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Winter Wheat Germplasm Improvement: Objectives of the Turkish - CIMMYT Cooperative Program

[redacted]. BRAUN, and B. SKOVMAND
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The International Maize and Wheat Improvement Center (CIMMYT) is one of the 13 international agricultural research centers supported by the Consultative Group on International Agricultural Research (CGIAR). The Center has a global mandate for germplasm development of bread wheat (*Triticum aestivum* L.), durum wheat (*T. turgidum* L.), and triticale (x *Triticosecale* Wittmack). The responsibility for wheat development in West Asia and North Africa is shared with ICARDA, which has the global mandate for barley (*Hordeum vulgare* L.), but shares that responsibility with CIMMYT for Central and South America.

Within this framework, the Government of Turkey and CIMMYT signed a memorandum of understanding in April 1986 to work on winter wheat germplasm improvement for Turkey and other countries with similar environmental conditions and production constraints (T.C. Resmi Gazete 1986). This represents a new dimension for the CIMMYT wheat program for two reasons: (i) the expansion in germplasm development will allow CIMMYT to be more directly involved in the improvement of true winter wheats and a substantial part of this program will be located outside Mexico, and (ii) this program also represents a shift in responsibility to a joint venture with a partner that was previously mainly a recipient of CIMMYT technology.

Two major gene pools of wheat have evolved, distinguished by growth habit. Winter wheats require vernalization, the need for which may vary as also for cold tolerance and winter hardiness. There are also interactions between their vernalization requirement and photoperiodism. Spring wheats have a continuous growth habit not requiring a cold period. There is a third, smaller group referred to as facultative wheats which do not require vernalization but have some degree of cold hardiness. Autumn-sown spring wheats which are common in many parts of the developing world (Leonard and Martin 1963; Hanson *et al.* 1982) at times are difficult to differentiate from facultative and winter wheats.

Winter wheats contribute substantially to overall wheat production in both developed and developing countries, although data on area in developing countries sown to winter and facultative wheats are imprecise (Table 1), and approximations should be used with caution.

Turkey is a major wheat producer and winter wheat accounts for about 75% of the total production. Turkey is also a center of origin and genetic variation of wheat. The variation found in the winter wheat germplasm represents, to some extent, the diversity of climates present in Turkey. There are nine macroenvironments for wheat

Table 1. Approximation of the area (x 000 ha) sown in developing countries to spring wheats requiring some cold tolerance, and facultative and winter wheats.

Country	Cold tolerance	Facultative	Winter
Turkey	2 910	470	5 785
Syria	1 350		
Jordan	100		
Iran	639	690	3 690
Afghanistan	1 000	1 100	200
Pakistan	400		
India	900		
Nepal	50		
China	10 200	9 350	3 910
Korea DPR			2 320
Korea R			1 620
Argentina	2 400		
Chile	470	155	155
Peru	100		
Uruguay	210		
Algeria	405		
Ethiopia	105		
Morocco	175		
Tunisia	195		

Sources: CIMMYT 1981; FAO 1983; Anon. 1985, 1987; Stone *et al.* 1985; Winkelmann 1985.

in Turkey, requiring spring, facultative, and true winter growth habit (Fig. 1). A recent analysis by Mizrak (1983) suggests 24 distinct environments within the macroenvironments.

Wheat improvement work dates back to more than 100 years, and winter wheat breeding programs have been active in Turkey and other developing countries for over 50 years. In Mexico, the spring wheat program was established by the Rockefeller Foundation in the early 1940s (Hanson *et al.* 1982).

The development of high-yielding, photoperiod-insensitive semidwarf spring wheats sparked a major change in wheat production throughout the world (Dalrymple 1978; Hanson *et al.* 1982). This germplasm produced increased yields in the coastal areas of Turkey (Demir 1976; Somel 1979). This achievement stimulated the signing of a bilateral agreement between Turkey and the Rockefeller Foundation in 1969 (Wright

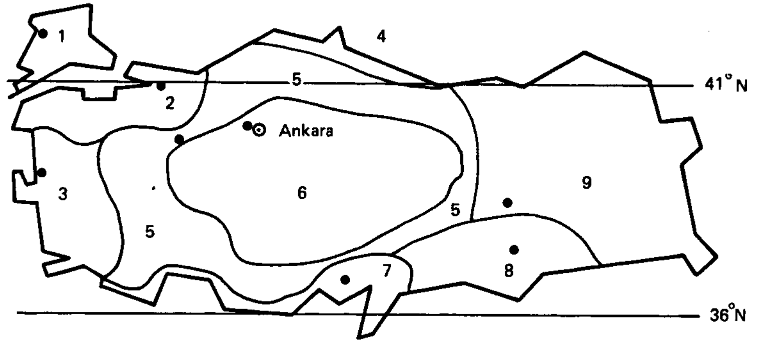

Fig. 1. Nine major wheat-growing zones in Turkey; winter wheats dominate in zones 1, 6, and 9; spring wheats in zones 2, 3, 4, 7, and 8; and facultative types in zone 5.

1977; Tansey 1984). As part of this project, staff from the Oregon State University and CIMMYT moved to work in Turkey (Kronstad 1981).

The project ended in 1982 and was reviewed by Tansey in 1984. Although, by then, the original objectives had largely been achieved, a number of issues remained to be resolved. Wheat production had increased from 10 to 17 million tonnes, and average yields from 1.1 to 1.8 t/ha. Sixty Turkish scientists had received training abroad, and 29 of them had undertaken postgraduate training in the United States of America (Tansey 1984).

Apart from the bilateral program with Turkey, CIMMYT had maintained a relatively small effort involving winter wheat germplasm development. Then, in the late 1960s, it initiated a spring x winter crossing program in close collaboration with the program at the Oregon State University (CIMMYT 1980). A number of improvements in spring wheats resulted from this program (CIMMYT 1987), but improvement in winter wheats was not realized to the same degree. A greater effort seems to be warranted so that positive characteristics from the spring wheats can be incorporated into the winter wheats.

A number of factors are in favor of locating the winter wheat program in Turkey. The latitude is similar to that of other major winter wheat growing countries, so development of germplasm with wide adaptation should be possible (Fig. 2). Turkey is located in the center of origin and diversity for several cereal species, and a wealth of germplasm will be accessible. The agroclimates vary from mild on the coast to harsh winters in the plateau (Mizrak *et al.* 1986), and most of the important wheat diseases are present for screening purposes (Iren 1981; Kinaci 1986).

Another important reason for locating the winter wheat program in Turkey is that the National Turkish Cereal Improvement Program and CIMMYT have had a long association. This joint project has initiated exchange of germplasm and scientists in winter wheat programs of North and South Americas, Europe, and the Far East.

Latitude	UNITED STATES	EUROPE	ASIA
45° N	Portland	Belgrade	Krasnodar
44° N		Bucharest	
43° N			
42° N		Sofia	
41° N	Lincoln, New York		
40° N	Denver	Madrid	ANKARA, Beijing
39° N	Kansas-City		
38° N			
37° N			
36° N	Oklahoma-City		Teheran
35° N	Amarillo		Kabul

Fig. 2. The latitude relationship of Ankara, ca. $40^{\circ} \pm 5^{\circ}$N, and some important cities located in winter wheat growing regions.

Regions and Macroenvironments

A review of resource allocation and priorities for wheat germplasm development, held at CIMMYT in March 1987, reaffirmed one of CIMMYT's basic objectives: undertaking to supply germplasm that can be used by national programs (CIMMYT 1987). These national programs are located in 10 geographic regions:

- Mediterranean and North Africa;
- The Middle East and the Nile Valley of Africa;
- East African highlands;
- Southern Africa;
- The Indian subcontinent;
- East Asia including China;
- Southern cone of South America;
- Andean region of South America;
- Central America including Mexico; and
- Tropical lowlands.

Within each region, different ecological zones or megaenvironments exist. Strategies for breeding of bread wheat, durum wheat, and triticale are formulated accordingly. The five megaenvironments defined by the bread wheat program are:

- Well-watered environments with no obvious soil problems;
- High-temperature environments, including rice/wheat rotation areas;
- Semi-arid environments;
- Acid-soil environments; and
- Environments needing winter wheats.

The durum wheat program also targets its germplasm development toward five mega-environments. They are, naturally, different to some degree from those of the bread wheat program.

- Well-watered environments;
- Semi-arid environments with drought stress;
- Highlands (more than 1000 m above sea level);
- Environments where some cold tolerance is required; and
- Winter or facultative durum wheat areas.

The triticale program has defined three megaenvironments:

- Acid-soil, tropical highlands;
- Semi-arid conditions; and
- Well-watered areas.

Within each of the megaenvironments, there are diverse ecological conditions. Certain ecological combinations could be considered as macroenvironments, with their own specific requirements.

Winter wheats have generally been considered to be more specifically adapted than the spring wheats because of the need for specific characters such as winter hardiness, vernalization, and photoperiodic response.

This concept of specificity has been established in breeding programs in the developed world over a period of years and has resulted in very high yields, but the germplasm is, in general, narrowly adapted. It is well suited for intensive agricultural management, but cannot be used directly in much of the developing world. Breeding for specificity involves a number of programs and a level of investment not available in most developing countries.

In contrast, CIMMYT's breeding philosophy for spring wheats has centered on the concept of wide adaptation (Rajaram *et al.* 1984). In order to review this concept and its application to winter wheat germplasm development, we selected some environmental traits that could be regarded as dominant factors in the winter wheat mega-environment. Using these factors we attempted to develop a model for illustrative purposes.

It is a simplistic model which assumes that each independent environmental factor produces a dominant response. In a situation involving several factors a number of unique combinations will be created. If the concept of absolute specificity is also accepted, the number of specific phenotypes required will equal the number of environments. For each environmental trait added, there would be a corresponding response. The number of specific phenotypes or cultivars required, therefore, would increase by the factors of 2^n, where n equals the number of environmental traits. This model is based on the principle that is applied to the determination of the kind of F_2 phenotypes possible from hybrid populations involving diallelic loci with full dominance.

If a subset of four environmental factors was taken independently, the number of specific phenotypes (cultivars) required would be 16 (Fig. 3a). If a germplasm pool incorporating some of the common but dominant factors could be developed, the number of specific phenotypes would be greatly reduced.

For example, a strong photoperiodic response is a requirement in 8 of the 16 subset environments. The neutralization of this trait in the general germplasm pool reduces the specifically adapted phenotypes by 50%, or from 16 to 8 (Fig. 3b). The same reduction holds true for any other characteristic in the example. That is, if a response to a dominant characteristic, such as cold hardiness, can be incorporated, the number of specific phenotypes can be reduced by another 50% (Fig. 3c).

The addition of selection criteria (factors) doubles the number of specific phenotypes required. For example, selection for disease resistance results in two classes per subset and adds to the number of unique combinations needed to satisfy the model. Consequently, no matter how widely adapted a germplasm pool becomes, specificity requirements will exist or can be imposed. This underlying principle dictates that a single cultivar will not and cannot become the one and only cultivar that will be grown from the Atlantic to the Pacific.

The concept of wide adaptation has been used to a great extent in the development of CIMMYT's spring wheat germplasm. The best high-yielding, semidwarf spring wheats in Mexico are well suited to a number of regions throughout the world (Dalrymple 1978; CIMMYT 1987). This is possible because of the combination of desirable agronomic and physiologic traits in the germplasm pool. We emphasize that this germplasm pool would have found little acceptance if resistance to major diseases had not been incorporated (Rajaram and Dubin 1977; Dubin and Rajaram 1981, 1982).

Environmental factor and response				Number of phenotypes
Photoperiod sensitivity	Period of cold	Snow cover	Moisture regime	
Strong	Long	Yes	Adequate	1
			Inadequate	2
		No	Adequate	3
			Inadequate	4
	Short	Yes	Adequate	5
			Inadequate	6
		No	Adequate	7
			Inadequate	8
Weak	Long	Yes	Adequate	9
			Inadequate	10
		No	Adequate	11
			Inadequate	12
	Short	Yes	Adequate	13
			Inadequate	14
		No	Adequate	15
			Inadequate	16

Fig. 3a. A model illustrating the number of specific phenotypes (cultivars) required to satisfy the needs for four independent environmental factors.

An important factor that has contributed to the development of wide adaptation as well as more durable resistance is multilocational testing. The trials allow one to identify phenotypes with wide adaptation as well as those with specific and useful traits. Lines that have superior disease resistance stand out as a result of exposure to different pathogens. The lines identified can then be used in breeding for target areas. In essence, the use of these phenotypes results in recurrent selection on a grand scale and has allowed CIMMYT to concentrate favorable genes, with

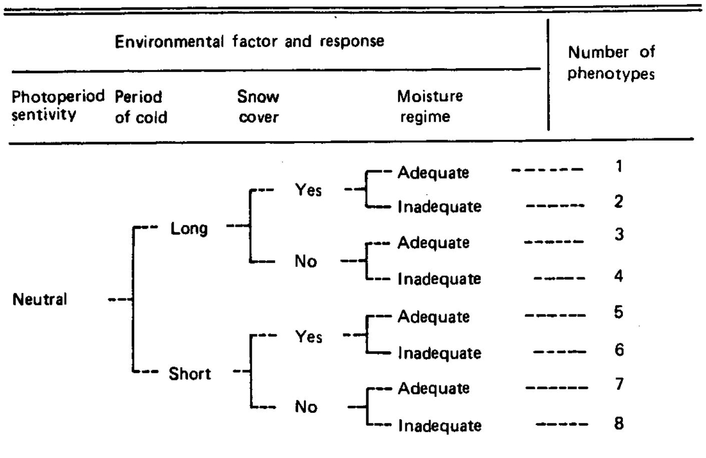

Fig. 3b. The neutralization of one environmental factor will reduce in half the number of specific phenotypes (cultivars) required (e.g. 16 to 8).

major additive effects over time. The combination of agronomic and physiologic traits with disease resistance made the pool useable worldwide. In other words, the germplasm pool, rather than the cultivar, has universal application.

Whether all or only part of this philosophy can be used in the development of winter wheat germplasm remains to be seen. Developing wide adaptation is the antithesis of the approach that has worked in the past for developed countries, namely, specific adaptation, but perhaps the end product is a reflection more of the breeding systems than of the requirements. Our underlying premise is that it is possible to incorporate some of the common parameters into the germplasm pool and to broaden adaptation.

The principal objective of the Turkish-CIMMYT Winter Wheat Program is to develop a germplasm pool with wider adaptation and stability of performance. This pool can be used as a vehicle for transferring desirable characters to the more specific environments. It is not intended or necessary that finished cultivars emanate from this program.

Wide adaptation has been defined by CIMMYT as the ability of a genotype to yield well in environments that differ from each other (CIMMYT 1987). For example, the spring wheat 'Seri 82' and the winter wheat 'Bezostaya 1' are considered by most scientists to be widely adapted.

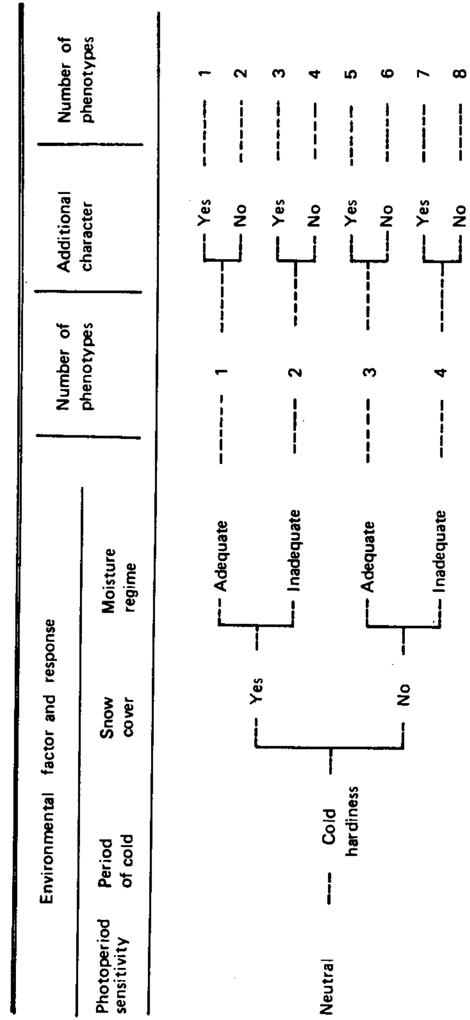

Fig. 3c. The number of specific phenotypes (cultivars) will be further reduced in half with the neutralization of each envrionmental factor and, conversely, the addition of selection criteria will double the number of specific phenotypes (cultivars) needed for every added character.

CIMMYT has defined site-specific adaptation as the ability of a genotype to yield well in an environment or environments that are similar to each other (CIMMYT 1987). It may be desirable to have specifically adapted cultivars, but they are not stable in yield because of differences between locations or differences between years at one location (Braun 1983; Pfeiffer and Braun 1985).

Stable performance of a genotype in a consistent or predictable environment over seasons is stability of specific adaptation; and stable performance in a set of fluctuating or unpredictable environments or seasons is stability of wide adaptation (CIMMYT 1987). We as plant scientists are primarily interested in high stable performance. We measure performance as yield relative to the check variety or the mean of the nursery. This is true for both widely adapted and specifically adapted cultivars. For both, the plant scientist is concerned with stability of factors that govern resistances to biotic and abiotic stresses.

Issues and Priorities in Germplasm Development

Characters that we feel have wide utility and should be incorporated into winter wheat germplasm are:

Yield potential: There is a great deal of variation in yield potential in both spring and winter wheats. In winter wheats, the known yield potential tends to be concentrated in specifically adapted varieties, many incorporating some degree of photoperiodism. If yield is considered in terms of grain production per day of available growth period, the spring wheats have an advantage over the winter wheats. The combinations of these two pools should provide opportunities to increase yields for a broad group of early winter wheats.

Photoperiodic neutrality: Traditionally and historically, the winter wheat programs have been located in areas that encouraged selection for photoperiodic sensitivity. Also, single-site selection favors photoperiodic specificity, as was found by the Rockefeller Foundation Program when it began work on spring wheat in Mexico. Do we need photoperiodic sensitivity in winter wheat? Can we develop photoperiodic-neutral cultivars and germplasm? These critical questions have to be answered.

Semidwarf stature: There is a substantial body of evidence on the value of the semidwarf character in more productive environments, as well as in drier areas, especially in favorable years. Numerous varietal comparisons confirmed superior yield ability of more recently developed semidwarf cultivars carrying reduced height genes, Rht 1 and Rht 2 (Gale and Youssefian 1985). It seems to us that this character presents few limitations and many positive attributes. Semidwarfs have certainly been effective in reducing the losses associated with lodging. Shorter coleoptyle is a character associated with some genes for reduced height (Allen 1970), although this is an undesirable characteristic where deep sowing is required.

Drought tolerance: Much desired but elusive is drought tolerance because types of drought stress differ or at least occur at different times in the life of the plant.

Can we use these features to develop or combine tolerance? Can differential sites supply part of the answer?

Cold hardiness: There is a need for various degrees of cold hardiness, and if a sufficient level of hardiness can be incorporated to satisfy the larger arena of winter wheats, only the locations requiring extreme hardiness would remain. Germplasm with a cold hardiness level of 'Bezostaya 1' would probably satisfy the need of most winter wheat areas of the developing countries. This level could serve as a bridging germplasm to transfer desirable characters to the extreme areas.

The distinction between winter hardiness and cold tolerance varies depending on the authority. We have chosen to use the term cold hardiness to cover the entire spectrum of chilling or freezing injuries (Olien and Smith 1981). We use the term winter hardiness to mean the ability of a plant to survive freezing temperatures when there is no visible growth. We use cold tolerance to designate the ability of a plant to survive chilling temperatures when there is visible growth.

Disease tolerance: Disease-resistant cultivars are a requirement in developing countries because dependency on chemical control is not feasible. Many diseases are area-specific and priorities have to be set among them in breeding for resistance. The losses caused by diseases must be compared with the costs of incorporating resistance. As we know, high levels of resistance usually come at the expense of yield. However, the protective value of resistance, or genetic insurance, for the unsuspecting farmers must also be given some consideration.

Earliness: Early maturity provides a number of benefits. It enables cultivars to escape terminal or late-season drought and damage inflicted by hot winds and high temperatures. Sometimes early-maturing cultivars can also escape the buildup of epiphytotic diseases, such as stem and leaf rust. Their disadvantage is that they cannot benefit from late-season rains. However, it seems that combining high-yield potential with earliness offers some interesting possibilities in winter wheat areas.

Quality: Wheat products and uses are diverse, and the quality requirements vary greatly. Initially, effort will be devoted to defining quality parameters required and cataloging the characters present in the gene pool. Once we have this data base, we will be able to plan an approach.

A number of specific traits also need attention. Substantial areas experience late frosts and early commencement of hot, desiccating weather. The characteristic of late heading with rapid grain filling and early maturity is required in such areas. The trait that governs the rate of yield gain or dry-matter accumulation per day appears to be a valuable focus.

Breeding for disease resistance will be aimed at incorporating protection against the bunts and smuts along with stripe rust. Our current understanding of snow mold resistance is limited, but it may be critical for winter survival in some areas. We will need to review this and a number of other diseases.

The Turkish-CIMMYT Winter Wheat Program will make extensive use of germplasm from both the winter x winter and winter x spring wheat crosses. In addition, introduced winter wheat germplasm and the germplasm in the Turkish program will be included in the pool.

Turkish winter wheats and material from North America, adapted to Turkish conditions, have been evaluated and distributed to international cooperators. The best lines were included in the first and second international winter wheat screening nursery (IWWSN). The results from these nurseries will be shared with cooperators and used in the formulation of future nurseries.

The spring x winter crossing program has demonstrated its value in the CIMMYT spring wheat germplasm: the highest yielding and most widely adapted materials have originated from this program. Since there is no scientific reason why winter wheat should not benefit to the same extent, it is our intention to give major emphasis to the use of this germplasm.

Summary

The joint Turkish-CIMMYT Winter Wheat Improvement Program is a new venture with great opportunities to broaden the winter wheat germplasm base. Turkey is ideally situated to contribute to this objective. The use of the international nursery network provides a mechanism by which the superior, widely adapted germplasm can be identified and can serve as a vehicle to transfer desirable traits that would benefit all winter wheat breeding programs.

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Discussion

E. Acevedo
In your conception of wide and specific adaptation, how do you define "similar" and "different" environments? From a physiological standpoint one can visualize traits of benefit to specific environments which may have a negative effect in other environments. Do you believe that this consideration may have any relevance to the level of adaptation?

E.E. Saari
1. "Similar" and "different" are used in a conceptual sense. The use of means does not satisfy our needs and maybe we should use standard deviation instead. We think of it (for example, similar temperatures) if all other factors remain the same. This is not the real world but some indicator (genes) plants as well as climatic data may provide a better measure of "similar" and "different".
2. Yes, a specific trait may have a negative effect on another. Example: strong photoperiod response may be desirable or even necessary in northern latitudes (50°N).

H.-J. Braun
In high-elevation areas the environmental variation at one location over years is for many locations as high as the environmental variation across locations in one year in a given region. If this is the case, widely adapted cultivars should be developed.

G. Dev
Wheat is grown in rotation with different crops, meaning thereby that there are different environments to which wheat is subjected and therefore its performance varies. Do you think that there is a need to evolve varieties suitable for different rotational environments? Has this approach any scientific basis?

E.E. Saari
Yes, there is a need and you can breed varieties for rotations. One example is that the early maturity of "Sonalika" in India allowed the rice-wheat rotation to develop. Before this variety, wheat was the main crop and no rice was grown. Another example is the heat tolerance of juvenile plants which carry a vernalization gene which allows early sowing of wheat in northern Australia. This allows better moisture use and higher yields.

Gurbuz Mizrak
Photoperiodic neutrality may not work in every case, such as in Eastern Anatolia. Photoperiodic sensitivity might help to escape from late frost.

E.E. Saari
True, there are situations where photoperiodic response may be necessary or desirable. There are a number of situations where other responses may also be desirable but this will be dictated by each situation and can be determined. However, in many cases photoperiod limits adaptation more than it provides an advantage.

M. Tahir
Are there genetic differences in wheat genotypes in their rate of grain-filling?

E.E. Saari
Yes. In triticale there is a large variance. The dry-matter deposition rate per day is associated with the high-yielding lines regardless of maturity grouping. There is evidence that oats and wheat escape epiphytotic diseases through this mechanism. Some of them are considered tolerant varieties.

B. Yilmaz
How do you classify certain important characteristics, such as root characteristics (subcrown internode length), and what is your opinion about their role in wide adaptation or specific adaptation?

E.E. Saari
I look upon such characteristics as specific traits which contribute to wide adaptation.

K.D. Koranne
Grain sprouting is a common phenomenon with wheat. What progress has been made to overcome this problem?

E.E. Saari
The best progress is associated with red grain color. In triticale, it has been possible to advance lines from base populations that were considered sprouting susceptible.