WHEAT QUALITY CONSIDERATIONS IN BREEDING PROGRAMS AND THE USE OF EARLY GENERATION SCREENING TESTS TO IMPROVE PROGRAM EFFICIENCY

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It is our contention that breeding for good milling and baking quality need not necessarily impede progress in the development of higher yielding varieties.

It has already been pointed out that in the Mexican program concurrent improvements are being made in developing higher yielding, broadly adapted varieties with improved agronomic type, improved disease resistance and improved milling and baking quality. Nevertheless, in the vast majority of the wheat breeding programs in the Americas such concurrent improvement is not being accomplished. Improvements in grain yields have lagged. The result has been that the wheat breeder too often unjustly blames the cereal chemist for setting quality standards he cannot attain while simultaneously increasing grain yields and improving other important characteristics. Too often breeders have resorted to the use of long backcross programs, to avoid problems with quality, but by so doing they have simultaneously greatly reduced the possibility of increasing grain yield.

Although we feel that the breeders are in part justified in their criticism of the inflexibility in grain quality standards, as explained in the following paragraphs, we nevertheless feel that many of the quality problems encountered by wheat

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breeders can be circumvented if an adequate series of early generation screening tests for quality are employed.

Before going into an explanation of some of the screening tests for quality that have been used successfully in the Mexican program, we wish to call attention to some of the overall considerations that influence wheat grain quality and wheat's present and possible future position in competition with other cereal grains in both the domestic and the international markets.

Certain factors affecting grain quality have been at work in the past which have provided a definite advantage quality-wise and market-wise to wheats from certain regions and countries. We feel that this "status quo advantage" is about to be broken because of breakthroughs in genetic improvement. If the heretofore "privileged regions" (quality-wise), such as the Northern Spring Wheat Regions of the U.S.A. and Canada, remain complacent, they will lose their unique market advantage.

Viewing the cereal grain markets broadly, everyone working in wheat research, wheat production, wheat utilization and wheat handling and industrialization, should be increasingly concerned about wheat's position in the future. Increasing competition from other cereal grains in international markets is almost certainly forthcoming.

The discovery of the Opaque 2 gene which greatly improves the nutritional value of corn, poses one threat and challenge. What are we doing about improving the nutritional value of wheat through genetic manipulation? Very little is being done up to the present time. Is the effort adequate?

Recent research breakthroughs such as the development of high yielding, broadly adapted semi-dwarf rice varieties I R 8, (bred by the International Rice Research Institute) will also bring wheat under greater competition in the grain markets of the world. What are we doing about this? Unless we increase yields and maintain, or better yet improve wheat quality, wheat will price itself out of its fair share of the expanding world grain markets within the next two decades.

What are we as wheat scientists going to do about these challenges in the next two decades?

Competition between Different Wheat Classes in Domestic and International Markets, and between Wheat and Other Cereals

The hard red spring wheat regions of the U.S.A. and Canada have traditionally occupied a favored position in the domestic and international wheat markets of the world. Their favored position has been attained because of:

1. The outstandingly good protein quality of the principal commercial varieties

The varieties Red Fife, Marquis, Thatcher and their derivatives were bred and selected for their excellent milling and baking quality. The unusual combination of strong well balanced (extensible) gluten strength has been their outstanding feature. This genetic superiority has been maintained for the past forty years by effective breeding programs.

2. High Grain Protein Levels

This important advantage is the result of the interaction of climate and soil conditions under which the Northern Hard Red Spring Wheat Market class has been grown. Scientists up to the present have contributed nothing to this advantage. In the future, however, the high protein advantage of northern spring wheats will come under increasing pressure and competition both in domestic and international markets as the result of increased grain protein content in wheats from other regions and other exporting countries.

In recent years it has been shown that the Frondoza or Atlas 66, high protein gene can increase grain protein content by 2 percent. This action is independent of grain yield. The incorporation of this gene into high yielding Hard Red Winter Wheat varieties will make this winter wheat region more competitive with wheats produced in the hard spring wheat region.

Aggressive agronomic research in the winter wheat region, which is currently largely lacking, designed to determine the best timing, rates, kinds and methods of nitrogenous fertilizer application will probably contribute to further increasing grain protein content in the foreseeable future. Progress through this approach will further erode the grain protein content advantage of the hard red spring wheat market class.

The protein quality (especially strength) advantages of spring wheats over winters will shrink in the future, as breeding programs in the hard red winter wheat region increase their effort to correct protein quality defects. This effort is already underway in a number of breeding programs, both hybrid and conventional. The gluten strength of Mexican spring wheat varieties Jaral 66, Tobari 66, INIA 66, CIANO 67, and an especially promising line from the cross II22429, (Tezanos Pintos Precoz-Sonora 64A) (Lerma Rojo 64A x Tezanos Pintos Precoz-Andes dwarf) are already being incorporated into hard winter wheats in a number of different U.S. breeding programs.

Eventually the genes controlling high levels of grain protein and better protein baking quality (strength) will both be incorporated into high yielding hard winter wheat varieties. When such varieties are grown under proper fertilization they will be fully competitive market wise with the hard red spring wheats.

We have reasons to believe that improvements in gluten (protein) strength will be forthcoming soon in French winter wheats. Similar improvements, through breeding, are under way to improve the protein quality of eastern European and Russian winter wheats.

Another change that will be forthcoming to further complicate the export position of Canadian and U.S. Hard Red Spring Wheats relates to the development of high yielding semi-dwarf hard white spring wheat varieties. No such variety exists at present.

Hard white wheats with strong gluten are preferred by all wheat consuming countries from Morocco to India. They are especially desirable for use in Chapattis in the Middle East countries. Currently the development of semi-dwarf, hard white varieties is well advanced in the Mexican, Indian and Pakistan breeding programs.

All of the forementioned predicted changes from breeding and agronomic research efforts already underway in the U.S.A. and in other countries will indirectly exert pressure on the current economic advantages of hard red spring wheats in the world markets. This is no time for the hard red spring wheat programs of the U.S.A.

and Canada to be satisfied with "status quo quality and grain yield".

<u>The Use of Early Generation Screening Tests for Wheat Quality in Breeding Programs</u>

Screening tests are simple tests that can be made rapidly and in large numbers on the small grain samples from individual plants to eliminate undesirable and worthless materials from a breeding program. They are not tests which are to be used for choosing the line that is to be multiplied as a new commercial variety.

The final choice of a superior line which is to be released as a new commercial variety must always be made by a series of well controlled milling and baking performance tests. In such performance tests the promising new advanced lines are carefully compared to the best commercial varieties to determine their suitability for specific consumer product (i.e. pan type bread, pastries, crackers, etc.)

The purpose and proper application of these two very different types of tests in breeding programs is frequently confused by both cereal chemists and plant breeders.

Breeding programs which restrict quality testing to the milling and baking performance tests, however, greatly reduce their efficiency, since such tests can not generally be made before the F_5 and F_6 endosperm generation. This means that many inferior, worthless lines are carried forward in the program for a minimum of two years. This is a waste of time, energy and money.

Five years ago, after two years of exploratory evaluation, a series of early generation screening tests for quality was adapted for use in the Mexican program.

These tests combined with the standard milling and baking tests in the advanced generations have been highly effective in improving the quality of the new wheats currently emerging from the Mexican program. The newer varieties INIA 66, Tobari 66, CIANO 67, Azteca 67, and Bajio 67 and many other even more promising lines in final stages of evaluation, are products of these methods.

The quality tests currently being used by the Mexican program differ primarily from those in use by other programs in North America in the way the plant materials are handled in the early segregating generations.

The preliminary screening tests for quality, are conducted on grain from individual plants in the F_3, and F_4 endosperm generations. Secondary screening tests are added in the F_5 endosperm generation. The secondary screening tests complemented by standard milling and baking tests are used on F_6 and succeding generations.

The type of test that can be used in preliminary screening is governed by the size of the grain sample and the number of individual plants that can be analyzed in the two to three week period between the harvest of the winter generation and replanting of the summer nursery. All preliminary screening tests must be conducted on an individual plant basis. Under our conditions each plant produces from 5 to 20 grams of seed. Three grams of sample are currently used in the preliminary screening tests. The remainder is used for replanting. From 5,000 to 7,000 individual plants are evaluated at each of two locations in each generation. Approximately 300 plants are evaluated each day. Generally 65 to 75 percent of the individual plants that are analyzed are discarded.

In the secondary screening tests between 300 to 500 of the most promising lines are evaluated each generation. Approximately 30 samples can be analyzed each day. Three hundred grams of sample are needed for these series of tests.

Only those samples showing good promise in the secondary screening tests are evaluated in the final milling and baking tests.

The types of tests conducted in the preliminary and secondary screening tests and in the final milling and baking performance tests are indicated in Table #1.

The Implementation of Quality Tests in the Mexican Breeding Program

Quality evaluations are not only used on lines under development in the breeding program but also for classifying the quality characteristics of potential parents. Data from the tests indicated in Table #1 clearly define the characteristics of each potential parent. This is used as a guide in planning the new crosses that are to be made each season.

In early segregating generations of crosses - the F_3 and F_4 endosperm generation - the preliminary screening tests are used exclusively. In these tests major emphasis is given to grain classification tests and to Pelshenke values (Table #1). The grain tests eliminate all lines that have poor kernel characteristics, which are likely to result in low grain test weight, high flour ash and low flour yield. The grain tests evaluate samples for grain size, plumpness, texture, vitriousness and color.

The Pelshenke test is used in the preliminary screening tests as a crude measure of gluten strength. It will separate weak wheats from strong wheats. It will not distinguish however, the strong "bucky" types from the well balanced strong types.

Table #1

Quality Tests Employed and Properties Studied by Mexican Wheat Program in Different Endosperm Generations

	Preliminary Screening Tests		Secondary Screening Tests /1		Performance Milling & Baking Tests	
	F_3	F_4	F_5	F_6	F_6	F_7
A Grain Properties:						
1. Plumpness	X	X	X	X		
2. Size	X	X	X	X		
3. Texture	X	X	X	X		
4. Color	X	X	X	X	-	-
5. Vitreousness	X	X	X	X	-	-
6. Test Weight	-	-	X	X	X	X
7. Protein	-	-	X	X	X	X
B Chemical and Physical Properties:						
1. Pelshenke (wheat meal fermentation) test	X	X	X	X	X	X
2. Flour Protein	-	-	X	X	X	X
3. Alveogram Tests	-	-	-	-	-	-
a) W value	-	-	X	X	X	X
b) P/G value	-	-	X	X	X	X
4. Mixogram	-	-	X	X	X	X
5. Sedimentation	-	-	X	X	X	X

1. Milling Properties	-	-	-	-		X	X
2. Water Absorption	-	-	-	-		X	X
3. Baking Test	-	-	-	-		X	X

/1 Tests performed whenever line is first cut in bulk; in most cases this is in the F_6 endosperm generation. However, in outstanding lines, after best plants have been selected individually, row is cut in F_4 endosperm generation

Mexico generally grows soft wheats, hard wheats and durum wheats in adjacent fields. There is no regional or geographic separation of wheat production by market classes. It is therefore absolutely necessary to use the preliminary tests - both grain and Pelshenke tests to identify the different market classes. The plants (lines) under study as potential soft wheat varieties must have large soft textured large kernels and weak elastic gluten characterized by low Pelshenke values (i.e. 30 to 45 minutes , like Lerma Rojo 64). The plants that are saved for the potential development of hard wheat varieties must by contrast have high Pelshenke values (120 to 180 minutes like Sonora 64 or INIA 66), plump, hard textured and medium sized kernels that are readily distinguishable from the soft wheats.

Distinguishable kernel types associated with corresponding gluten types are absolutely necessary to avoid mixing between soft and hard wheats in marketing.

Ocassionally in outstanding crosses, involving a soft and a hard wheat parent plants in the F_3 endosperm generation with intermediate Pelshenke values (i.e. 70 to 100 minutes) are kept. Such plants are generally heterozygous for both grain type and gluten type. They will segregate in the next generation into both soft and hard wheat types.

The secondary screening test which is considered by us to be of a greatest value for identifying outstandingly promising soft and hard wheats is the Alveogram test. The Alveogram "<u>W value</u>" is a general measure of gluten strength. Wheats with W values above 400 are considered strong wheats, whereas wheats with less than 250 are considered soft wheats.

The Alveogram "P/G value" is the ratio between measured dough tenacity (P) and extensibility (G). The P/G and W values can be used as a guide to selecting wheats with well balanced gluten strength and extensibility in both soft and hard wheats. Wheats either soft of hard - which possess good balance will have P/G values approximating 1/100 of the W value. Wheats with P/G values higher than 1/100 are "bucky".

The P/G and W Alveogram values, supplemented by mixogram scores and sedimentation values determine which lines are worthy of evaluation in the standard milling and baking performance tests.

The correlations between various tests - both preliminary and secondary screening tests and milling and baking quality tests - together with the multiple regression of loaf volume (with bromate) on 4 independent variables for a group of 25 wheats varying from weak to strong gluten are shown in Table #2.

The data show that the Pelshenke value, which is the measure of gluten strength used in the preliminary screening test, is highly correlated with the Alveograms "W value", which is the principal secondary screening test used for judging gluten quality. It is also highly associated with mixing time, sedimentation, mixogram and protein. The Alveogram W value is in turn highly correlated with loaf volume (non-bromated) . The correlation (relationship) between Pelshenke value and loaf volume as used in the Mexican program is therefore an indirect one via the Alveogram W value.

It is evident from the data in Table #2 that the sedimentation value is both directly and highly correlated with loaf volume. Therefore it could also be used successfully as a preliminary screening test. We, however, prefer to use the Pelshenke test as the preliminary screening test since it both lends itself better to small grain samples and permits the analysis of from 3 to 4 times more samples that can be evaluated in a given period of time with the sedimentation test.

The multiple regression involving loaf volume with bromate and the four independent variables indicated in Table #2 accounts for 78.1% of the variability for loaf volume. That is by combining only alveograph (both P/G and W) with mixogram and water absorption, we can predict loaf volume on the basis of the preliminary tests.

After five years of employing the aforementioned preliminary and secondary screening tests for quality we are convinced that these tests greatly increase the efficiency of our breeding program. They alone are not used for selecting the lines that will be released as commercial varieties. Standard milling and baking tests are used to make this final choice.

In the light of these data and results why are preliminary and secondary screening tests not employed by most plant breeders and cereal chemists?