin screening for material with resistance to this pathogen.

In eastern Turkey, common and dwarf bunts cause damage when farmers do not treat their seed. Screening for resistant material will be expanded and is likely to involve other countries in the region.

In the Chukurova area, the spring wheat variety Orso was seriously affected by leaf rust. Orso has been the main variety for a number of years, but its susceptibility to leaf rust is causing it to be replaced by newer varieties.

Varietal Use Patterns

The total amount of land planted to wheat in Turkey is 9,100,000 ha. Of this, 6.6 million hectares (73%) is planted with winter wheat and 2.5 million hectares (27%) with spring wheat. Bread wheat is grown on 6.85 million hectares, whereas 2.5 million hectares are devoted to durum wheat production.

Fifty percent of the total land area used for wheat production is planted to the new, improved varieties listed in Table 5. Older varieties (30%) and landrace varieties (20%) cover the remaining half of the land under wheat cultivation.

Among winter wheat varietes, the most widely grown are Bezostaya, Bolal 2973, and Kunduru 1149. Cakmak and Gerek 79 will soon be grown extensively in the winter wheat area, and Kirkpinar will probably replace Bezostaya in Thrace. The most common spring wheat varieties are Orso, Dicle 74, and Cumhuriyet 75. In coastal regions, new spring wheat varieties Gonen, Ata 81, and Lachich are replacing currently cultivated spring varieties. Table 6 lists the percent of recommended varieties grown in each region in the country.

Production Campaigns

Most institutes working on cereal improvement have started on-farm demonstration programs conducted with the cooperation of the extension service. In many of the institutes, breeders implement the demonstrations.

Results from on-farm demonstrations conducted by the agronomy group at the Ankara Institute indicate the impact such work can have. During 1984, the program conducted 54 trials in 7 provinces in the Central Anatolian Plateau and in the Northern Transitional zone. The agronomy group conducted 12 of these trials, 7 in the Central Plateau and 5 in the Northern Transitional zone. Basically, the trials are demonstrations of new varieties in combination with improved growing techniques.

The widespread use of new, improved varieties in the Central Plateau would be expected to increase yields significantly over yields obtained from the local variety (Table 7). A new variety grown under improved management in the demonstrations gave a 71% yield increase, and improved management with no change in variety brought about a 12% gain in yield over farmers' traditional management practices. In the Northern Transitional zone, the improved varieties yielded 70% more than the local variety. In demonstration plots, a new variety combined with improved management practices increased yields 142%, and improved management without a change in variety gave a 41% yield increase.

Though no comparison to farmers' yields was made in another group of trials whose results are reported in Table 8, the data show benefits in yield similar to those obtained in the trials just described.

Additional experiments, conducted near Sivas in the Central Plateau, studied the effects of herbicides, fertilizers, and planting technology. The use of herbicides raised yields 46%, while drilling seed produced yield gains of 26% over broadcasting with a moldboard plow. Phosphorus and nitrogen at 60 kg/ha increased yields 23%, whereas nitrogen and phosporus alone raised yields by 21% and 13%, respectively.

It is anticipated that as farmers adopt these new varieties and management techniques, they will realize the production increases indicated in the experiments.

Training

Turkey—No formal training course was offered in Turkey in 1984, but informal visits to review germplasm and methodology were made to the following institutes: Ankara, Eskisehir, Adapazari, Yesilkoy, Edirne, Samsun, Ersurum, Diyarbakir, Adana, and Izmir.

A visit from staff of the bread wheat, durum wheat, and agronomy programs in Mexico was used to conduct a travelling workshop. This workshop gave two of the Turkish national staff the opportunity to visit the institutes and breeding programs in Adana, Diyarbakir, Ankara, Eskisehir, and Izmir.

In-Service Training in Mexico—One individual, Mr. Zeynel Yavus from the Ankara Institute, went to Mexico to take part in the Experiment Station in-service training course. Four other persons have been selected for training in Mexico in 1985.

Table 1. Wheat varieties received in 1984 and yield-tested for adaptation throughout Turkey

Origin	Variety
USA	
Texas	TAM 101, TAM 105, TAM 107, TAM 108, MIT
Oklahoma	Payne, Chisholm
Kansas	Newton, Arkane
Colorado	Vona, Wings, Mustang, Hawk
Nebraska	Siouxland, Brule.
BULGARIA	Vratza, Dobrudja, Monchill, Sadova 1, Panda

Table 2. Number of nurseries received from CIMMYT, Mexico

Type of material	Bread wheat	Durum wheat	Triticale	Barley		Total
Advanced lines	24	24	9	8		
Segregating material	6	15	4	7		
Disease nurseries	10	—	—	2		
Total	40	39	13	17	//	109

Table 3. Advanced lines of winter bread wheat and winter barley evaluated for possible release

Line		Institute	Crop
ES 7	Hyslop-7C	Eskisehir	Bread
No. 55	Romany//Scout 5/Agent	Eskisehir	Bread
EGVD12	Tzpp/Bezostaya	Ankara	Bread
EGVD14	CO693591/Ctk	Ankara	Bread
69003	K.M. 1718/7C	Halkeli	Bread
Bozok 82		Ankara	Barley
Obruk 82		Ankara	Barley

Table 4. Advanced lines of spring durum and bread wheat evaluated for possible release

Line	Institute	Crop
Ata 81	Izmir	Bread
Lachich	Izmir	Bread
Y50E/3*Kal//Cut75	Izmir	Bread
Bobwhite 'S'	Several	Bread
Veery 'S' (several sisters)	Several	Bread
Florida Line/Jilgero	Sakarya	Bread
Kop 'S'	Diyarbakir	Bread
Win 'S'/USA0237//Gad 'S'	Izmir	Durum
Oyca 'S'/Magh 'S'//Ruff 'S'/Fg 'S'	Izmir	Durum
Bittern 'S'	Izmir	Durum
Diyarbakir 81	Diyarbakir	Durum

Table 5. Winter and spring bread and durum wheat varieties released in Turkey

Wheat type	Variety
Winter bread wheat	
Released before 1978	Bezostaya Bolal 2973 Lancer Kirac 66 Ankara 093/44 Porsuk 2800
Released or introduced after 1978	Gerek 79 Kirkpinar 79 Haymana 79 Sadova 1 Vratza Dobrudja
Spring bread wheat	
Released or introduced before 1978	Cumhuriyet 75 Penjamo 62
Released or introduced after 1978	Gonen Malabadi

(continued)

Table 5 (continued)

Wheat type	Variety
Spring to alternative	
Introduced	Libellula
	Orso
	Argelato
Winter durum wheat	Kunduru 1149
	Cakmak 79[a]
	Tunca 79[a]
Spring durum wheat	Diele 74
	Gediz 75
	Gokgol 79

[a] New release

Table 6. Percent of recommended varieties grown in Turkey by region

Region	% Recommended varieties
Thrace	100
Marmara	85
Aegean	85
Mediterranean	70
Black Sea	30
Transitional	30
Central Plateau	50
Southeast	30
East	10

Table 7. Comparison of improved technology and farmer technology from 12 demonstration trials conducted by the Ankara Institute, 1983-84

Zone and treatment	Average yield (kg/ha)	% Increase of improved technology over farmer technology	
		Variety[a]	Management[b]
Central Plateau[c]			
Best variety	3720	53	71
Mean of varieties	3180	31	47
Farmer variety[a]	2430	—	12
Farmer management[b]	2170	—	—
Northern Transitional[c]			
Best variety	4530	72	142
Mean of varieties	3730	42	99
Farmer variety[a]	2630	—	41
Farmer management[b]	1870		

[a] Farmer or local variety within trial

[b] Farmer yield next to trial

[c] Seven trials in the Central Anatolian Plateau; five in the Northern Transitional zone

Table 8. Average yield and percent increase of improved technology over farmer technology from 42 demonstration trials conducted by the Ankara Institute in cooperation with local extension services, 1983-84

Treatment	Average yield (kg/ha)	% Increase over local variety
Central Plateau[a]		
Best variety	2950	45
Mean of varieties	2590	28
Farmer variety[b]	2030	—
Northern Transitional[a]		
Best variety	3430	63
Mean of varieties	2980	42
Farmer variety[b]	2100	—

[a] 28 trials in the Central Anatolian Plateau; 14 in the Northern Transitional zone

[b] Farmer or local variety within trial

CIMMYT/ICARDA Cooperative Bread Wheat Breeding Program

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Introduction

Bread wheat ranks first among the cereals grown in West Asia and North Africa. In 1983, about 10% (approximately 48 million tons) of the total world wheat crop was produced in this area; 78% of this was bread wheat and 22% was durum wheat (FAO, 1984)(Table 1). Between 1969 and 1983, bread wheat production in the region rose by 13.8 million tons, an increase attributed to the adoption of high-yielding varieties and better agronomic practices.

In West Asia and North Africa, most bread wheat is grown on rainfed land. Over 50% of the crop is estimated to be produced in areas receiving less than 400 mm annual rainfall; diseases, insect pests, stress factors (drought, heat, cold, and salt), and poor agronomic practices are persistent problems. The CIMMYT/ICARDA cooperative bread wheat improvement program seeks to ameliorate such problems by developing high-yielding germplasm that is resistant to diseases and insects, responsive to management, and suitable for zones where rainfall is low. An account of these activities is also given in the ICARDA *Annual Report*, 1984.

Breeding

Germplasm development—During the 1983-84 cropping season, 622 F_1s (simple and top-crosses) were made. Special emphasis was placed on incorporating specific traits into widely adapted, high-yielding lines possessing good nutritional and milling and baking quality. Among these traits were resistance to the three rusts, bunt, loose smut, bacterial blights, and septoria leaf blotch, as well as resistance to many insect pests, including sawfly, Hessian fly, suni bugs, and aphids. Other desirable traits sought were tolerance to drought, heat, cold, and salt.

Germplasm evaluation and selection—The program tested 10,133 segregating crosses and advanced lines during 1983-84 (Table 2). Of this material, 79% was developed by the CIMMYT/ICARDA cooperative program; the remaining 21% was received directly from CIMMYT/Mexico and other international cooperators. For the past four years, the amount of germplasm received from outside Syria through international observation nurseries or seed exchanges has been kept at approximately 21%, thus ensuring the additional genetic variation necessary to create bread wheats suited to the diverse environments and problems encountered in the region.

Figure 1 shows the movement of germplasm in the CIMMYT/ICARDA bread wheat breeding program. Segregating generations and yield trials are grown and evaluated at Tel Hadya experiment station under two kinds of management. Under one, rainfed crops are supplied with a small amount of fertilizer; under the other, crops receive supplementary irrigation and recommended quantities of fertilizer. These two forms of management make it possible to select simultaneously for high yield and yield stability.

To complement the breeding work at Tel Hadya, other stations and substations inside and outside Syria are used for multilocational testing and breeding. The material developed is distributed to cooperators in West Asia and North Africa through ICARDA/CIMMYT international and regional nurseries.

Preliminary and advanced yield trials—During the past two cropping seasons, preliminary and advanced yield trials were conducted in two locations under three different moisture levels: at Tel Hadya under rainfed conditions (about 230 mm rainfall) and supplementary irrigation (380 mm), and at Terbol in Lebanon (596 mm). In 1982-83, a few lines yielded significantly higher than the checks, Mexipak 65 and Golan; in 1983-84, a greater number of lines were superior to Mexipak 65 (Table 3). A combination of factors produced these gains. First, higher selection pressure for disease resistance, agronomic type, and yield was applied to lines promoted to preliminary and advanced yield trials; second, Mexipak 65 suffered an increased susceptibility to stripe rust. A high level of stripe rust resistance was present across the lines in preliminary and advanced trials. Superior lines were

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particularly prevalent in more favorable, irrigated environments. Under rainfed conditions in 1983-84, 25 lines yielded better than Sham 2 in the preliminary yield trials, and 13 yielded better than the check in the advanced trials.

Drought tolerance—Lines superior to Sham 2, the improved check, were identified in advanced trials conducted under conditions of low rainfall (230 mm annual precipitation) (Table 4). The highest yield was 4211 kg/ha, and one line yielded 41% more than Sham 2. Superior lines were promoted to the Crossing Block to be used as parents.

In addition to identifying advanced, drought-tolerant material, the program tested F_2 and F_3 segregating populations at Tel Hadya under conditions of limited moisture and less than optimal amounts of fertilizer. Selection criteria included seedling vigor, tillering ability, and large fertile heads. Other locations — Breda (approximately 275 mm rainfall), Khanasser (approximately 240 mm rainfall), and the late planted nursery at Tel Hadya — were used for complementary tests of this material.

Earliness in germplasm for dry environments—Early maturing, high-yielding bread wheat germplasm is essential for zones with lower rainfall, as early maturity allows the crop to escape the detrimental effects of late drought. Although early maturity is not a true genetic resistance mechanism, each day of earlier maturity in bread wheat grown under conditions of limited moisture in Syria imparts a yield advantage of approximately 54-120 kg/ha. Several advanced bread wheat lines compared to Sham 2 at Tel Hadya under rainfed conditions (230 mm) combined earliness with high yields (Table 5). These lines headed 6-8 days earlier than Sham 2, and matured about 7-10 days earlier. The program will make extensive use of these lines in next year's crossing program.

Grain characteristics and wide adaptation—Bread wheat is the principal food for most people in West Asia and North Africa, where more than 150 kg/cap/yr is consumed. Because wheat is such an important component of the diet in this area, nutritional and grain quality receive special attention in the breeding program. It is essential that quality be maintained or improved when selecting for higher yields. Lines combining acceptable levels of protein and high 1000-kernel weights with good regional adaptation were identified through the regional testing system (Table 6).

Regional Performance of Bread Wheat Lines

Bread Wheat Observation Nursery—In the 1982-83 Bread Wheat Observation Nursery (WON), 19 lines were selected from 8 or more of the 30 locations from which data were received. Agronomic data, disease data, and quality characteristics of lines selected at nine or more locations are shown in Table 7. These lines, originating from ICARDA, CIMMYT, Egypt, and Turkey, were selected visually by national program personnel for superiority to both local and long-term checks. The nursery was evaluated in a wide range of environmental and disease conditions in West Asia and North Africa and other locations throughout the world.

Regional Wheat Yield Trial—The performance of the highest-yielding lines in the 1982-83 Regional Wheat Yield Trial (RWYT) is summarized in Table 8. Grain yield and other agronomic data were compiled from 30 different locations in rainfed areas and under supplementary irrigation. The locations included two simulated environments at Tel Hadya. The average yield of the entries, excluding national checks,

Dr. Guillermo Ortiz (left), CIMMYT scientist with the CIMMYT/ICARDA Cooperative Bread Wheat Breeding Program, with two assistants at Tel Hadya Research Station.

was 4308 kg/ha, with means for individual entries ranging from 3851 kg/ha to 4862 kg/ha.

Yields of the top entries in this trial were not significantly superior to the bread wheat check, Mexipak 65. However, the first four entries in Table 8 are significantly better than the durum check, Waha. The highest-yielding line, Drira Out Cross triticale, was among the top 10 entries in 20 of 30 locations. The second highest-yielding line, HD 2206/Hork 'S', ranked among the top 10 entries at 19 locations and was superior to the national check at 15, even though it was moderately susceptible to leaf and stem rust.

The advanced line Flk 'S'/Hork 'S' ranked third and combined high yield with good yield stability. It was among the top 10 entries at 21 locations and performed better than the national check at the greatest number of locations (17). This line looks promising since the national check is usually a recommended high-yielding variety with proven adaptation at each testing location.

Pathology

Common bunt—In 1983-84, 180 lines of the Key Location Disease Nursery (KLDN), together with 60 bunt-resistant lines selected the previous year, were tested for resistance to bunt. Before planting, seed was inoculated with chlamydospores of both pathogens, *Tilletia foetica* and *T. caries*, collected from bunted heads in different locations within Syria. The average number of infected heads among all entries was very high (52.2%) and only two lines showed resistance (5% or less infected heads):

Pvn 'S'/5/Fr/K53//N108/3/Gv55 /4/Sr64/Tzpp*2/An
CM 32328-4AP-2AP-0AP-2AP-0AP

Cnr/4/Inia 'S'/7C//Cno 'S'/Gll/3/ Pci 'S'//Bb/Inia
CM 46935-2AP-0AP-4AP-2AP-0AP

Additionally, a large number of lines furnished by Dr. R.J. Metzger, USDA-Oregon State University, Corvallis (USA), were planted in the 1984 KLDN nursery for evaluation and multiplication. Some of these are known to have resistance to one or more races of bunt; others are resistant to highly virulent bunt races. A great number of the lines were collected from Turkey and from mountainous areas in Yugoslavia. Some of the Turkish lines (143) have already been screened at Pendleton, Oregon for resistance to selected races of bunt. Of the total lines screened in the KLDN, 624 showed resistance (less than 5% infected heads), and 99 showed moderate resistance (less than 10% infected heads) to common bunt.

In another nursery, 15 advanced lines and commercial varieties were tested for resistance to 12 different bunt isolates: 3 from Syria, 2 from Turkey, 1 each from Lebanon, Tunisia, and Iran, and 4 isolates with identified virulences. The nursery was harvested by hand to avoid dispersing bunt spores; evaluation was done in the laboratory. Of the 15 entries tested, 4 varieties (Nugaines, Moldova, Kirac 66, and Sham 2) were resistant to common bunt, with the least infection (0.2%) occurring in Kirac 66.

Other diseases—The 1984 KLDN, with 171 lines, was planted in 20 disease "hot spots"; useful information on stripe rust (*Puccinia striiformis*), leaf rust (*P. recondita*), and septoria leaf blotch (*Septoria tritici*) was obtained from Syria, Lebanon, Tunisia, Portugal, and Pakistan. Table 9 indicates the number of lines with resistance to these diseases.

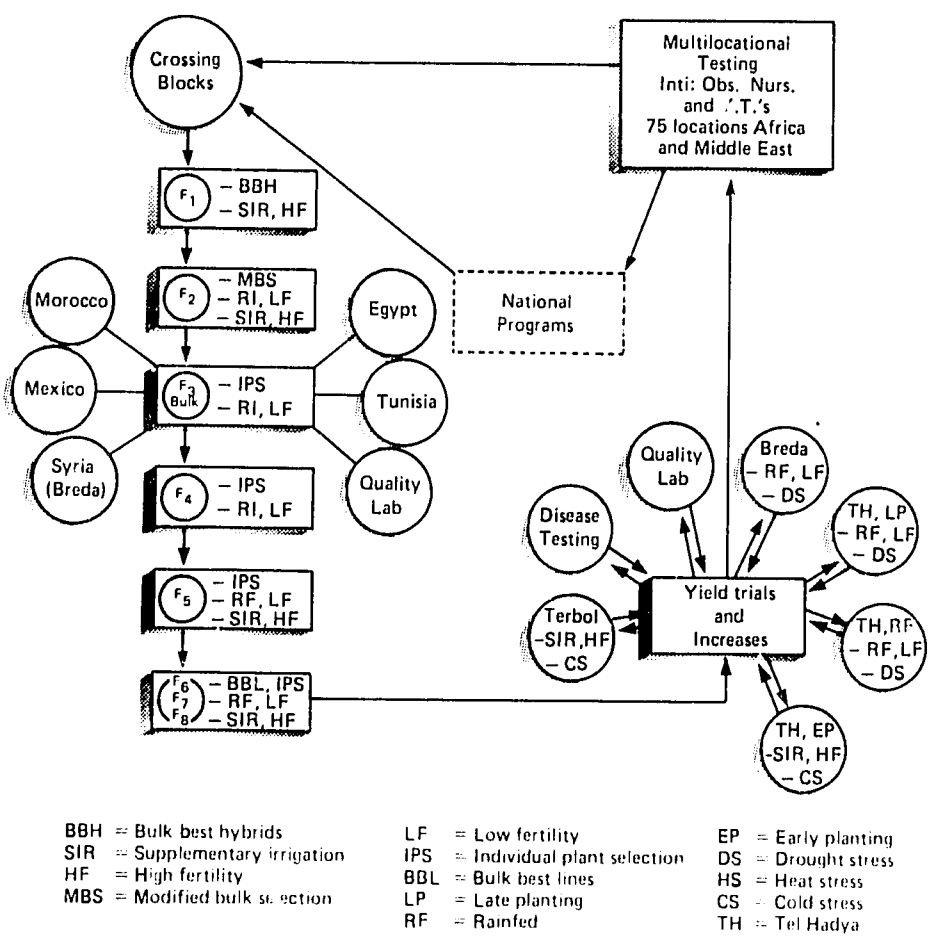

Figure 1. The breeding strategy of the Bread Wheat Program.

The severe septoria epidemic in Elvas, Portugal, resulted in only eight resistant lines. In Lattakia, Syria, the disease, although well developed on durum wheat, was negligible on bread wheat, a difference that may be due to the environment or to virulences at the two locations.

The 1984 Wheat Septoria Nursery (WST), initiated in the 1983-84 cropping season, included 50 bread wheat lines selected from preliminary screening the previous year at Afrin, Syria. The nursery was planted in Tel Hadya, Lattakia, Elvas, and Beja (Tunisia). Disease development in Tel Hadya and Lattakia was negligible and only data from Beja and Elvas were considered. Twelve lines were resistant (5 or less on a 0-9 scale) at both locations, and will be included in the WST-85 to reconfirm their resistance in multilocational trials.

Bread Wheat Grain Quality

The most important quality characteristics in bread wheat are grain hardness and gluten strength. The hardness of wheat affects flour yield, starch gas production during fermentation, and water absorption. Wheats of medium hardness produce the best milling yields, and harder wheats give much more starch. Gluten strength is the capacity of flour dough to retain gas produced during fermentation, to be elastic, and to give good texture to the bread.

Hardness and gluten strength are easily tested: hardness is evaluated by near infrared reflectance spectroscopy, and gluten strength is measured by the Pelshenke test or Farinograph.

Protein content has an important influence on wheat meal fermentation time (WMFT), and may be greatly affected by growing conditions. The WMFT is strongly correlated to farinograph stability within a growing location, but the strength of this relationship changes between locations. Excessive variability between locations is a bad characteristic; the best lines maintain gluten strength over a wide range of sites. Growing nurseries in a series of locations differing in fertility permits new genotypes to be evaluated thoroughly. Some bread wheat lines that have medium hardness and gluten strength are listed in Table 10.

Insect resistance

As in previous seasons, emphasis was placed upon screening for resistance to wheat stem sawfly, aphids, and suni bugs. Studies on the economic importance of the suni bug were terminated.

Sixty-two bread wheat lines were screened for resistance to wheat stem sawfly at Suran under natural infestation and at Tel Hadya under artificial infestation. Twenty-three of the lines tested appeared promising. Of the 62 bread wheat lines tested for resistance to aphids, only 7 were resistant. None of the bread wheat lines tested in 1983-84 were rated resistant to suni bug. Lines that seemed promising at first proved to be susceptible, and the search for resistance to this pest has been discontinued.

The effect of planting seed damaged by suni bugs was again studied at Tel Hadya to assess the economic importance of this pest. Seeds were classified in damage grades: 0 = saved seeds (check); 1 = average of 1/3 of each grain affected; 2 = average of 2/3 of each grain affected; and 3 = entire grain affected. Increasing percentages of affected seeds of each damage grade were mixed with sound seeds and then planted. The results indicated that planting seed damaged by suni bugs always affected the final yield (Table 11), reducing germination significantly (up to 85%) and reducing plant vigor at different growth stages.

References

FAO. 1984. Monthly Bulletin of Statistics 7:3.

Table 1. Bread wheat and durum wheat production compared with total wheat production in the ICARDA region, 1969-71, 1979-81, and 1983

	Production (1000 t)		
	1969-71	1979-81	1983
Total wheat	31.8	45.1	47.8
Bread wheat	23.3	34.8	37.1
Durum wheat	2.3	10.3	10.7
Percentage bread wheat	73.7	77.2	77.7
Percentage durum wheat	26.3	22.8	22.3[a]

Source: FAO Monthly Bulletin of Statistics, v.7, March 1984

[a] Estimate

Table 2. Summary of bread wheat germplasm grown at Tel Hadya, 1980-84

Type of nursery	Number of lines			
	1980-81	1981-82	1982-83	1983-84
Yield trials	2970	1440	1606	1416
Regional wheat yield trials	24	24	24	24
International yield trials	110	186	186	134
Regional nurseries (ICARDA/CIMMYT)	1264	1335	1077	1349
International nurseries	1700	2259	1286	1187
Seg. population F_2	2222	2000	1655	1287
Seg. populations F_3-F_8	8870	7420	8317	4211
F_2 populations	853	1336	423	525
Total ICARDA/CIMMYT material	14781 (82%)	11997 (75%)	11545 (79%)	8002 (79%)
Total material from outside Syria	3232	4003	3023	2131
Grand total	18013	16000	14568	10133

Table 3. Number of lines yielding significantly higher ($p<0.05$) than the local check, Mexipak 65, and improved checks, Golan and Sham 2, in the 1982-83 and 1983-84 yield trials

Location/trial	Average yield (kg/ha)		No. of lines tested		No. of lines yielding higher than Mexipak		No. of lines yielding higher than Golan and Sham 2	
	1982-83	1983-84	1982-83	1983-84	1982-83	1983-84	1982-83	1983-84
Tel Hadya RF[a]								
PWYT	3592	3661	858	528	9	228	8	25
AWYT	4137	4196	176	144	0	45	7	13
Tel Hadya SIR								
PWYT	4928	4713	396	456	9	245	30	89
AWYT	5266	4949	176	144	17	95	7	49
Terbol IRR								
AWYT	5495	6282	176	144	0	10	15	50

[a] RF = Rainfed (230 mm); SIR = Supplementary Irrigation (380 mm); IRR = Irrigation (596 mm); PWYT = Preliminary Wheat Yield Trials; AWYT = Advanced Wheat Yield Trials

Table 4. Lines that yielded best under low rainfall conditions (230 mm) compared to improved check Sham 2, Advanced Wheat Yield Trial (AWYT), Syria, 1983-84

Cross and pedigree	Yield (kg/ha)	% of Sham 2	LSD (5%)	CV (%)
Flk 'S'/Hork 'S' CM39816-1S-1AP-0AP	4211	120	502	8.8
II 58-57/4/Maya/Cgn/3/CC/Inia//Cal CM40742-27M-1Y-2M-3Y-3M-1Y-08	4144	120	576	10.8
Crow 'S' CM40457-5M-3Y-2M-2Y-0M	3894	121	673	12.9
Pvn 'S'/Sprw 'S' CM46702-2AP-0AP-2AP-1AP-0AP	3755	141	579	11.5
Pco/Pvn 'S' CM46710-1AP-1AP-1AP-1AP-0AP	3588	135	579	11.5

Table 5. Advanced bread wheat lines combining earliness with high yield potential compared with the improved check, Sham 2, at Tel Hadya under rainfed conditions (230 mm), 1983-84

Cross and pedigree	Days to heading		Days to maturity		Yield (kg/ha)[a]		Relative (%)
	Line	Sham 2	Line	Sham 2	Line	Sham 2	
Arz/Sa 42 ICW 77162-K-1AP-1AP-4AP-2AP-0AP	126	134	168	176	3144(1)[b]	3522	89
Chr/5/Tp/Cno/Inia/3/Sr/4/Hork CM46934-2AP-0AP-1AP-1AP-0AP	129	136	168	178	3027(1)	2655	114
Pvn 'S'/Oln CM46693-1AP-1AP-4AP-1AP-0AP	130	136	168	178	3372(2)	2655	127
Pri 'S' CM25988-8Y-3Y-2Y-1M-1Y-0B	127	133	170	177	3050(1)	3277	93
Cmh 72-428/Mrc/Flk 'S' CM46869-2AP-0AP-2AP-1AP-0AP	128	136	170	178	2872(1)	2655	108
Bjy 'S' CM5287-J-1Y-2M-2Y-3M-0Y	129	133	170	177	3272(1)	3277	100
Crow 'S' CM40457-5M-3Y-2M-2Y-0M	129	136	170	176	3894(2)	3205	122

a The LSDs (5%) for comparing mean yield of these lines with their respective checks are: 502, 579, 579, 788,579,788, and 673 kg/ha, respectively
b 1 = Not significantly different; 2 = Significantly different

Table 6. Lines combining acceptable protein content and 1000-kernel weight with good regional adaptation; Wheat Observation Nursery (WON), 1982-83 (20 locations)

Cross and pedigree	Protein[a] (%)	1000-kernel weight[a] (g)	No. locations where entry selected[b]
Sakha 18//Cno/Cal/4/Sakha/3/Tzpp//Sn64/Napo S2896-100-1S-3S-0S	13.6	49.6	11
Cno/Gll//3b/Inia CM21840-5S-9S-0S	15.1	49.7	8
Ana/Mon 'S' CM51743-S-2714-1GM-2GM-0GM	15.4	48.9	8
Sprw 'S'/Bch 'S' CM35216-35M-1Y-2GM-0GM	14.2	48.8	7
L 2451.134.611/Pvn 'S'/Vcm/3/Cno/7C CG3049-1Gm-1Gm-0Gm	15.2	47.2	6
Sakha 14/5/Inia//Tob/Napo/3/Cno/SI0B3/4/Mab S2377-200-1S-2S-0S	14.3	47.2	6
Mexipak 65 (regional check)	12.9	40.2	5

a Data from two locations
b Number of locations where the entry was selected as promising, based on visual evaluation of agronomic type and disease resistance

Table 7. Agronomic and disease data of the most frequently selected lines in the Wheat Observation Nursery (WON), 1982-83 (30 locations)

Variety and cross and pedigree	No. locations where entry selected[a]	Days to heading	Days to maturity	Height (cm)	Protein (%)	1000-kernel weight (g)	Average coefficient of infection		
							Stripe rust	Stem rust	Leaf rust
Bb/2*7C//Y50E/3*Kal CM29014-7S-2AP-1AP-4AP-0AP	11	103	152	93	13.0	41.5	5	3	10
Sakha 18//Cno/Cal/4/Sakha/3/Tzpp//Sn64/Napo S.2896-100-1S-3S-0S	11	97	146	89	13.6	49.6	18	0	11
Snb 'S' CM34630-D-3M-3Y-1M-1Y-0M	9	108	153	87	12.7	41.9	10	0	2
7C/Pvn 'S' CM36596-8Y-1M-1Y-2M-0Y	9	102	150	88	14.5	43.5	5	0	2
Gv/Ald 'S' L.0882-1AP-0AP-2AP-0AP	9	105	152	88	14.5	44.9	8	0	0
Sakha 69	9	99	146	89	12.5	47.1	22	4	17
Mexipak 65	5	102	149	87	12.9	40.2	36	29	45

[a] Number of locations where the entry was selected as promising, based on visual evaluation of agronomic type and disease resistance

Table 8. Performance of highest yielding lines in the Regional Wheat Yield Trial (RWYT) at 30 locations, 1982-83

Variety or cross and pedigree	Yield (kg/ha)	CHK[a]	SEL[b]	Days to maturity	Height (cm)	Protein (%)	1000-kernel weight (g)
Drira Out Cross (triticale) X21295-0AP	4862	16	20	158	115	11.1	46.4
HD 2206/Hork 'S' CM39808-62M-1Y-1M-0Y	4845	15	19	159	86	11.7	33.3
Flk 'S'/Hork 'S' CM39816-1S-1AP-0AP	4832	17	21	159	80	11.8	35.1
Inia/Napo//3*Cal/3/Cj/4/Kpk NCP 212-A-1K-3AP-0AP	4815	16	17	158	88	12.0	31.2
Mexipak 65 (bread wheat check)	4518	14	12	158	89	11.6	34.1
Waha (durum wheat check)	4256	8	10	158	84	12.8	41.0
Overall mean	4308						
LSD (5%)	488						
CV (%)	14						

[a] CHK = Number of locations where line was superior to national check
[b] SEL = Number of locations where lines were among the 10 highest yielding entries

Table 9. Number of lines resistant to stripe rust, leaf rust, and septoria leaf blotch in different locations of the 1984 Key Location Disease Nursery (KLDN)

Disease	Syria			Lebanon	Tunisia	Portugal	Pakistan	Resistant all locations	
	Tel Hadya	Lattakia	El Ghab					No.	(%)
Stripe rust[a]	72		92	81		125		47	27
Leaf rust[a]		91				159	44	42	25
Septoria leaf blotch[a]					58	24		13	8

[a] Selection criteria:
Rust: less than 5% severity
Septoria: 5 or less on 0-9 scale

Table 10. High-yielding bread wheat lines selected for suitable milling and baking quality

Variety or cross and pedigree	Potential size index[a] (%)	Wheat meal fermentation time[b] (min)	1000-kernel weight (g)	Protein (%)
Maya 74 'S'/Nr-Resel CM40691-3KE-1AP-0AP-3AP-1AP-0AP	50	191	33.7	15.6
II 58-5714/Maya 74 'S'// Cgn/3/CC/Inia//Cal CM40742-27M-1Y-2M-3Y-3M-1Y-0B	50	193	35.4	16.9
Yr/Pam 'S' CM46091-4M-1Y-5M-0Y	52	184	37.4	15.0
Kvz//Cno/Pj SWM 1285-2Y-3M-1Y-0M	52	179	36.1	13.2
Ymh/Ald 'S' SWM 3142-8L-4AP-0AP-1AP-0AP	53	153	35.7	14.9
Ymh/Ald 'S' SWM 3142-8L-4AP-0AP-2AP-0AP	50	179	35.2	15.1

[a] 40 is very hard, 70 is very soft
[b] 30 is very weak, 200+ is very strong; 120-180 is suitable for baking flat bread

Table 11. Percent yield losses incurred by planting Mexipak bread wheat seed damaged by suni bugs

Suni bug damage grade[a]	% Infected seeds in the mixture[b]		
	50%	100%	Mean
1	17.6	28.1	22.8
2	26.3	32.8	29.0
3	29.0	38.4	33.7
Mean	24.0	33.1	28.5

[a] 1 = Average 1/3 of each grain affected
2 = Average 2/3 of each grain affected
3 = Entire grain affected
[b] Increasing percentages of affected seed of each damage grade mixed with sound seed and planted

LSD 5% for suni bug damage grades = 8.0
LSD % for percent seeds in the mixture = 5.1

CIMMYT/ICARDA Cooperative Durum Wheat Improvement Program

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Introduction

In 1984, CIMMYT and ICARDA established a joint durum wheat program with the aim of developing complementary durum wheat research at both institutions, coordinating germplasm distribution, and working closely with national programs. An account of these activities also appears in the ICARDA *Annual Report*, 1984.

The central objectives of the Aleppo-based program are to:

- Improve yield and stability of durum wheat in rainfed areas;
- Incorporate resistance to stripe rust, stem rust, leaf rust, septoria leaf blotch, common bunt, and other diseases prevalent in West Asia and North Africa;
- Improve resistance to such insect pests as wheat stem sawfly, suni bug, Hessian fly, and aphids;
- Maintain and improve grain quality characteristics; and
- Encourage national programs to develop agronomic practices for improving durum wheat production in the West Asian and North African region.

Threshing wheat in Morocco, one of the many North African and West Asian countries in which the CIMMYT/ICARDA durum wheat program works.

Breeding

The area of land planted to durum wheat in West Asia and North Africa is approximately 8.6 million hectares, some 45% of the total land area devoted to durum wheat cultivation in the world. Nearly 98% of the durum wheat produced in the region is grown under rainfed conditions. About 3.7 million hectares of land are planted to durum wheat in the high-rainfall zones (over 400 mm), 4.7 million hectares in the low-rainfall zones (less than 400 mm), and 0.2 million hectares in irrigated areas.

The average regional yield of durum wheat is 1000 kg/ha in high-rainfall areas and 600 kg/ha in low-rainfall areas; both averages are about 30% less than average bread wheat yields in the region.

Germplasm development—To produce germplasm suitable for rainfed areas in West Asia and North Africa, a program was established to develop durum wheats tolerant of or resistant to environmental stresses, diseases, and insects. The program also aims to develop germplasm that performs well under favorable growing conditions. Potential parental material is evaluated at sites in North Africa and the Middle East. After superior parental lines are combined, early-generation populations are exposed to various stresses. Plants are selected in the following environments:

- Tel Hadya, rainfed (230-370 mm annual precipitation, 40 kg N/ha, and 60 kg P_2O_5/ha);

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- Tel Hadya, early planting with supplementary irrigation (approximately 450 mm precipitation simulated, 100 kg N/ha, and 60 kg P_2O_5/ha);
- Breda (160-270 mm annual precipitation, 20 kg N/ha, and 30 kg P_2O_5/ha for droughty conditions); and
- Tel Hadya, late planting (40 kg N/ha and 60 kg P_2O_5/ha).

Segregating populations—Each segregating family is planted in two different environments at Tel Hadya: 1) relatively favorable conditions (early planting and irrigation), and 2) rainfed conditions.

Selection in the relatively high-input environment during 1983-84 was affected by a high incidence of stripe rust. In the rainfed environment, drought influenced selection: precipitation in the 1983-84 season was only two-thirds (230 mm) of the amount received in an average year in northern Syria. Wheat stem sawfly was endemic in the rainfed nurseries. Selections were made for heat (late planting) and drought tolerance.

Durum Wheat Observation Nursery—Promising advanced lines in the Regional Durum Wheat Observation Nursery (DON) are subjected to preliminary screening at national program testing sites. Selected data from the 31 sites of the 1982-83 DON are reported in Table 1.

Tan spot and barley yellow dwarf virus (BYDV) were the major constraints to grain yield throughout the region, but most of the advanced germplasm also needs additional resistance to leaf, stem, and stripe rusts.

Earliness was associated with higher yields and prevented plants from being attacked by such diseases as stem rust. However, early-heading durum wheat lines suffered more damage from powdery mildew, *Septoria tritici*, and *Helminthosporium tritici repentis* than late-heading types.

Regional yield trials—Two kinds of regional durum yield trials, comprising lines that performed best in the DON, were distributed in 1982-83. The Regional Durum Yield Trial (RDYT) is intended for favorable environments, and the Regional Rainfed Durum Yield Trial (RFDYT) is for rainfed areas in the Mediterranean region. Yield data were received from 17 locations for the RDYT and 16 for the RFDYT. Yield performance and other important characteristics of the two best lines are summarized for each trial in Tables 2 and 3.

Two durum wheat lines from the RDYT, Mallard and Oum Rabia, were selected for their yield performance for the second consecutive year. Both entries head and mature early. Out of 24 entries tested in the RFDYT, 2 lines — Cr'S'/Stk'S' = Belikh and Rabi/PI-94587//Cit/3/Mexi/Valn = Po — were the highest yielding entries for the second year.

Preliminary yield trials—Selected lines from F_5 and later segregating generations enter the yield testing phase when they become homozygous for such important phenotypic characters as height, disease resistance, and chaff color. The first replicated testing of these lines occurs in the Preliminary Durum Yield Trials (PDYT).

In the 1983-84 PDYT, 14 yield trials were conducted under supplementary irrigation and rainfed conditions at Tel Hadya. Each trial consisted of 21 entries and 3 checks (Stork, Sahl, and Haurani). Table 4 lists the highest yielding lines in the 1983-84 PDYT, giving their yield percentage over Stork and Sahl under both growing conditions. Based on their yield performance in both environments and on their disease resistance, grain quality, and maturity, the best lines were promoted for further evaluation in the Advanced Durum Yield Trial (ADYT).

Advanced Yield Testing

Lines found promising after preliminary testing are included in the advanced testing program, in which they are yield tested in contrasting environments, screened for resistance to diseases and insects at "hot spots" in the region, evaluated for stress tolerance to frost, drought, and heat, and tested for quality characteristics.

During 1983-84, Stork was an excellent check in advanced tests for rainfed as well as high-input environments. The highest yielding durum lines under these different environmental conditions are shown in Table 5. The good performance of these lines across contrasting environments may be the result of their earliness.

Environmental Stress Tolerance

Drought tolerance—The 399 durum wheat lines that constituted the ADYT were evaluated visually for drought tolerance in 1983-84 at locations with different amounts of rainfall, including Tel Hadya under supplementary irrigation (approximately 450 mm) and rainfed conditions (230 mm), Breda (approximately 160 mm), early planting (mid-October,450 mm), late planting (February, 300 mm), and Terbol (Lebanon) (approximately 500 mm). Forty-five lines were selected at Breda, and these lines differed markedly in number of days to heading.

Among the 399 advanced lines, 17 were classified as early heading; of these, 4 lines similar to Stork in maturity were selected at Breda for drought tolerance. However, the number of selected lines with heading dates similar to those of Haurani and Gezira 17 was higher than the number with heading dates similar to Stork (Table 6). These results confirm that screening for

drought tolerance at Breda was affected by low temperatures, particularly during the vegetative growth stage, which favored the selection of medium-late to late genotypes similar to Haurani and Gezira 17. More attention has to be given to developing early, drought-tolerant lines suited to other environmental conditions within the region. Under such conditions, earliness is an important factor for attaining high and consistent yields, and the effect of low temperatures during the vegetative stage is insignificant. Table 7 shows the average yield range of advanced durum wheat lines with different heading dates.

Heat tolerance—For the past five years at Tel Hadya, grain yield has been related to precipitation and temperature during different growth stages of durum wheat. The importance of each of these factors is clearly demonstrated in Table 8. Precipitation during the growing season influenced yield most, followed by precipitation during the early stages of plant development. The number of days of rainfall during the vegetative stage was also important for final grain yield.

Mean temperature was negatively correlated with yield, especially during the grain-filling stage: the higher the temperature, the lower was the yield. The minimum temperature during the early stages of plant establishment and development had a positive effect on final grain yield.

Pathology

Common bunt—In the 1983-84 Common Bunt Nursery I, 670 lines were tested, including 520 from the 1984 KLDN. Before planting, seed was inoculated with spores of *Tilletia foetida* and *T. caries* collected from bunted heads in different locations within Syria. Average infection for all entries was 29.4%, and 10 lines had good resistance (less than 5% infected heads) to the disease (Table 9). These lines will be tested again next season.

In Common Bunt Nursery II, 11 advanced lines and commercial varieties were tested for resistance to 12 different bunt isolates: 3 from Syria, 2 from Turkey, 1 each from Lebanon, Tunisia, and Iran, and 4 isolates with identified virulences. The nursery was harvested by hand and evaluated in the laboratory. Haurani and Stork had good resistance (less than 5% infected heads) to all isolates used.

Septoria leaf blotch—The Durum Septoria Nursery (DST-84), initiated in the 1983-84 cropping season, included 150 durum lines selected during 1982-83 at Afrin, Syria. The nursery was planted in Tel Hadya and Lattakia (Syria), Beja (Tunisia), and Elvas (Portugal). At each site, artificial inoculation was accomplished with isolates of *Septoria tritici* prevalent in the country. Lines with the best resistance are listed in Table 10.

Screening advanced breeding material—The 1984 KLDN included lines from the advanced yield trials: 243 of those lines had been tested in the 1983 KLDN. This nursery was planted in 20 disease "hot spot" locations and data on stripe rust (*Puccinia striiformis*), leaf rust (*P. recondita*), septoria leaf blotch (*Septoria tritici*), and barley yellow dwarf virus (BYDV) were obtained from Tel Hadya, Lattakia, and El Ghab in Syria; Terbol, Lebanon; Taiz, Yemen; Beja, Tunisia; Elvas, Portugal; and Montreal, Canada.

Table 11 presents the number of lines resistant to these diseases at different locations over two years. In 1983 and 1984 in Tel Hadya and Terbol, similar numbers of lines (68 and 66) were resistant to stripe rust. In all locations tested and over both years, 34 lines (14% of the lines scored) proved to be resistant to stripe rust.

Numerous lines were resistant to leaf rust in 1984 at Tel Hadya, Lattakia, Terbol, and Elvas: 367, 94, 475, and 391 lines, respectively. Over all locations in 1984, 82 lines were resistant, but when data from 1983 and 1984 are considered, only 1 line was resistant at all locations. For better screening, a set of the KLDN will be planted late at Tel Hadya and Terbol during the next season.

Data on septoria leaf blotch were obtained from Tel Hadya, Lattakia, El Ghab, Beja, and Elvas, where 63, 30, 34, 57, and 462 lines, respectively, showed resistance to the disease. Over all locations and for both years of screening, however, no single line showed complete resistance. To improve the level of disease resistance, the Durum Septoria Nursery was initiated in 1983-84 and planted in three septoria "hot spots."

Information on BYDV was available from Beja and Elvas. A good number of lines (158) showed resistance to the disease at both locations.

Nitrogen Application: A Strategy

Durum wheat is grown under conditions in which modest responses to nitrogen fertilizer are obtained. The magnitude of the grain yield response to applied nitrogen is likely to vary in the 250-350 mm rainfall zone, the most important durum wheat-producing area in West Asia and North Africa. The risk of using nitrogen fertilizer for durum wheat production in this zone is quite high.

Cereal productivity in the region is relatively low, and the gap between farmers' yields and yields obtained on research stations has been estimated to range from 53% to 74% in durum wheat (Fifth Cereals Workshop, Algiers, Algeria, May 5-9, 1979). Unimproved varieties, low levels of fertilizer, and poor weed control are among the main reasons for this difference.

Apart from the scarcity of capital for obtaining improved inputs and the occasional unavailability of the inputs themselves, the risk associated with climatic uncertainity is often the paramount factor influencing farmers' decisions. One means of minimizing this risk is to use split applications of nitrogen fertilizer. Some nitrogen may be applied at sowing, and the remainder applied in the spring at tillering, when seasonal conditions and prospects for the crop's development can be better assessed. In some cases, no nitrogen is applied at sowing and the entire amount is applied at tillering. Splitting nitrogen applications reduces or delays the expenditure for a relatively costly, risky input.

During the 1983-84 season, an experiment on rates and timing of nitrogen application was conducted. The aim of this trial was to study the effect of nitrogen on durum wheat by applying it at different rates during sowing and tillering. Five rates of nitrogen, applied at sowing and tillering in all possible combinations of rate and timing, were applied to Sham 1 durum wheat grown under rainfed conditions (Sham 1 is newly released in Syria). There was no significant difference in grain yield for applications made at the sowing and tillering stages. The difference was not significant when nitrogen was applied at different rates (Table 12), and the interaction between rate and timing of application also showed no significant difference, results that confirm data from previous years. This lack of response to nitrogen may have been due to drought during the vegetative growth of the crop in 1983-84.

Grain Quality

Durum wheat quality is affected both by season and site. Figure 1 shows the variation in different quality parameters from wheat grown at different sites in Syria. Protein content was the parameter most affected; 1000-kernel weight and sedimentation showed insignificant variation across sites. As expected, protein content and percentage vitreousness were reduced at wetter sites.

Gluten strength—The SDS sedimentation test gives an estimate of the gluten strength of wheat, and results depend on the protein content of the wheat tested. Very low SDS levels were recorded for lines grown in areas that produced grain with low protein content; this relationship was particularly apparent in grain grown under irrigated conditions. Differences in quality parameters were noticeable from location to location, even in material grown under irrigation.

Yellow pigment content—The yellow or amber color of durum wheat is caused by carotenoid pigments, mainly xanthophyll. The higher the grain pigment content, the better the grain is suited for export and for making burghul, semolina, and pasta. For khobz bread, durum lines with lower pigment content are acceptable. The pigment content of entries in several yield trials is presented in Table 13.

Resistance to insect pests

At Suran, Syria, the resistance of 99 durum wheat lines to wheat stem sawfly was assessed under natural infestation, and at Tel Hadya under artificial infestation. Thirty-two lines were rated resistant. The resistance of 99 durum lines to suni bug was tested at Tel Hadya under artificial infestation and at A'azaz under natural infestation. Four lines were found to be resistant.

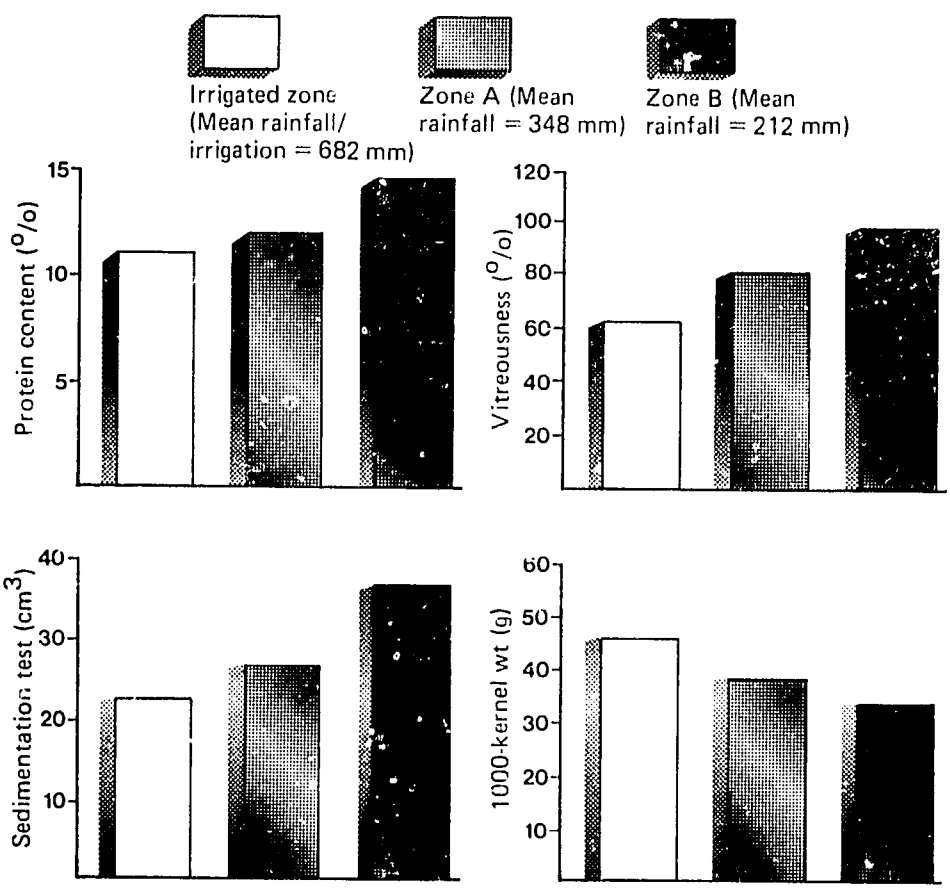

Figure 1. Differences in four quality parameters of durum wheat over three rainfall zones, 1983-84

Table 1. Agronomic and disease data of the most frequently selected lines (14 or more sites) in the Regional Durum Wheat Observation Nursery (DON), 1982-83

Line	Days to heading	Average coefficent of infection[a]			*Septoria tritici*[b]	Powdery mildew[b]	Tan spot[b]	BYDV[b]
		STR	LR	SR				
Cr 'S'/T.D.Vern//Gll 'S'	122	23	5	11	5	5	2	1
Win 'S'/USA.02237//Gad 'S'	125	19	4	19	4	5	2	1
Rabi 'S'/3/Ld 390//Gelle/Tc60	126	12	0	0	4	7	1	1
Fg 'S'/Jo 'S'/3/Gu 'S'// 61-130/Lds	119	6	4	1	5	4	2	1
Shwa//Magh 'S'/Bit	120	10	3	10	3	5	1	2
Duro3/Ibis 'S'//1150/KR569	119	12	3	8	4	7	2	1
USA.0640/Fg//Fg/Ruff	122	7	1	3	4	7	2	3
Waha (regional check)	119	2	3	3	5	5	3	2
Sahl (regional check)	121	1	1	8	5	7	3	1

[a] Lower numbers indicate resistance and low disease severity at the sites used, 0-100 scale; STR = stripe rust; LR = leaf rust; SR = stem rust

[b] Resistance scored on a 0 (resistant) to 9 (susceptible) scale

Table 2. Performance of highest yielding entries and variety Sham 1 in the Regional Durum Yield Trial (RDYT), 1981-82 and 1982-83

Entry	1981-82[a] Yield (kg/ha)	1981-82[a] Rank	1982-83[b] Yield (kg/ha)	1982-83[b] Rank	Yield (% Sham 1)	Heading date	Maturity date	Protein (%)	Vitreousness (%)	1000-kernel weight (kg/hl)
H505-71A/Bgl2 (triticale)	—	—	4638	1	104	116	162	13.1	n.a	34.9
Stk 'S'//Chap/ 21563/Mal 'S'	4627	3	4600	2	103	119	163	14.5	99	36.6
Oum Rabia	4697	2	4544	3	102	118	163	14.7	99	38.1
Sham 1 (regional check)	4772	1	4456	7	100	120	164	14.8	99	37.0
Nursery mean	4377		4261		95					
LSD (5%)	200		237							
CV (%)	16		17							
Observations per mean	4									

[a] 23 locations
[b] 17 locations

Table 3. Performance of highest yielding entries and variety Sahl in the Regional Rainfed Durum Yield Trial (RFDYT), 1981-82 and 1982-83

Entry	1981-82[a] Yield (kg/ha)	1981-82[a] Rank	1982-83[b] Yield (kg/ha)	1982-83[b] Rank	Yield (% Sahl)	Heading date	Maturity date	Protein (%)	Vitreousness (%)	1000-kernel weight (kg/hl)
J11089 (triticale)	—	—	4386*	1	116	115	159	15.1	n.a	40.6
Cr 'S'/Stk 'S' = Beilikh	3759	2	4222*	2	111	119	160	14.1	98	38.6
Ral : PI-94587// Cit/3/Mexi/4/ Valn/Po	3710	4	4192*	3	111	126	161	14.2	99	40.8
Sahl (regional check)	3579	11	3791	15	100	118	158	13.6	100	38.9
Nursery mean	3562		3852							
LSD (%)	192		209							
CV (5%)	17		15							
Observations per mean	4									

[a] 23 locations
[b] 17 locations
* Significant at 5% level

Table 4. Durum wheat lines that yielded significantly ($P < 0.05$) better than Stork and Sahl under rainfed conditions, and yielded well under high input management in Preliminary Durum Yield Trials (PDYT), Tel Hadya, 1983-84

Cross and pedigree	Rainfed yield (kg/ha)	% of Stork	Irrigated yield (kg/ha)	% of Sahl
Pg//Ch/21563/3/Rabi/Fg ICD78-0362-4AP-3AP-6AP-0AP	4477*	129	5422	110
Stk//Ch/21563/3/AA//Fg ICD78-0415-2AP-2AP-2AP-0AP	4366*	122	5283	116
Plc/CII//Jo/RD119/3/Oyca ICD78-0623-4AP-4AP-2AP-0AP	4288*	120	5450*	121
Rabi/Fg//GdoVZ579/3/Bit CD26109-0AP-2TR-1AP 1AP-0AP	4033*	119	5077	98

* Significant at 5% level

Table 5. Advanced durum wheat lines with high yielding ability and stability, Tel Hadya, 1983-84

	Yield								
	Rainfed		Early planting		Supplementary irrigation		Terbol, Lebanon		
Entry name	(kg/ha)	% of Stork	(kg/ha)	% of Stork	(kg/ha)	% of Stork	(kg/ha)	% of Stork	Heading date
ADYT 711 Shwa//21563/AA/3/Bit	3511	118	5588	167	4988	113	6484	103	142
ADYT 713 Ovi/Cp//Cando	3411	115	5666	169	4838	110	5894	94	155
ADYT 716 Shwa/Mexi75//Bit	3416	125	5455	163	5300	121	5883	94	143
Stork	2955	100	4333	1000	4383	100	6255	100	135
LSD (5%)	598		577		943		1058		
CV (%)	12.2		10.8		12.7		11.1		

Table 6. Relationship between different ranges of heading dates and drought tolerance in advanced durum wheat lines, Breda, 1983-84

Earliness group	Range of days to heading	No. of entries	No. of entries selected at Breda
Stork	135-138	17	4
Waha	139-147	122	8
Haurani	148-155	175	15
Gizera 17	156-163	85	19

Table 7. Mean yield of some advanced durum wheats having different ranges of heading dates

Earliness group	Range of days to heading	Yield (kg/ha)		No. of lines
		Mean	Range	
Stork	135-138	3756	3011-4533	17
Waha	136-147	3672	2294-4600	122
Haurani	148-155	3488	2111-4450	175
Gezira 17	156-163	3392	2033-4672	85

Table 8. Correlation between grain yield of durum wheat lines and rainfall and temperature at different growth stages, Tel Hadya rainfed yield trials, 1978-83

Factor	Seedling stage	Vegetative stage	Reproductive stage	Seasonal average
Precipitation				
Amount	+0.78*	+0.57	+0.96***	+0.65
No. of days	+0.66	+0.82*	+0.76*	+0.74*
Temp (°C)				
Mean	+0.21	-0.63	-0.92**	-0.66
Mean min. temp.	+0.78*	-0.69	-0.91**	-0.70
Mean max. temp.	+0.39	-0.54	-0.86*	-0.52

Table 9. Material with resistance (<5% infected heads) to common bunt (*Tilletia foetida* and *T. caries*), Tel Hadya, 1983-84

Cultivar or cross and pedigree	% Infected heads[a]
Ch/21563//Cr 'S'/3/Gediz ICD77-0085-2AP-1AP-0AP	1
Cr 'S'/3/21563//61-130/Ld/4/Ente 'S' ICD78-0029-2AP-4AP-0AP	5
Gediz 75/Bit 'S' CD26820-1AP-1AP-0AP	5
Shwa/Pt1 'S' CD 20632-2AP-2AP-3AP-0AP	5
Ovi/Cp//Cando ICD78-0001-7AP-2AP-2AP-0AP	5
W-2057	5
GdoVZ 469/Plc 'S'//Jo ICD77-0027-4AP-2SH-1AP-0AP	5
Ato 'S'/D-10 ICD77-0080-8AP-6SH-2TL-0AP	0
Cit 'S'/GdoVZ 579 ICD74-0105-4L-1AP-2AP-1AP-0SH-0AP	5
Haurani	1

[a] Inoculum density: 2.2 x 10^5 spores/seed

Table 10. Lines resistant to *Septoria tritici*, Durum Septoria Nursery (DST), 1984

Variety or cross and pedigree	Origin DST-84
Shwa 'S'/Bit 'S' CD20626-5M-4Y-2Y-0Y	1
Pg 'S'/3/Gll 'S'//T.D.Vern/Gll 'S' L0532-1L-2AP-1AP-0AP	15
Gs 'S'/Aa 'S'//Plc 'S'/3/Cit71 L0576-2L-1AP-2AP-0AP	19
Snipe 'S'//Amarelejo/Haynaldia ICD77-0216-1AP-0AP	33
ZF/Lds//Kobak2916/3/61-130/4/ Stk 'S'/Fg 'S' ICD77-0233-2AP-2AP-0AP	34
Jo 'S'/Cr 'S'/5/Gll 'S'/4/Br 180/ LK//GZ220/3/21563/Aa 'S' ICD77-0045-4AP-0SH	50
Algerian 83/Mexi75 CD32954-2TR-1AP-0AP-0SH	112
GdoVZ 385/Gs 'S'/4/D.dwarf S15// T.D.Vernum/Gll 'S'/3/Plc 'S' ICD77-0134-4AP-1AP-4AP-0AP-0SH	113
Riccya (Winter)-1149 YE023-26-1-1-4-0E	136
PI 29847	141
Ente 'S'/Stk 'S' CD08153-12M-3Y-3M-1Y-0M	146
Reichenbachi/BD 1645 FAO25.190	147

Glossary

AARI: Ayub Agricultural Research Institute, Faisalabad, Pakistan
ACWYT: African Cooperative Wheat Yield Trial
ADYT: Advanced Durum Yield Trial
ALSN: Aluminum Screening Nursery
APHIS: Animal and Plant Health Inspection Service, USDA
ARM: Aluminum Resistant Material
ASN: Aluminum Screening Nursery
AVT: Advanced Variety Trial, Zimbabwe
AWYT: Advanced Wheat Yield Trial
BARI: Bangladesh Agricultural Research Institute
BC: backcross, i.e., a cross between an F_1 and one of its parents; BCI, BCII, etc., refer to the first, second, etc. backcross generations, in which the progeny of the previous generation is again crossed with the same parent
BID: Interamerican Development Bank (Banco Interamericano de Desarrollo)
BPI: Bureau of Plant Industry, the Philippines
bulked: bulk-harvested
bulk-harvested: a mixture of seed harvested from more than one plant, e.g., an entire line or population (vs. individually harvested); also applied to mixtures of different races or collections of pathogen spores
BYD: barley yellow dwarf, a viral disease of a large number of grasses, including most cereals
BYDV: barley yellow dwarf virus
CB: Crossing Block
CDRI: Cereal Disease Research Institute, Pakistan
CIANO: the Yaqui Valley Agricultural Experiment Station (Campo Agricola Experimental Valle del Yaqui) of the Northwestern Agricultural Research Center (Centro de Investigaciones Agricolas del Noroeste), administered by the National Institute of Agricultural Research (INIA); 39 m elevation, 27°N latitude
CIAT: International Center for Tropical Agriculture (Centro Internacional de Agricultura Tropical), Cali, Colombia; also the Tropical Agricultural Research Center (Centro de Investigación Agricola Tropical), Bolivia
CPAC: Centro de Pesquisa Agropecuária do Cerrados, EMBRAPA, Brazil
Culiacan: experiment station administered by the National Institute of Agricultural Research (INIA); 53 m elevation, 24°N latitude
CV: coefficient of variation
cv: cultivar
DMRT: Duncan's Multiple Range Test of statistical significance
DON: Durum Wheat Observation Nursery
DRSS: Department of Research and Specialist Services, Ministry for Agriculture, Zimbabwe
DST: Durum Septoria Nursery
EDYT: Elite Durum Yield Trial
EEZON: Elite Yield Trial for the Northern Zone (Ensayo Elite de la Zona Norte)
El Batan: experiment station and CIMMYT headquarters; 2249 m elevation, 19°N latitude
ELISA: enzyme-linked immunosorbent assay
EMBRAPA: Brazilian Agency for Agricultural Research (Empresa Brasileira de Pesquisa Agropecuária)
ENMP: National Plant Breeding Station (Estação Nacional de Melhoramento de Plantas), Elvas, Portugal
ERCA: Andean Barley Yield Trial (Ensayo de Rendimiento de Cebada Andino)
ESWYT: Elite Selection Wheat Yield Trial
F: filial generation; F_1 refers to the progeny of a cross between any two plants; F_2, F_3, F_4, etc. refer to the successive generations
FAO: Food and Agriculture Organization of the United Nations, Italy
FECOTRIGO: Federation of Brazilian Wheat and Soya Cooperatives (Federação das Cooperativas Brasileiras de Trigo e Soja)
F_2 MATN: F_2 Masa Aluminum Tolerant Nursery
g/ha: gram(s) per hectare
ha: hectare(s)
hl: hectoliter(s)
HSN: Helminthosporium Screening Nursery
Huamantla: off-station site used by CIMMYT; 2500 m elevation, 19°N latitude
IAPAR: Agronomy Institute of Paraná, Brazil
IBTA: Bolivian Institute of Agricultural and Livestock Technology (Instituto Boliviano de Tecnología Agropecuaria), Bolivia
IBWSN: International Bread Wheat Screening Nursery
ICA: Colombian Agricultural and Livestock Institute (Instituto Colombiano Agropecuario)
ICARDA: International Center for Agricultural Research in Dry Areas, Aleppo, Syria
IDSN: International Durum Screening Nursery
IDTN: International Disease Trap Nursery
IDYN: International Durum Yield Nursery
IDYT: International Durum Yield Trial
IICA: Interamerican Institute of Agricultural Sciences (Instituto Interamericano de Ciencias Agricolas), Turrialba, Costa Rica
individually harvested: seed collected separately from each plant (vs. bulk-harvested)
INIA: National Agricultural Research Institute (Mexico: Instituto Nacional de Investigaciones Agricolas; Chile: Instituto Nacional de Investigaciones Agropecuarias; Spain: Instituto Nacional de Investigaciones Agronómicas)
INIAP: National Institute of Agricultural Research (Instituto Nacional de Investigaciones Agropecuarias), Ecuador
INIPA: National Institute of Agricultural Research and Extension (Instituto Nacional de Investigación y Promoción Agropecuaria), Peru
INTA: National Institute of Agricultural Technology (Instituto Nacional de Tecnología Agropecuaria), Argentina
IPB: Institute for Plant Breeding, the Philippines
ISEPTON: International Septoria Observation Nursery
ISSN: International Scab Screening Nursery
ISWYN: International Spring Wheat Yield Nursery
ITSN: International Triticale Screening Nursery
ITYN: International Triticale Yield Nursery

Table 11. Number of lines resistant to stripe rust, leaf rust, septoria leaf blotch, and barley yellow dwarf virus (BYDV) in different locations, Key Location Disease Nursery (KLDN), 1983 and 1984

Disease and year[a]	Syria Tel Hadya	Syria Lattakia	El Ghab	Lebanon	Yemen	Tunisia	Portugal	Canada	Resistant all locations No.	Resistant all locations %
Stripe rust										
1983	129			224					123	51.0
1984	188			148			387		87	18.0
1983 + 1984	68			66					34	14.0
Leaf rust										
1983	223			243	7	228		158	4	2.0
1984	367	94		475			391		82	17.0
1983 + 1984	163			231					1	0.5
Septoria leaf blotch										
1983	22								22	9.0
1984	63	30	34			57	462		1	0.2
1983 + 1984	8								0	0.0
BYDV										
1984						492	158		158	32.0

[a] Lines planted in 1984-85 KLDN; 243 of these lines were planted in the 1983 KLDN.
Selection criteria: Rust: less than 5% severity; Septoria: 3 or less on 0-9 scale; BYDV: 2 or less on 0-4 scale.

Table 12. Influence of nitrogen rates and time of application on yield (kg/ha) of Sham 1 durum wheat, 1983-84

Nitrogen rates at tillering (kg/ha)	Nitrogen rates at sowing (kg/ha) 0	30	60	90	120	Mean
0	2044	2359	2099	1945	2404	2170
30	1791	2276	2252	2322	2220	2172
60	2257	2375	2022	2264	2086	2201
90	2099	2286	2058	2283	2202	2186
120	2070	2063	2245	2006	2138	2104
Mean	2052	2272	2135	2164	2210	

LSD (5%) = 397 kg/ha
Coefficient of variance = 13

Table 13. Distribution of color in entries from different durum yield trials

Trial[a]	Transmission[b] 20-30 %	30-40 %	40-50 %	50-60 %	60-70 %	70-80 %
ADYT (EP)	2	18	51	49	20	2
RFDYT (DP)	—	2	8	12	1	1
RDYT (EP)	—	—	5	8	10	1
RFDYT	—	—	10	8	4	1
RDYT	—	—	4	7	12	1
Total	2	20	78	84	47	6

[a] ADYT = Advanced Durum Yield Trial
RFDYT = Regional Rainfed Durum Yield Trial
RDYT = Regional Durum Yield Trial
DP = Delayed planting
EP = Early planting

[b] Lower transmission indicates greater color; if the transmission is higher the color will be pale

kg: kilogram(s)
kg/cap/yr: kilogram(s) per capita per year
kg/ha: kilogram(s) per hectare
KLDN: Key Location Disease Nursery
LACOS: Advanced Lines of the Southern Cone (Lineas Avanzadas del Cono Sur), a regional nursery for the Southern Cone region
Lagunilla: an off-station site near La Lagunilla, Hidalgo, Mexico; used by CIMMYT
LO: Observation Lines (Lineas de Observación)
Los Mochis: the Fuerte Valley Agricultural Experiment Station (Campo Agricola Experimental Valle del Fuerte), administered by the National Institute of Agricultural Research (INIA); 40 m elevation, 26°N latitude
LSD: least significant difference
m: meter(s)
MAV: an isolate of barley yellow dwarf virus transmitted specifically by the aphid *Sitobion avenae* (formerly *Macrosiphium avenae*)
Mexicali: experiment station administered by the National Institute of Agricultural Research (INIA); 1 m elevation, 32°N latitude
mm: millimeter(s)
mono-5B: a genetic stock of the Chinese Spring variety of bread wheat in which one number of the normally paired chromosome 5B is missing; in intergeneric hybrids lacking this chromosome, pairing is enhanced at meiosis
MPS: multiplication plots
MT: million metric tons
NARC: National Agricultural Research Centre, Pakistan
NFA: National Food Authority, the Philippines
NPBS: National Plant Breeding Station, Kenya
nursery: a small amount of seed or a small number of plants of a line or variety used in an experimental plot
NWDSN: National Wheat Disease Screening Nursery, Pakistan
NWFP: Northwest Frontier Province, Pakistan
NWPP: National Wheat Pilot Project, the Philippines
NWRTN: National Wheat Rust Trap Nursery, Pakistan
OCEPAR: Organization of Cooperatives of the State of Paraná (Organização das Cooperativas do Estado do Paraná), Brazil
OPC: Observation for Parental Collections
Patzcuaro: the Tarascan Mountains Agricultural Experiment Station (Campo Agricola Experimental "Sierra Tarasca"), administered by the National Institute of Agricultural Research (INIA); 2180 m elevation, 18°N latitude
PAV: an isolate of barley yellow dwarf virus transmitted nonspecifically by *Rhopalosiphum podi* and *Sitobion avenae*
PBI: Plant Breeding Institute, Cambridge, England
PC: small seed multiplication plot (parcela chica); also Parental Collection, Kenya
PCARRD: Philippine Council for Agricultural Resources, Research, and Development
PDYT: Preliminary Durum Yield Trial
PNC: National Cereals Program (Programa Nacional de Cereales) of the National Institute for Agricultural Research and Extension (INIPA), Peru
Poza Rica: The Poza Rica Experiment Station, administered by CIMMYT; 60 m elevation, 21°N latitude
ppm: parts per million
Pre-OPC: Preliminary Observation for Parental Collections
PSH: *Puccinia striiformis* f. sp. *hordei*
PST: *Puccinia striiformis tritici*
PWYT: Preliminary Wheat Yield Trial
qq: quintals (10 qq = 1 t; 1 quintal = 100 kg)
r^2: coefficient of determination
RDYT: Regional Durum Yield Trial
RFDYT: Regional Rainfed Durum Yield Trial
Rio Bravo: the Rio Bravo Agricultural Experiment Station (Campo Agricola Experimental "Rio Bravo"), administered by the National Institute of Agricultural Research (INIA); 30 m elevation, 26°N latitude
RWYT: Regional Wheat Yield Trial
Sanidad Vegetal: the Mexican Plant Protection and Quarantine Agency
SIN: Selections from International Nurseries
SNACWYT: Screening Nursery for the African Cooperative Wheat Yield Trial
SRSN: Scab Resistant Screening Nursery
t: metric ton(s)
Tampico: experiment station administered by the National Agricultural Research Institute (INIA); 4 m elevation, 22°N latitude
Tepatitlan: experiment station administered by the National Agricultural Research Institute (INIA); 1700 m elevation, 20°N latitude
t/ha: metric ton(s) per hectare
Tlaltizapan: the Tlaltizapan Experiment Station, administered by CIMMYT; 940 m elevation, 19°N latitude
Toluca: the Toluca Experiment Station, administered by CIMMYT; 2640 m elevation, 20°N latitude
TON: Thailand Observation Nursery
top cross: a cross between an F_1 and a variety or line genotypically different from either of the parental varieties or lines
ULVA: ultra-low volume applicator
UNA: National Agriculture University (Universidad Nacional Agraria), Peru
UPLB: University of the Philippines at Los Baños
USAID: United States Agency for International Development
USDA: United States Department of Agriculture
VEOLA: Disease and Observation Nursery in Latin America (Vivero de Enfermedades y Observación en Latinoamérica)
WMFT: wheat meal fermentation time
WON: Wheat Observation Nursery
WST: Wheat Septoria Nursery
yellow rust: synonym of stripe rust
YRPC: Yellow Rust Parental Collection