RELATIONSHIP OF KERNEL HARDNESS WITH CERTAIN END-USE QUALITY CHARACTERISTICS IN SOME HRW WHEATS

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CHAPTER I

INTRODUCTION

Among the food crops, wheat is the major food source for an increasing percentage of the world's population. In the USA, the production of wheat is devoted to both domestic use and export markets. In both cases, trading of wheat is done according to market classes in which class indicates end-use properties as well as influencing market price. Currently, wheat in the USA is classified into five distinct market classes according to such visual kernel characteristics as color, bran texture, brush, shape of cheeks and growing habits (spring or winter) into five distinct market classes. These market classes are: hard red spring (HRS), hard red winter (HRW), soft red winter (SRW), white, and durum wheats. According to these criteria, wheats produced in the southern great plains of USA are traditionally classified as HRW wheats.

During the last 20 years, wheat breeders in an effort to obtain superior genotypes that could reach higher yields in a wide variety of biotic and abiotic environments have crossed different classes of wheat. Many of the resulting genotypes have superior agronomic performance and good end-use quality, but possesses kernel characteristics of more than one class. Therefore, according to the current kernel morphology classification system, these genotypes are likely to be classified by grain dealers as mixed wheat. The mixed wheat class, which is discounted at the market place, would create some additional problems in wheat marketing. As a result, it has become apparent that this system based on visual kernel characteristics is no longer adequate to classify US wheats.

Recently, the Federal Grain Inspection Service (FGIS) has proposed that the subjective kernel morphology system be replaced by an analytical-objective kernel hardness test as a means of determining market classes of wheat. The Near Infrared Reflectance (NIR) spectroscopy system, which is the proposed procedure, scores kernel hardness with great accuracy, however it is unable to detect mixtures of hardness types in a wheat sample. Therefore, work is in progress to devise instrumentation to determine single kernel hardness which will be used jointly with the NIR system.

One of the basic assumptions made by the FGIS to support this proposed system is that kernel hardness (as measured by the NIR) has a strong relationship to end-use quality. However, this relationship may be of small magnitude and of little use in predicting end-use quality, at least in HRW wheats. For example, the kernel hardness value of the variety 'Chisholm' is at the low end of the HRW wheat hardness scale, although it is considered as having good HRW end-use milling and baking quality (Cox et al., 1989). The rather low NIR hardness level of this variety, which until recently was extensively used as a progenitor in the Oklahoma wheat breeding program, is likely to be reflected in many of the breeding lines generated by this program. Therefore the objective of this study is 1) to examine hardness levels of the Oklahoma wheat breeding lines and 2) to study the relationship of kernel hardness with important milling and baking quality characteristics such as flour yield content, flour protein content, mixing time, mixing tolerance, and specific sedimentation. The resulting information on the relationship of hardness and these end-use quality characteristics is needed in order to re-structure the current breeding strategies of the Oklahoma wheat breeding program and meet the proposed hardness standards required by the FGIS to maintain good HRW end-use quality.

CHAPTER II

LITERATURE REVIEW

Among the different components of the wheat kernel, the endosperm is the most important component for bread production. Physical properties of the endosperm, such as hardness or softness, are reported to be closely related to technologically important flour properties such as starch damage, particle size, and size distribution (Obuchowsky and Bushuk, 1980).

Theories of Grain Hardness

The degree of adhesion between starch and protein is one of the two theories involving the relation between these components that has been suggested to explain the hardness of the wheat kernel. This theory is supported by the wetting (adherence or coating) of proteins on starch which is much tighter with hard wheats than with soft wheats. Thus, increased wetting gives rise to a stronger bond between starch and protein. This phenomena can be observed in the number of starch granules that are broken when the kernel is fractured. Soft wheats have essentially no broken granules (weaker bond), hard wheats a moderate level, and durum wheats a high level (strongest bond), (Hoseney, 1986, Pomeranz, 1988). Another explanation suggested by Stenvert and Kingswood

(1977), is that hardness depends upon the degree of the filling or continuity of the protein matrix, whose principal function is to enclose the union of starch granule cells. An unfilled or non-continuous matrix with many air spaces results in a weak matrix and thereby, a soft wheat endosperm.

During milling, the percentage of mechanical damage that occurs to the starch granules of soft wheats is smaller in comparison to the hard wheats (Kent, 1983). The resulting flour with high content of damaged starch of the hard wheats is associated with characteristics of higher water absorption, diastatic activity and gassing power, which are important traits for baking purposes (Williams, 1967).

Genetics of Hardness

The primary factor that determines wheat hardness is genetically controlled and appears to be related to factors influencing the degree of compactness of endosperm cell components (Stenvert and Kingswood, 1977). In two separates studies, Symes (1965, 1969), evaluated the genetics of kernel hardness as measured by the particle size index (PSI). In both studies he used the cultivars 'Falcon' (hard wheat) and 'Heron' (soft wheat). In the first study, kernel hardness was measured on an F2 population derived from the cross between these genotypes. In the second; hardness was estimated from isogenic lines. In both cases, he concluded that hardness was controlled primarily by one major gene, although its influence was slightly modified by at least two minor genes. Also, he associated the superiority of Falcon in milling extraction, loaf texture, and dough handling characteristics with the gene which causes it to have a hard endosperm. On the other hand Baker (1977), used an "inbred backcross" model as well as grinding time to study the inheritance of kernel hardness in two spring wheats: 'Pitic 62', a soft wheat, and 'Neepawa', a hard wheat. From this study he concluded that hardness was governed by two major genes and one or more minor genes.

In further studies on wheat hardness, Sampson et al. (1983), used grinding time and NIR scores of different genotypes with a wide range of hardness derived from the cross 'Pitic 62' (soft) X 'Opal' (hard). A hard X hard cross gave only hard progeny; a medium X soft cross gave mostly soft progeny; a soft or medium X hard gave a wide range of hardness types. From these results, he suggested a single gene difference between hard and soft wheats.

Lukow et al. (1989), pointed out that since there were apparently no major genes conferring medium kernel hardness, the development of wheat varieties of the Canada Prairie Spring class could be achieved only by the accumulation of minor (modifier) genes which either soften the effect of the major gene for hardness or conversely harden the effects of the major gene for softness.

To determine the degree to which chromosome number and species directly affect grain hardness in wheat, Williams (1986) reported that using the PSI method, cultivars with the DD chromosome have very soft kernel texture. Tetraploid cultivars with the assemblage of chromosomes AABB had a very hard kernel texture. But contrary to the expectations, the resulting hexaploid AABBDD (common wheats), derived from the combination between DD genome types and the AABB (durum types), possessed the full range of hardness from very soft to very hard.

The chromosome substitution lines 7B and 5D of the hard red winter wheat cultivar 'Cheyenne' were identified with the PSI method as possessing the genes for high flour yield, and the 5D line was identified as possessing genes for kernel hardness (Mattern et al., 1973). These findings were supported by the results obtained by Doekes and Belderok (1976), in which they used a different set of chromosome substitution lines as well as different methodology to assess kernel hardness (starch damage content). They found that higher kernel hardness values and increased baking absorption were located on chromosome 5D in all the plant materials they used. They added that genetic factors for dough making and certain baking properties were located on chromosomes different from those responsible for kernel hardness and baking absorption.

Measure of Kernel Hardness, The Near Infrared Reflectance (NIR) Method

Several methodologies have been used to describe the hardness of the wheat kernel (Symes, 1961, Pomeranz and Miller, 1982, Gaines, 1986, Pomeranz et al., 1988), but despite the wide use of hardness in trade and classification, no one method has been commonly accepted. Among the techniques, the Near Infrared Reflectance (NIR) Spectroscopy has recently gained popularity because of its rapidity and accuracy in screening a large number of samples. The principle of this method is that the reflectance signal in the near infrared spectrum increases with increasing particle size, and the particle size of whole ground wheat increases with the level of hardness (Norris et al., 1989).

The NIR system was used by Williams (1979), to screen wheat samples for protein as well as hardness. He pointed out, that the analysis of the NIR was markedly affected by the mean particle size (MPS) of the ground material and this tended to be highly correlated with the PSI. The NIR, after being calibrated against the PSI of hard and soft wheats was sensitive enough to detect hardness differences within the hard as well as soft wheat classes.

Four methods (work to grind, time to grind, particle size (PSI) of ground wheat, and NIR reflectance of ground wheat), were used to measure the hardness of wheat cultivars by Miller et al., (1982). The cultivars represented a wide range of hardness from common wheats (soft and hard), to durum wheats. Of the four methods, the work to grind method was the only method that did not distinguish between common wheats and durum wheats. Hard red winter (HRW) wheat was distinguished from hard red spring (HRS) by work to grind and PSI. The differences however were extremely small. The NIR, was able to distinguished between HRW and SRW wheat and between durum and all other wheat classes.

In an effort to establish a tentative NIR index for the identification of wheat on basis of hardness, Williams and Sobering (1986), used the logarithm (base 10) of the reciprocal of reflectance (log 1/R) that at any point on the NIR spectrum increases with increasing particle size of whole ground wheat. Hence, the larger the reciprocal of the reflectance the harder the wheat and vice versa. To develop the index, in which wheats are evaluated on scale from 0 to 100, they used NIR values at 1680 and 2230 nm which were found to be highly correlated with PSI values.

The definitive breakthrough of the use of NIR in determining wheat kernel hardness was achieved recently by Norris et al. (1989), when they proposed a different definition of hardness. For their study, they included the same wave lengths (1680 and 2230 nm), that were used by Williams and Sobering (1986). The main difference between definitions consisted in that the measurements were not calibrated on the basis of PSI values. Instead, they chose coefficients to maximize the precision of the measurement. They then defined kernel hardness by the following equation: Hardness Score = (a + b1680) (L1680) + (b2230) (L2230), where: a and b are standardizing constants, and L is the log (1/reflectance) value at 1680 and 2230 nm.

Besides the equation, Norris et al. (1989) developed a standardized methodology for grinding wheat samples, taking the required NIR measurement and translating the measurement into a scale in which hardness scores of common wheat (soft and hard), ranged from 0 to 100 units. With the use of this scale, a set of soft wheats (SRW, white, club) averaged 25 units and the hard wheats (HRW, HRS) averaged 75 units. In general the precision of the measurement (average standard deviation of replications) was approximately 2.5 hardness units. At present, this method has been accepted as standard procedure (Method 39-79) by the American Association of Cereal Chemists, (AACC, 1983).

In a recent comprehensive study in which the NIR approved method was used, Slaughter (1989), reported on the hardness evaluation of more than 1900 wheat samples representing more than 125 varieties. From this study, he concluded that wheat hardness varied with variety, growing environment, and growing location. Moreover, Martinez (1989) pointed out that on the samples described by Slaughter (1989), there was a range in hardness values within each wheat market class examined and also there was some overlap in hardness between market classes.

Correlation Between Kernel Hardness With Flour Yield, Protein Content, Mixing Time and Sedimentation Value. High flour yield extraction is one of the milling characteristics which is presumed to be closely associated with kernel hardness. Finney et al. (1987), reported that either extremely hard or extremely soft wheat kernels usually had lower flour extraction. When Baker and Dyck (1975), compared soft and hard wheats, they found that hard wheats had significantly higher flour yield extraction. Wheats having good quantity of protein as well as good quality of protein are traditionally described as desirable from the viewpoint of bread-making properties as well as nutritional aspects. The relationship between protein content and kernel hardness has been studied with different methodologies by a number of investigators. Obuchowsky and Bushuk (1980), reported that protein content of debranned wheat had no effect on endosperm hardness. Similar results were obtained by Seka (1989), with the use of the NIR. Moreover, Pomeranz and Miller (1982), studied this relationship with four different methods (including NIR) and concluded that the protein content for samples within classes did not significantly affect hardness.

Wheats of good baking quality should have adequate mixing times as well as stable dough (Doekes and Belderok, 1976). Dough is develop during mixing and fermentation of the flour. Lebsock et al. (1963), stated that a long mixing tolerance is one of the most important quality characteristics considered in the evaluation of early generation progenies of bread wheat. Studies of the relationship between mixing time and kernel hardness as measured by different methodologies have shown conflicting results. Fowler and De la Rouche (1975), evaluated hardness with grinding time and concluded that this relation was positive and highly significant in different spring and winter European wheats. Conversely, Baker and Dyck (1975), found that this relationship was also significant, but negative in two spring wheat (hard and soft) crosses. On the other hand Doekes and Belderok (1976), found no relation between these characteristics when they estimated kernel hardness based on starch damage content.

In addition, mixing time can also be used to predict bread loaf volume, dough oxidation requirement, bread making and water absorption of hard wheats (Finney et al., 1987).

Hoseney (1986), stated that protein quality described the ability of the gluten proteins to form a strong cohesive dough that retains gas and is independent of protein content. The "strength" of the wheat is estimated by the sedimentation test (Method 56-61A), (AACC, 1983). This method has been reported by the Board of Grain Commissioners for Canada as a more reliable method in comparison to protein content for expressing the relative baking quality of early generation wheats (Lebsock et al., 1963). The correlation between this test and kernel hardness (estimated as PSI) was reported as high by Fowler and De la Rouche (1975). However, Baker and Dyck (1975), found that this relationship tends to be nonsignificant within either hard or soft wheats classes.

CHAPTER III

MATERIALS AND METHODS

Grain samples of four different winter wheat genotype-evaluation nurseries from the Oklahoma wheat breeding program were used in this study. The samples were taken from the crop year 1989 at Lahoma and Stillwater, OK. In crop year 1990 three of the four nurseries were sampled from Lahoma and Stillwater, while the remaining nursery (VHPN) was sampled only at Stillwater. Each of the four nurseries contained different sets of HRW wheats cultivars that were developed through different breeding procedures in order to meet different objectives.

The Intermediate Wheat Performance Nursery (IWPN) as well as the Advance Wheat Performance Nursery (AWPN), contained different sets of winter wheats lines that were developed by the Oklahoma wheat breeding program. Generally the IWPN contains F6 generation lines, while the AWPN contains lines in F7 to F9 generations. The number of lines and check cultivars included in the IWPN for this study was 30 in 1989 and 15 in 1990. The lines and check cultivars evaluated in the AWPN were 30 in 1989 and 18 in 1990.

The Southern Regional Performance Nursery (SRPN), contained 45 HRW wheats lines and cultivars in 1989 and 38 in 1990. These HRW wheats were developed through different private and public breeding programs in the region.

The Variety Hybrid Performance Nursery (VHPN), contained varieties as well as hybrid wheats that are intended to be released and marketed in the state of Oklahoma. These materials were developed by various breeding programs in the region, both public and private. The VHPN contained a total of 40 cultivars in each year.

Samples consisting of 150 grams of cleaned grain from each entry were taken after harvest for analyses by the Wheat Quality Laboratory, Agronomy Department, Oklahoma State University. There, the following variables were evaluated: protein content, percent flour yield, mixing time, mixing tolerance, specific sedimentation and kernel hardness.

Due to the time required to analyze the samples for the variables listed above, it was decided to perform the analyses only in those materials coming from the first replication from each nursery. Moreover, this is the standard procedure in the Oklahoma program for handling quality analysis of breeding samples. Consequently, for statistical analyses, locations were used as replications.

The analyses were conducted according to standard procedures of the American Association of Cereal Chemists (AACC, 1983) as follows:

Protein Content and Kernel Hardness
(AACC Methods 39-10 and 39-70)

A representative sample of approximately 13 g of wheat was ground on a Udy Cyclone mill and the ground sample analyzed for grain protein content and kernel hardness (14% moisture basis) using a near-infrared reflectance (NIR), Technicon 400, in which a wavelength of 2180 nm was used to estimate flour protein content. To minimize the interference over this wagelength, it is necessary to include the wavelengths 1680 and 2100 nm. The 2100 nm wavelength estimates the starch content whereas the 1680 nm wavelength is independent of protein and moisture (Rotolo, 1979). The results of the analysis of protein content performed with this method were periodically checked according to standard laboratory procedures, i.e. Crude Protein Kjeldahl with Boric Acid Modification (AACC Method 46-12). The resulting values of flour protein are commonly used to screen HRW wheats according to the following standards: flours with insufficient quantity of protein (<10.9%) are considered unsatisfactory for baking purposes. Flours with protein quantities from 11 to 13% generally are required for pan bread. Those flours with less than 12% of protein are considered less acceptable because they require longer mixing times (Pomeranz, 1988). Kernel hardness was estimated with the same equipment, but with the wavelengths of 1680 and 2230 nm. The reflectance values obtained with the NIR measured kernel hardness on a scale from 0 to 100 units, with 0 being the soft end and 100 the hard end of the range.

Wheat samples of 125 grams, were tempered (water added) to attain 15.5 % moisture for 16 to 24 h. The purpose of this tempering is to condition the bran and endosperm to facilitate separation of these parts of the kernels in the milling process. Following the tempering, the samples were milled on the Brabender Quadramat Senior mill to obtain flour for additional quality tests.

Flour Yield

Flour extraction was estimated on the basis of wheat milled at 14% moisture basis in a three step calculation. The first step included the calculation of the weight of the tempered wheat (Y) at 14% moisture basis. The second step estimated the weight of the flour "as received" (X) at 14% moisture basis. The third step was the calculation of percentage of flour recovery or milling yield which involved the results of the first and the second steps, i.e.: Flour Yield = (X * 100) / Y.

Mixing Time and Mixing Tolerance (AACC Method 54-40)

Wheats of poor baking quality may be screened from a breeding program based on mixing time. To evaluate the mixing properties of the flour, samples of 10 grams of flour were placed in Swanson-Working Mixograph. The mixograph records the resistance of the dough to mechanical mixing. From the resulting mixograph, mixing time was estimated as the time required (in minutes) for the dough to reach a state of minimum mobility or mixogram peak time. Flours with a short mixing time (0 to 3 min) correspond to poor quality flours which produce a low loaf volume bread. An acceptable flour has a medium to medium-short mixing time (3.25 to 3.75 min). A less acceptable flour is indicated by a medium mixing time (4 to 5.25 min). Flours with a very long mixing time (>5.5 min) are not acceptable because they to have to be blended prior the use (Dougherty, 1990). To estimate mixing tolerance, the mixograph is visually graded. The descending angle as well as the width of the curve from the point of the mixing peak are taken in consideration to score the graph from 1 to 10. Where 1 is poor and 10 is highly tolerant. A weak flour, i.e. an intolerant flour is indicated by a curve that after reaching the mixogram peak, shows a narrow curve width as well as rapidly descending angle. By contrast, a strong flour, i.e. a highly tolerant flour, is indicated by a wider curve width as well as by a less rapidly descending angle. Weak flours, considered as unacceptable have scores from 1 to 2. Flours with acceptable tolerance have scores between 3 and 6. Those considered as highly tolerant flours have scores from 7 to 10 (Dougherty, 1990).

Specific Sedimentation

In order to measure this variable which is affected by the quantity as well as the quality of the protein, it is necessary to obtain the value of the Sedimentation Test (AACC method 56- 61A). This test measures the quality of the protein and is based on the swelling properties of flour protein in a slightly acid suspension. The sample is shaken mechanically in a lactic acid medium for ten minutes and then allowed to settle for exactly five minutes. The height of the settled sample is the sedimentation value and reflects the degree of swelling of the protein in the sample. Specific sedimentation is obtained by dividing the flour protein content by the sedimentation value. Very poor quality flours may be screened out when indicated by very low sedimentation values. (Abbott, 1990).

Statistical Analysis. Separate analysis of variance (ANOVA) for each nursery at each year were done to determine differences between genotypes in each of the six variables described above. In those analysis locations were used as replications. Least significant differences (LSD) were calculated to compare means. The mean square for errors were used to estimate coefficients of variation (CV) as well as the LSD. Correlation coefficients for each nursery in each year were also calculated to assess the relationship between kernel hardness with the other five variables. Additional correlation coefficients in which the four nurseries were combined on yearly basis were also calculated with the same purpose. The analysis of variance as well as the correlation coefficients were calculated with the use of the MSTAT version 4.0 (Nissen, 1986).

CHAPTER IV

RESULTS AND DISCUSSION

Kernel Hardness Patterns

Values for kernel hardness and five end-use wheat quality characteristics from individual tests, locations, and years are shown in Tables 1 to 15.

Kernel hardness scores for the cultivar 'Chisholm' ranged from 44.7 to 58.0, with an average of 50.9 units across locations and years. On the other hand the cultivar '2180' (formerly Pioneer 2180) had hardness values ranging from 83.0 to 101.1 units with an average of 92.9. This would likely be one of the highest scores for HRW wheats. Most of the other check cultivars in the various tests fell between 'Chisholm' and '2180' (Tables 1 to 15).

Although the break point score for kernel hardness of HRW wheats has not yet been established by the FGIS, the score of 50.0 has frequently been mentioned. In addition, it is presumed that a break-point score above the score of 50.0 would be desirable to allow for some variation due to environmental effects. Therefore, a score of 60.0 would seem to be a realistic target as a minimum hardness score for breeders of hard red winter wheat (Smith, 1990).

With respect to the hardness scores for the genotypes included in the SRPN, these ranged from 29.4 to 95.7 units, but most of these genotypes had values above 60.0 units in both locations and years (Tables 5 to 14).

A large majority of the pure lines genotypes as well as hybrids included in the VHPN had acceptable performance with respect to kernel hardness (scores above 60.0 units). The highest and the lowest scores observed corresponded to '2180' and 'Collin' with 98.1 and 26.2, respectively (Tables 7 to 15).

The average kernel hardness values as well as the average values for five end-use quality characteristics from two locations for each of the four nurseries sampled in 1989 and 1990 are shown in Tables 16 to 22.

With respect to the AWPN in 1989, 11 out of 18 Oklahoma breeding lines (identified by OK prefix followed by an identification number) were below hardness average value of 60.0 and would be of concern to the plant breeders. Four of these lines had hardness values below that of 'Chisholm' (Table 16).

From the lines included in the IWPN in 1989, 15 of 24 Oklahoma breeding lines fell below the average of 60.0 hardness units, and 9 of these were below the hardness value of 'Chisholm' (Table 17).

The AWPN in 1990 included 11 Oklahoma breeding lines, 5 of which had hardness averages below 60.0. None of these lines was below 'Chisholm' (Table 18).

In 1990 the IWPN contained 9 Oklahoma lines all of which had hardness scores above 'Chisholm'. Only 1 of these lines was below 60.0 units (Table 19).

The hardness scores of 5 Oklahoma lines included in the SRPN in 1989 ranged from 50.5 to 70.0, with only one line falling below 60 units. In terms of source of origin, the lines generated by the Texas A & M University wheat breeding program had the highest hardness scores, followed by lines from the University of Nebraska wheat breeding program (Table 20). During 1990, the hardness scores for all 4 Oklahoma lines included in this nursery were below 60 units. In terms of origin, the University of Nebraska lines ranked first according to kernel hardness followed by the lines from Texas A & M University and Kansas State University. The Oklahoma lines had lower hardness scores in comparison to those lines (Table 21).

Of the 40 genotypes included in the VHPN in 1989, 8 had hardness scores below 60.0 units. Traditionally this nursery has been an important source of progenitors for the Oklahoma wheat breeding program. Consequently, those lines below 60.0 units cannot be considered as useful parents stock in a breeding program.

In terms of kernel hardness approximately 50% of the Oklahoma breeding lines in the 1989 and/or 1990 AWPN, had scores of sufficient magnitude to be considered as potential cultivars (Tables 1, 2, 9, 10). These were: OK84286, OK84287, OK86215, OK86216, OK87512, OK87555, OK87558, OK87575, OK88701, OK 88745 and OK88775.

Slightly more than 50% of the breeding lines in the 1989 and/or 1990 IWPN had acceptable hardness scores (Tables 3, 4, 11, 12). These were: OK88701, OK88753, OK88773, OK88775, OK88803, OK88810, OK88813, OK88829, OK88735, OK85182-61, OK85276-49, OK89328, OK89399, OK89421, OK89428, OK89451, and OK89499.

Although some genotypes were tested in both years of the study, no attempt was made to identify year to year variation in kernel hardness because the study was not designed to investigate this type of influence on hardness variation. Other studies have been initiated in Oklahoma to examine this aspects of kernel hardness.

Relationship Between Kernel Hardness and Five End-Use Quality Characteristics

An analysis of variance was conducted on a yearly basis to evaluate the six variables estimated in each of the four nurseries (Table 23 and 24). For the purpose of the analysis the two locations, Lahoma and Stillwater, were used as replications. On the other hand, since the VHPN was analyzed from only one location (Stillwater) during 1990, it was excluded from the analysis of variance for that year. The results of this analysis indicated the presence of significant differences among genotypes in all nurseries for kernel hardness, flour protein content, mixing time and specific sedimentation in both 1989 and 1990. The analysis of variance did not show significant genotype differences for flour yield or mixing tolerance in all of the nurseries in either year. For flour yield, only the IWPN had no significance genotypic differences either year. For mixing tolerance, no genotypic differences were observed in the IWPN in 1989 or the AWPN in 1990. In general the coefficients of variation (C.V.) were low for most of the variables in both years. An exception was observed for mixing tolerance, which had the highest C.V. (from 12.2% to 24.2%) (Tables 23 and 24). These high

C.V.'s can probably be attributed to the subjectivity of the visual scale, which was the method used to score tolerance.

Simple correlation coefficients between all pairs of variables for each nursery during 1989 as well as 1990 are presented in Tables 25 to 32. Similarly correlation coefficients bases on the combination of the four nurseries from both locations were carried out for each year (Tables 33 and 34).

With respect to the correlations between kernel hardness and flour protein content, an absence of correlation was observed during 1989 in all nurseries. But in 1990, as shown in Tables 28 and 32, two nurseries out of four were correlated with r values of 0.336* (AWPN) and, 0.285* (SRPN). On the other hand, correlation coefficients calculated for the combination of nurseries (Tables 33 and 34), indicated an absence of correlation between these two variables in both years. The null relation between kernel hardness and flour protein content was also reported by Pomeranz and Miller (1982) and by Seka (1989).

Kernel hardness and flour yield, were positively correlated for the SRPN in both years (r = 0.289** and 0.394**), but the magnitude of these correlation was relatively low (Table 31 and 32). From the remaining three nurseries, the VHPN was also positively correlated (r = 0.411**), but only during 1990 (Table 30). In the case of the combination of nurseries, a significant correlation coefficient (r = 0.230**) was also found, but only in 1990 (Table 34).

Correlation coefficients between mixing time, mixing tolerance and specific sedimentation with kernel hardness revealed significant negative relationships. With regard to mixing time vs. kernel hardness and mixing tolerance vs. kernel hardness, the IWPN showed significant negative correlations in both paired combinations in both years. These relations in 1989 were (r = -0.326** and r = -0.321**) and in 1990 were (r = -0.645** and r = -0.635**) for mixing time vs. kernel hardness and mixing tolerance vs. kernel hardness respectively (Table 25 and 26). For the rest of the nurseries, only the AWPN showed a significant negative correlation between mixing time and kernel hardness (r = -0.418**) during 1990 (Table 28). The combination of nurseries also indicated significant and negative correlation in both years, but only with mixing time vs. kernel hardness (r = -0.224** and r = -0.283**) (Tables 33 and 34).

For specific sedimentation vs. kernel hardness, significant and negative correlations were found for the IWPN (r = -0.404** and r = -0.556**), and for the AWPN (r = -0.317** and r = -0.413**) during 1989 and 1990 respectively (Table 25 to 28). Similar negative correlations were found from the combination of nurseries in both years (r = -0.267** and r = -0.273**), between kernel hardness and specific sedimentation (Table 33 and 34). These results are contradictory to the findings of Baker and Dyck (1975) as well as Fowler and De la Rouche (1975), in which the former, reported the null relation between these variables with either soft or hard wheats and the latter, found a strong relationships between these characteristics.

Of all the other two way comparisons involving flour protein content, flour yield, mixing time, mixing tolerance and specific sedimentation, only one comparison, that of mixing tolerance vs. mixing time showed consistent significant correlations. These ranged from r values of 0.365** to 0.806**.

CHAPTER V

SUMMARY AND CONCLUSIONS

The determination of kernel hardness by near infrared reflectance (NIR) has been proposed as a new analytical method to replace the existing subjective kernel morphology system as a way to classify US wheats into market classes. The basic assumption made is that kernel hardness has a strong relationship to end-use quality. There are concerns about this new method of classification since preliminary tests have indicated that Oklahoma wheats are on the low end of the HRW hardness scale. Therefore the objectives of this study were to examine the hardness levels of the Oklahoma wheat breeding lines with the NIR system and to study the relationship of kernel hardness with important milling and baking quality characteristics. Information on kernel hardness would impact on current and future breeding strategies in Oklahoma.

In this study the kernel hardness and five other milling and baking quality characteristics of four different winter wheat nurseries from the Oklahoma Agricultural Experimental Station wheat breeding program were evaluated during the crop years 1989 and 1990.

Based on the kernel hardness averages over two locations, the range of hardness of 24 Oklahoma breeding lines included in the AWPN in both years was from 50.0 to 76.1 units. However, 13 of these had hardness values below 60.0 units, the target break point for HRW wheats set for the breeding program. A similar situation was observed in which 17 out of 33 Oklahoma lines in the IWPN in both years had hardness scores below 60.0 units. The range of hardness in the Oklahoma lines in the IWPN was from 45.6 to 90.1 units. In the SRPN, in 1989 only 1 of 5 Oklahoma lines averaged less than 60.0 units. However, in 1990, 4 Oklahoma lines included in this nursery had averages of less than 60 units. The VHPN has been an important source of genotypes to be used as parents crossing in the Oklahoma wheat breeding program. Therefore those varieties with hardness averages below 60.0 units would not likely be considered for this purpose. It turns out, however, that the majority of genotypes in the VHPN would be potentially useful as parents stock for the Oklahoma program in so far as hardness is concerned.

A null relationship of kernel hardness with flour protein content was observed in both years. This result supports the general idea of lack of correlation between these characteristics. There was an indication that flour yield was positively correlated with kernel hardness in 1990. This correlation, although statistically significant had a low magnitude of coefficient. Mixing time was negatively correlated with kernel hardness in both years. It was observed in some cases that flours with longer mixing times had lower kernel hardness than the average values. A total absence of correlation was observed between kernel hardness and mixing tolerance in both years. With regard to the significant negative correlation between specific sedimentation and kernel hardness, this relation if it were strong would be undesirable for HRW wheat breeders since higher specific sedimentation values are required. However the correlation observed in this study was of small magnitude.

In conclusion, kernel hardness was positively correlated with flour yield and consistently but negatively correlated with the mixing time and specific sedimentation. These data suggest that with the possible exception of specific sedimentation, there would be no undesirable side effects to breeding for harder wheat kernel. Moreover, there did not appear to be any strong positive relationship between kernel hardness and any of the end-use quality characteristics examined in this study. This finding does not support the assumption that NIR hardness could be used to predict end-use quality values. The results suggest that good quality HRW wheats could be found within a wide range of hardness values. This study was limited to four nurseries grown at two locations in Oklahoma. Other studies might find different results.

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APPENDIX

TABLES

TABLE 1

MEAN PERFORMANCE FOR SIX VARIABLES OF 30 GENOTYPES IN THE AWPN GROWN AT STILLWATER, OK IN 1989. RANKED ACCORDING TO KERNEL HARDNESS.

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)
2180	96.0	12.8	53.8	5.5	3	5.0
TX81V6607-2	80.0	12.3	52.4	7.2	7	5.7
OK86215	79.5	13.1	54.6	8.7	4	5.5
OK87558	78.4	12.7	55.3	6.2	6	5.5
OK86216	73.5	12.5	51.4	5.2	4	5.0
Karl	70.9	13.5	56.2	7.7	5	5.3
OK84287	70.6	12.0	56.7	9.0	6	5.5
Mesa	70.2	12.6	54.6	5.7	4	5.4
Century	69.4	12.6	48.2	6.2	5	5.2
OK84286	67.8	12.5	54.7	7.3	3	5.1
OK87512	66.1	12.6	55.3	5.2	4	5.3
OK87555	66.0	13.3	56.1	8.5	5	5.2
TAM200	63.0	12.4	51.3	6.7	5	5.2
TX84V1336	63.0	12.3	53.8	8.2	6	5.6
OK87675	61.6	12.6	54.6	6.0	6	5.4
OK87575	60.8	13.0	54.7	8.2	5	5.3
CO820026	58.5	13.0	54.6	8.0	7	5.3
TAMW-101	56.1	12.7	53.0	6.2	5	5.6
Siouxland	55.9	12.5	56.1	6.7	4	5.3
OK84343	54.8	12.4	53.2	4.2	3	5.2
OK87542	54.3	12.5	54.6	7.7	5	5.6
OK87W667	53.4	12.6	55.5	8.7	6	5.6
OK87557	51.6	12.4	53.3	9.7	6	5.7
OK87630	51.4	12.2	52.9	7.7	4	5.7
OK87672	50.2	12.4	51.3	8.0	8	5.7
OK87W663	49.4	12.4	53.0	8.5	6	5.7
Chisholm	49.0	12.0	56.8	6.0	5	5.7
OK87507	47.0	13.2	51.4	4.5	3	5.0
OK86223	46.7	12.6	52.2	5.7	4	5.4
TX84V1317	43.3	12.0	53.2	9.7	9	6.1

TABLE 2

MEAN PERFORMANCE FOR SIX VARIABLES OF 30 GENOTYPES IN THE AWPN GROWN AT LAHOMA, OK IN 1989. RANKED ACCORDING TO KERNEL HARDNESS.

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)
2180	86.4	11.5	60.1	4.5	4	5.6
OK87512	74.8	12.1	61.1	4.0	4	5.6
Century	72.7	11.3	58.6	4.5	5	5.6
TX81V6607-2	69.5	11.4	60.1	4.7	4	5.8
OK86216	66.1	11.1	60.2	4.0	4	5.1
Mesa	66.1	11.7	63.6	5.0	3	5.7
OK84286	66.1	11.7	61.8	5.0	4	5.5
TAM W-101	64.6	12.0	58.6	4.5	4	5.8
OK87672	63.2	11.2	61.7	6.7	6	6.3
OK86223	62.5	11.5	61.1	5.0	4	5.7
OK86215	61.4	11.6	60.1	7.0	5	6.0
OK84287	61.1	11.5	63.4	5.7	5	5.7
Karl	61.1	12.2	61.1	6.5	4	5.5
Siouxland	60.1	11.6	61.8	4.5	4	5.4
OK87557	59.8	11.5	58.6	6.2	6	6.2
TAM200	59.8	11.5	58.7	5.2	5	5.9
Chisholm	58.0	11.3	60.3	5.3	4	5.0
OK87558	58.0	11.9	62.0	4.0	4	5.5
OK87555	57.5	12.6	60.3	6.7	4	5.6
OK87575	55.6	11.5	63.5	5.5	5	5.7
OK84343	55.0	12.3	57.0	3.0	2	4.6
CO820026	54.7	12.0	58.6	6.7	6	5.8
OK87W667	53.9	11.8	58.7	6.0	5	5.9
OK87507	53.4	12.1	59.5	3.5	3	5.1
OK87W663	53.1	11.8	61.9	6.2	5	5.9
OK87542	52.4	11.4	60.3	5.5	6	6.1
OK87675	49.9	12.4	59.9	5.2	3	5.2
OK87630	48.6	11.6	62.6	5.2	5	6.1
TX84V1336	43.6	11.0	65.1	6.0	6	6.2
TX84V1317	42.3	10.8	56.7	8.0	5	6.6

TABLE 3

MEAN PERFORMANCE FOR SIX VARIABLES OF 30 GENOTYPES IN THE IWPN GROWN AT STILLWATER, OK IN 1989. RANKED ACCORDING TO KERNEL HARDNESS.

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix Time (min)	Mix Tol. (1-10)	Spec Sed. (Units)
2180	91.6	13.0	51.2	5.5	4	5.0
Mesa	83.5	12.1	56.8	5.2	3	5.4
OK88829	81.0	12.3	54.3	4.7	3	5.2
OK88813	79.2	12.8	57.6	5.7	4	5.4
Siouxland	68.3	13.3	59.6	10.7	6	5.3
OK88735	67.5	12.9	53.2	7.0	7	5.5
TAM W-101	67.3	12.6	53.9	5.5	4	5.6
OK88773	64.9	12.7	54.4	7.0	7	5.5
OK88810	64.4	12.6	58.4	5.2	5	5.7
OK88775	64.1	12.9	52.8	6.2	6	5.0
OK88753	62.1	13.4	56.1	6.5	3	5.1
OK88721	59.3	11.6	56.8	5.0	4	5.7
OK88853	58.7	12.6	49.7	5.7	3	4.4
OK88803	58.6	13.1	59.2	5.5	4	5.4
OK88822	58.2	12.6	55.7	7.2	4	5.7
OK88701	57.5	12.4	51.7	5.2	5	5.4
OK88727	57.4	12.9	54.8	5.7	5	5.6
TAM 200	56.1	12.6	52.2	7.2	5	5.3
OK88718	55.8	11.9	54.7	7.2	4	6.0
OK88745	54.1	12.7	52.5	8.7	6	5.7
OK88729	54.0	13.2	53.3	10.2	6	5.5
OK88750	52.8	12.8	56.5	10.5	5	5.6
OK88W833	52.1	12.0	51.8	7.2	4	5.8
OK88796	52.0	12.8	53.8	9.5	5	5.5
Chisholm	51.5	12.6	51.6	10.7	5	5.6
OK88776	49.3	12.9	50.4	5.5	3	5.3
OK88744	48.8	12.8	53.2	6.7	6	5.6
OK88767	47.5	12.7	50.2	5.7	4	5.5
OK88W836	46.9	12.0	51.4	6.7	5	5.5
OK88712	46.0	11.4	53.9	6.2	4	6.1

TABLE 4

MEAN PERFORMANCE FOR SIX VARIABLES OF 30 GENOTYPES IN THE IWPN GROWN AT LAHOMA, OK IN 1989. RANKED ACCORDING TO KERNEL HARDNESS.

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix Time (min)	Mix Tol. (1-10)	Spec Sed. (Units)
2180	94.9	12.1	55.2	3.7	3	5.3
OK88829	83.6	12.2	60.2	3.2	3	5.6
OK88813	76.6	12.0	61.9	4.3	3	5.7
Mesa	73.9	11.9	62.0	4.5	3	5.9
OK88735	72.4	11.6	59.4	5.2	5	6.0
Siouxland	71.9	11.3	59.5	4.2	2	4.9
OK88701	67.4	11.6	59.1	5.2	4	5.8
OK88775	65.9	12.0	59.6	4.7	5	5.4
OK88773	65.5	11.7	65.3	4.7	4	5.9
TAMW-101	63.9	11.9	61.8	4.2	3	5.9
OK88753	61.9	11.7	63.1	8.5	7	5.9
OK88803	61.7	12.1	59.5	4.7	2	5.8
TAM200	60.2	11.1	63.6	6.2	5	5.8
OK88810	59.9	11.6	63.5	5.2	4	6.0
OK88727	59.5	12.0	59.4	4.7	5	5.9
OK88721	58.2	11.6	64.9	4.2	4	5.7
OK88776	57.3	12.0	58.7	6.0	5	5.7
OK88718	56.6	11.5	62.4	4.7	4	6.0
OK88853	56.5	12.2	54.6	4.0	3	5.1
Chisholm	54.1	11.8	61.9	7.7	7	6.0
OK88767	53.4	11.6	65.4	6.2	6	5.9
OK88750	52.2	11.6	60.3	7.0	6	6.0
OK88796	51.4	11.7	60.4	6.2	5	5.9
OK88729	48.7	12.2	61.9	7.5	5	5.8
OK88822	47.8	12.2	60.3	4.2	4	5.9
OK88712	47.2	10.9	60.7	4.7	4	6.2
OK88745	45.9	11.4	63.5	5.0	5	6.1
OK88744	45.7	11.9	62.0	5.7	6	6.0
OK88W836	44.4	11.1	61.1	6.0	4	6.0
OK88W833	43.9	11.7	61.8	5.5	4	6.0

TABLE 5

MEAN PERFORMANCE FOR SIX VARIABLES OF 45 GENOTYPES IN THE SRPN GROWN AT STILLWATER, OK IN 1989. RANKED ACCORDING TO KERNEL HARDNESS.

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix Time (min)	Mix Tol. (1-10)	Spec Sed. (Units)
2180	88.6	12.7	53.3	5.7	5	5.2
TX86V1110	82.0	14.0	55.1	2.2	3	5.1
TX86V1109	81.8	13.7	56.7	3.7	4	5.2
RL845472	80.5	12.0	54.1	3.2	4	3.8
NE83498	78.2	12.7	58.9	7.5	4	5.0
TXGH12588	77.0	11.1	59.0	6.2	6	5.5
OK84287	75.2	12.1	60.7	7.0	4	5.6
T1-2	75.0	11.8	54.2	5.5	6	5.5
TX87V1233	74.4	12.6	51.7	4.7	4	5.0
TX85V1326	73.7	12.8	58.1	4.2	5	5.4
WH32362	73.5	13.1	58.4	3.7	4	5.1
Scout 66	73.3	12.3	59.0	5.0	5	5.5
CLP#6	73.3	13.6	62.2	6.7	4	5.0
T15-2	72.3	12.4	51.8	3.5	5	5.3
XH900	72.0	12.5	56.7	5.7	5	4.9
NE86582	70.2	12.0	59.9	7.5	6	5.3
NE86606	69.2	12.6	57.4	8.0	5	4.8
NAW84-229	69.1	12.9	57.4	4.2	4	5.3
OK86216	68.8	12.3	54.0	6.7	5	5.4
TAM 105	68.7	11.9	56.5	4.2	5	5.2
2163	68.6	12.4	55.7	4.2	5	5.2
RL844677	68.2	11.4	58.9	4.2	5	5.4
NE84557	68.1	13.1	58.9	6.0	4	4.7
KS8010-72	67.5	12.6	58.2	5.5	4	4.6
TX84V1307	67.5	12.5	51.6	5.7	7	5.2
NE83407	66.8	11.5	58.3	5.0	5	5.5
OK86215	65.9	12.6	54.2	7.7	5	5.5
KS8010-142	65.9	12.4	55.7	3.7	4	4.9
TX86V1405	65.6	13.2	55.8	6.0	5	5.2
OK84286	65.5	12.4	56.0	6.5	4	5.3
XH736	65.5	12.9	56.7	4.5	5	5.0
NAW83-256	64.6	12.4	55.0	4.2	5	5.1
CLP#3	63.6	13.2	58.3	3.2	4	4.9
TX87V1316	63.4	12.7	54.9	3.5	3	4.7
XH884	60.1	12.2	55.8	5.2	7	5.2
WH52498	59.4	12.9	56.8	4.7	5	5.0
CO830014	58.5	12.5	56.5	6.0	4	5.4
TX86A8072	56.4	12.1	50.0	4.5	5	5.6
T21-1	53.6	12.4	58.2	3.2	4	5.0
OK86223	53.1	12.0	56.5	5.7	5	5.5
2157	52.0	13.2	54.3	6.0	5	5.3

TABLE 5 (Continued)

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix Time (min)	Mix Tol. (1-10)	Spec Sed. (Units)
WH180001	49.2	12.9	55.9	5.7	5	5.1
Kharkof	47.8	12.0	56.6	4.2	3	5.2
TX86A7041	46.0	12.0	51.9	4.5	3	5.5
TX84V2036	29.9	11.9	48.6	5.2	3	4.6

TABLE 6

MEAN PERFORMANCE FOR SIX VARIABLES OF 45 GENOTYPES IN THE SRPN GROWN AT LAHOMA, OK IN 1989. RANKED ACCORDING TO KERNEL HARDNESS.

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix Time (min)	Mix Tol. (1-10)	Spec Sed. (Units)
2180	86.4	12.1	54.5	4.0	4	4.8
T15-2	84.7	11.5	52.1	3.2	4	4.4
TX86V1109	79.6	12.1	59.3	3.0	4	5.5
TX85V1326	78.5	11.8	58.8	4.0	5	5.2
TX86V1405	77.2	11.3	56.9	4.5	5	5.9
TX86V1110	76.6	11.9	58.6	3.0	5	5.6
TXGH12588	76.0	10.4	54.4	5.0	6	5.6
T1-2	74.9	10.9	56.5	4.5	6	5.5
Scout 66	72.7	12.4	58.4	3.7	4	5.3
TAM 105	72.6	11.4	55.1	4.5	6	5.4
TX87V1316	72.5	12.1	55.7	3.0	3	4.5
NE84557	72.4	12.8	63.3	3.7	4	5.3
TX84V1307	72.2	10.6	55.3	5.0	6	5.6
CLP#6	72.1	13.4	59.0	2.7	3	4.9
RL845472	71.2	10.9	57.4	3.5	3	4.5
NE86582	71.2	12.0	61.3	7.0	5	5.7
NE83498	71.1	12.0	60.5	5.0	5	5.2
NE83407	71.0	12.3	61.4	4.7	4	5.6
TX87V1233	70.1	11.5	52.0	4.0	5	5.3
OK84286	70.1	11.4	57.7	5.7	7	5.5
CLP#3	70.1	12.8	59.1	2.7	3	5.0
WH52498	70.0	12.5	56.8	3.5	4	5.3
KS8010-142	68.3	12.2	59.3	3.0	3	4.1
OK86216	68.2	12.1	53.0	5.5	6	5.5
WH32362	68.0	12.7	60.8	3.5	4	5.2
XH736	67.3	12.3	60.6	5.0	5	5.1
CO830014	67.1	11.6	57.3	4.5	4	5.9
NE86606	67.0	11.7	62.2	5.2	5	5.8
2163	66.6	11.5	58.1	4.5	5	5.3
XH900	65.1	11.9	57.4	3.7	6	5.3
XH884	64.9	11.6	59.8	6.5	6	5.9
OK84287	64.8	11.5	58.6	6.2	6	5.4
RL844677	64.1	10.7	62.3	4.5	4	4.3
NAW83-256	62.7	11.2	59.1	3.7	4	4.7
KS8010-72	61.3	11.6	58.8	5.0	4	5.2
OK86215	59.9	11.8	54.5	9.0	6	5.2
TX86A8072	59.8	10.8	54.4	5.0	5	5.9
NAW84-229	59.8	12.0	60.7	3.2	3	5.1
T21-1	57.1	11.9	59.9	3.7	4	5.4
2157	54.2	11.9	59.9	4.7	4	5.7
TX86A7041	53.1	11.7	52.2	4.5	4	5.2

TABLE 6 (Continued)

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix Time (min)	Mix Tol. (1-10)	Spec Sed. (Units)
WH180001	52.0	12.5	55.9	4.2	4	5.4
Kharkof	48.6	12.3	52.5	5.5	4	4.8
OK86223	48.0	11.9	56.2	5.5	6	5.5
TX84V2036	29.4	12.1	48.9	5.2	4	5.2

TABLE 7

MEAN PERFORMANCE FOR SIX VARIABLES OF 40 GENOTYPES IN THE VHPN GROWN AT STILLWATER, OK IN 1989. RANKED ACCORDING TO KERNEL HARDNESS.

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix Time (min)	Mix Tol. (1-10)	Spec Sed. (Units)
2180	98.1	12.8	50.5	5.2	5	4.8
Lamar	94.5	12.9	57.0	7.7	6	5.1
Hawk	82.7	12.5	58.1	6.7	7	5.4
Thunderbird	82.4	13.1	59.4	5.0	5	5.2
Cody	78.5	12.1	52.2	6.5	6	5.0
Abilene	77.6	13.3	53.0	6.5	7	5.4
Mesa	77.3	11.9	55.5	4.2	5	4.5
Mustang	76.1	12.7	54.7	5.5	6	5.4
Stallion	74.6	13.5	55.5	6.2	5	5.1
WH32362	74.4	12.2	53.9	4.2	5	5.1
TAM107	73.8	11.8	50.0	7.7	7	5.7
Osage	73.0	12.4	56.0	4.2	5	5.3
QT554	72.8	12.3	54.3	4.5	5	4.8
Arapaho	72.2	12.4	54.1	5.2	5	4.8
Scout 66	72.1	12.8	52.9	5.2	5	5.4
Redland	72.1	11.7	56.1	7.0	7	5.3
W84-229	71.4	12.5	57.1	4.5	4	4.8
TAM200	69.9	12.0	50.4	5.7	6	5.4
Arkan	69.6	13.0	54.7	7.2	5	5.3
Century	68.8	12.5	46.0	8.7	6	5.3
Dodge	68.0	13.8	53.8	7.2	5	4.9
TAM105	67.8	11.9	51.3	5.2	6	5.7
TAM201	67.6	12.2	51.5	5.7	6	5.6
Triumph 64	67.1	13.8	55.6	6.2	4	5.2
RHS7837	65.2	13.3	51.6	9.5	6	5.2
Karl	64.2	13.3	54.7	7.2	6	5.3
Payne	63.1	12.6	49.2	6.7	6	5.4
RHS7846	63.0	12.8	52.3	5.7	5	5.2
QT574	62.8	12.7	48.3	6.5	6	5.1
TAMW-101	62.0	12.2	50.5	4.7	5	5.7
QT578	61.6	12.8	50.7	5.0	6	4.8
Siouxland	61.5	12.1	54.6	5.0	5	4.3
WH52498	59.7	12.9	51.5	5.0	5	5.0
Newton	59.5	12.5	56.2	6.5	6	5.3
Vona	59.5	12.3	50.6	6.0	6	5.2
WH18000	56.9	11.5	51.7	4.5	5	5.4
171	52.8	12.8	50.6	6.0	4	5.3
Chisholm	48.6	12.3	51.6	7.7	8	5.6
2157	47.4	13.6	53.8	8.2	5	5.3
Collin	34.6	12.0	48.6	6.7	7	5.0

TABLE 8

MEAN PERFORMANCE FOR SIX VARIABLES OF 40 GENOTYPES IN THE VHPN GROWN AT LAHOMA, OK IN 1989. RANKED ACCORDING TO KERNEL HARDNESS.

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix Time (min)	Mix Tol. (1-10)	Spec Sed. (Units)
2180	83.0	12.1	54.4	4.2	4	5.3
Lamar	82.2	12.0	61.8	4.2	5	5.5
Mesa	77.9	12.0	57.7	4.2	4	5.7
Thunderbird	76.8	12.2	62.0	3.5	4	5.6
TAM107	75.0	10.5	59.9	4.5	5	6.1
Scout 66	74.6	12.2	61.7	3.7	4	5.5
Arapaho	73.2	11.9	63.4	4.5	5	5.5
Cody	73.1	11.4	61.8	6.2	6	5.6
Redland	72.8	10.9	64.0	5.2	6	6.1
Century	70.4	11.6	52.1	4.7	5	5.6
Payne	69.7	12.2	58.7	5.2	5	5.6
Siouxland	69.1	11.2	61.2	4.0	3	4.8
TAM105	68.9	11.0	58.4	4.2	5	6.2
Hawk	68.1	11.3	60.9	5.0	5	5.8
QT554	67.7	12.2	58.5	4.7	5	5.5
Mustang	67.3	11.2	62.6	3.2	4	5.1
Abilene	67.1	11.8	62.5	5.0	4	5.8
Arkan	66.4	11.9	60.2	4.7	4	5.6
Stallion	66.3	11.9	60.1	5.5	4	5.7
WH32362	66.2	12.6	60.3	4.0	4	5.5
Vona	63.9	11.1	57.7	5.2	6	5.8
TAM201	63.2	11.0	54.4	4.5	6	6.4
WH52498	62.7	12.1	58.6	3.7	4	4.7
QT578	62.5	12.2	58.4	3.7	4	4.6
Karl	61.8	12.5	61.0	6.7	5	5.6
Dodge	61.1	13.2	61.1	5.2	5	4.7
2157	60.4	12.0	62.5	5.5	4	5.7
TAM200	59.4	10.7	57.6	5.5	6	5.5
RHS7837	58.5	12.1	60.1	6.5	5	5.7
QT574	58.0	12.2	56.9	4.0	5	5.5
W84-229	58.0	12.2	58.5	4.2	4	5.7
TAMW-101	57.7	12.0	57.7	3.2	5	5.8
Triumph 64	55.9	12.1	60.1	4.0	4	5.6
Osage	55.7	12.2	58.8	2.7	4	5.6
WH18000	54.7	12.4	54.9	5.5	5	5.4
RHS7846	54.1	11.3	60.9	5.0	4	4.9
Newton	52.0	12.0	58.6	4.5	5	5.7
Chisholm	44.7	11.5	59.6	5.2	4	5.9
171	40.9	12.2	55.3	4.0	3	5.7
Collin	26.2	11.7	52.1	5.0	5	5.4

TABLE 9

MEAN PERFORMANCE FOR SIX VARIABLES OF 18 GENOTYPES IN THE AWPN GROWN AT STILLWATER, OK IN 1990. RANKED ACCORDING TO KERNEL HARDNESS

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)
2180	95.5	12.0	58.3	3.5	5	4.7
Cimarron	77.3	11.3	60.1	5.5	6	4.7
OK88775	76.9	11.9	58.3	3.2	4	3.8
Karl	73.5	12.4	61.4	6.0	5	5.4
OK87575	69.9	12.3	61.6	4.0	4	4.6
Mesa	68.4	11.3	57.5	5.5	7	4.4
OK84286	68.1	11.3	59.9	4.7	5	4.6
TAM200	66.1	11.7	53.5	4.0	3	4.2
OK87555	65.0	12.0	62.4	5.2	4	5.1
Delange7846	63.6	12.0	59.1	3.2	4	4.5
OK88701	63.2	11.7	61.4	4.5	4	4.3
OK88745	59.5	11.8	64.7	4.5	4	5.3
OK88767	59.3	12.0	58.3	3.7	3	4.8
OK87542	59.0	11.8	55.1	4.7	4	5.4
OK87W66	56.1	11.0	59.7	4.7	4	4.8
OK88W833	52.5	11.9	60.7	5.7	4	5.3
OK88750	52.0	11.5	62.3	5.0	5	5.0
Chisholm	49.2	11.5	60.0	5.7	4	4.7

TABLE 10

MEAN PERFORMANCE FOR SIX VARIABLES OF 18 GENOTYPES IN THE AWPN GROWN AT LAHOMA, OK IN 1990. RANKED ACCORDING TO KERNEL HARDNESS.

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)
2180	94.2	12.6	60.5	3.0	1	3.4
OK88775	75.4	12.1	58.4	3.7	4	3.7
Cimarron	71.6	12.0	60.1	5.2	5	4.8
OK87575	71.0	12.6	61.5	5.2	3	4.5
Karl	70.7	12.9	59.7	4.5	4	5.0
OK84286	70.2	11.9	61.5	5.5	4	4.6
Delange7846	68.8	12.5	57.2	3.5	3	4.0
Mesa	66.8	11.8	59.3	4.5	5	4.2
OK87555	62.4	12.8	60.8	6.2	4	5.0
OK88745	61.3	12.1	60.6	5.0	4	5.0
OK88750	60.5	11.9	62.3	5.0	4	4.7
OK88701	58.5	11.7	59.0	5.0	4	4.4
OK87542	58.3	12.2	61.6	5.2	4	5.2
OK88W833	57.6	11.8	56.7	5.0	3	4.4
TAM200	56.4	11.9	55.1	4.2	3	4.1
OK87W66	56.1	11.8	58.2	6.0	3	4.5
Chisholm	51.9	11.6	58.2	4.5	3	4.5
OK88767	50.4	12.1	56.6	4.5	5	4.9

TABLE 11

MEAN PERFORMANCE FOR SIX VARIABLES OF 15 GENOTYPES IN THE IWPN GROWN AT STILLWATER, OK IN 1990. RANKED ACCORDING TO KERNEL HARDNESS.

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)
2180	101.1	12.2	60.3	2.7	3	3.6
OK89499	94.4	11.9	62.6	2.5	2	3.5
OK85276-49	84.0	11.9	60.2	3.0	3	3.3
OK89399	83.4	11.9	58.6	2.7	3	3.6
OK89328	75.7	12.6	59.5	2.5	3	3.1
Mesa	74.7	11.2	60.1	3.5	4	3.9
Siouxland	73.8	11.7	61.7	3.7	3	3.6
OK85182-61	73.7	11.9	59.4	4.2	4	3.7
OK89428	68.0	10.9	58.2	4.5	5	3.9
OK89421	66.4	11.5	59.4	4.7	5	4.5
OK89451	65.0	11.4	61.1	5.0	5	4.0
TAM200	62.4	11.5	56.1	3.7	5	3.8
Karl	57.6	12.9	60.3	4.0	4	4.4
OK89449	56.5	11.1	63.4	4.2	4	3.6
Chisholm	50.3	11.3	60.2	4.0	5	4.0

TABLE 12

MEAN PERFORMANCE FOR SIX VARIABLES OF 15 GENOTYPES IN THE IWPN GROWN AT LAHOMA, OK IN 1990. RANKED ACCORDING TO KERNEL HARDNESS.

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)
2180	93.9	13.0	56.0	3.7	4	3.6
OK89399	86.1	12.8	59.3	3.0	2	3.3
OK89499	85.8	13.5	61.8	2.7	3	3.4
Siouxland	79.4	11.9	56.7	3.2	2	3.2
OK89328	72.3	12.6	56.0	2.2	2	3.0
OK89428	71.8	11.5	64.1	4.7	4	4.2
OK85276-49	71.7	12.1	57.4	3.2	4	3.4
OK89421	68.8	12.0	60.1	4.7	4	4.1
OK85182-61	67.2	13.1	57.0	3.2	3	4.0
Mesa	65.3	11.7	58.4	3.7	4	4.0
Karl	64.7	13.2	58.6	4.5	4	4.7
OK89451	61.7	12.2	61.7	5.7	5	4.2
OK89449	59.2	11.6	61.0	5.2	5	3.9
Chisholm	55.0	12.3	57.8	4.5	4	4.0
TAM200	52.0	11.9	55.2	4.5	4	4.1

TABLE 13

MEAN PERFORMANCE FOR SIX VARIABLES OF 38 GENOTYPES IN THE PN GROWN AT STILLWATER, OK IN 1990. RANKED ACCORDING TO KERNEL HARDNESS.

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Unit)
NE87403	95.7	12.7	58.2	4.0	6	3.9
NE86582	92.8	12.1	61.3	5.0	6	4.0
XH1176	88.2	11.7	59.8	4.2	4	3.5
NE87615	87.3	12.4	62.2	4.7	6	3.9
CO850034	87.1	12.6	56.0	3.7	5	3.9
TX86D1310	86.1	13.1	57.6	3.5	4	4.8
2163	85.7	12.3	58.1	4.5	6	3.9
NE83498	85.3	12.1	60.6	4.2	4	3.5
TAM107	85.2	12.6	58.2	3.0	4	4.1
NE86606	85.1	11.5	62.2	4.2	5	4.0
KS87H6	83.5	12.3	59.0	4.2	5	4.2
TX87V1316	83.2	12.4	61.6	2.7	2	3.3
TX86V1405	83.1	12.0	54.9	3.5	5	4.0
KS8010-142	82.6	12.5	59.9	3.2	1	2.9
TAM105	80.7	12.2	57.2	3.2	3	3.5
KLEO-R	80.5	13.0	59.8	3.0	3	3.6
KS8010-72	79.2	12.6	62.3	3.7	2	3.0
XH209	79.0	11.9	59.0	4.5	4	3.6
TX87V1233	78.5	11.9	53.4	3.2	5	3.8
KLEO-W	78.2	12.7	60.6	2.7	2	3.4
TX86D1332	78.1	13.0	60.0	4.0	4	5.2
CO850260	76.7	11.9	55.0	4.2	4	3.7
TX84V1307	75.6	12.8	55.0	3.5	5	4.2
XH1017	75.5	11.7	59.1	3.5	3	3.4
CO850267	73.6	12.7	55.9	3.0	3	3.3
Scout 66	72.9	13.4	58.8	2.7	3	3.8
TXGH12588	71.2	11.9	55.7	3.0	4	4.3
CO850061	70.0	12.1	54.3	3.5	6	4.3
TX85V1326	68.5	12.7	58.5	2.7	4	3.9
TX86A8072	68.3	12.3	53.4	3.0	4	4.0
2158	63.5	11.9	57.4	3.7	3	4.0
XH1235	63.3	12.2	56.6	3.5	3	3.6
OK86223	62.9	11.9	56.6	4.0	4	4.1
Kharkof	60.6	12.9	54.5	3.5	3	3.4
OK87542	55.4	11.8	59.8	5.7	4	4.5
OK87W663	54.9	11.3	62.2	4.5	5	4.4
OK87630	50.7	11.9	56.6	5.5	5	5.4
TX84V2036	38.5	11.8	51.4	4.0	4	3.8

TABLE 14

MEAN PERFORMANCE FOR SIX VARIABLES OF 38 GENOTYPES IN THE SRPN GROWN AT LAHOMA, OK IN 1990. RANKED ACCORDING TO KERNEL HARDNESS.

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)
TX86D1310	92.6	12.8	57.7	3.2	4	4.9
NE87403	89.9	12.3	58.8	4.0	5	3.7
NE86582	87.3	12.4	61.1	5.2	6	4.4
2163	86.1	12.9	58.1	3.7	3	4.2
KS8010-142	85.8	13.2	59.4	3.2	2	2.8
NE87615	83.9	12.3	58.8	5.7	6	4.3
TAM107	83.6	11.8	58.4	3.0	4	3.8
KLEO-W	82.7	13.2	59.8	3.0	3	3.6
TX87V1316	82.1	12.0	60.9	2.7	2	3.2
TX86D1332	80.3	13.1	56.9	4.5	6	5.1
CO850260	80.2	11.1	55.1	4.2	6	3.6
XH209	79.7	12.7	59.0	4.5	4	4.5
CO850034	79.5	12.6	59.4	4.0	5	3.5
KLEO-R	78.7	13.6	60.7	3.7	3	3.9
KS87H6	77.9	12.6	59.4	6.0	5	5.1
XH1176	77.8	12.7	57.5	4.5	4	3.7
NE86606	77.7	11.7	65.9	4.5	5	4.2
XH1017	76.1	12.5	56.6	3.7	3	3.4
NE83498	75.4	12.0	61.8	5.7	6	3.7
Scout 66	75.2	13.1	59.8	3.2	4	3.7
TX85V1326	75.2	12.4	58.5	3.2	4	3.9
TXGH12588	74.7	11.3	55.1	3.5	4	3.9
TX86V1405	73.4	11.6	55.1	4.0	4	3.7
TX87V1233	72.6	11.1	55.2	3.2	3	3.5
TAM105	70.1	12.1	55.9	3.5	4	3.6
KS8010-72	68.1	13.4	62.6	3.5	3	2.9
TX84V1307	67.3	12.3	56.0	3.2	5	3.8
CO850267	64.8	12.5	53.5	3.7	3	3.4
CO850061	64.0	11.3	54.3	4.7	6	3.9
TX86A8072	62.9	11.9	56.0	3.0	4	3.8
2158	61.5	12.8	57.2	3.5	4	4.7
Kharkof	59.8	13.3	52.5	2.7	2	3.1
OK87542	55.9	12.4	61.7	5.2	4	4.9
OK87W663	55.8	12.1	59.3	5.7	4	4.3
XH1235	52.2	12.7	55.7	3.7	6	3.9
OK86223	50.9	12.0	58.3	4.2	4	4.1
OK87630	48.7	12.0	56.7	5.5	5	5.4
TX84V2036	30.9	11.0	53.4	4.5	3	3.8

TABLE 15

MEAN PERFORMANCE FOR SIX VARIABLES OF 18 GENOTYPES IN THE VHPN GROWN AT STILLWATER, OK IN 1990. RANKED ACCORDING TO KERNEL HARDNESS.

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)
2180	97.4	11.7	61.1	3.5	1	4.0
Sierra	90.7	11.4	58.8	4.0	5	3.9
Cody	88.8	11.3	62.6	6.7	7	4.1
Thunderbird	86.1	11.9	62.0	4.2	5	4.9
Lamar	85.6	12.8	64.3	5.2	6	4.9
Rall	85.6	13.5	62.8	3.7	3	4.7
Arapahoe	84.5	11.9	63.4	6.0	6	3.7
Payne	83.0	12.2	59.6	4.5	4	4.1
TAM-107	82.3	12.0	56.5	3.2	4	4.7
Hawk	82.2	12.0	62.8	6.0	7	4.3
Siouxland	81.4	11.9	63.7	3.7	2	3.4
KSWhite	81.1	12.7	55.7	6.5	4	5.2
TAM-105	79.8	11.3	56.4	3.7	4	3.7
Vona	79.6	11.9	57.1	4.5	6	4.1
Abilene	78.7	11.6	61.9	4.0	5	5.2
Scout 66	78.0	13.3	62.1	4.2	4	4.9
Carson	77.8	12.7	59.6	6.7	7	5.4
Redland	76.8	11.5	60.2	4.2	4	4.1
TAMW-101	76.2	11.7	59.6	3.2	5	4.9
Siouxland89	74.7	12.2	62.1	4.7	3	4.0
Century	74.0	11.6	56.5	4.5	4	4.0
Osage	72.5	13.2	61.3	4.0	2	4.8
AGSECO 7846	70.6	11.9	59.7	3.5	2	3.8
Quantum 577	70.6	11.7	58.9	4.2	5	3.7
Quantum 578	68.4	11.8	56.5	4.0	6	3.8
Karl	68.0	13.0	60.6	5.2	5	5.2
2157	67.7	11.5	62.7	3.5	2	4.1
Rio Blanco	67.5	12.0	59.6	5.2	8	4.6
Stallion	66.9	11.8	59.6	4.7	6	4.0
Mesa	66.3	11.1	60.4	4.0	2	4.1
Cimarron	64.8	10.9	59.6	7.5	5	4.6
Quantum 574	64.5	11.7	58.0	4.0	5	3.9
Triumph 64	64.4	12.9	62.1	3.5	3	4.7
Arkan	64.0	12.8	59.8	4.2	4	4.6
2158	64.0	11.7	59.6	3.7	3	4.1
Quantum 589	62.9	11.8	58.2	3.7	6	4.0
TAM-200	61.1	11.8	53.3	3.7	4	4.1
Newton	56.9	11.9	58.1	4.2	6	3.9
Chisholm	47.7	11.3	59.7	6.5	6	4.5
Collin	46.4	11.5	54.8	4.0	6	3.8

TABLE 16

MEAN PERFORMANCE FOR SIX VARIABLES OF 30 GENOTYPES IN THE AWPN GROWN AT LAHOMA AND STILLWATER, OK IN 1989. RANKED ACCORDING TO KERNEL HARDNESS.

Genotype	Kernel Hard. (1-100)	Flour Prot. (%)	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)
2180	91.2(1)	12.1(14)	56.9(18)	5.0(26)	3.5(27)	5.3(27)
TX81V6607-2	74.7(2)	11.8(24)	56.2(22)	6.0(16)	5.5(7)	5.7(10)
Century	71.0(3)	11.9(19)	53.4(30)	5.4(21)	5.0(13)	5.4(21)
OK87512	70.4(4)	12.3(6)	58.2(10)	4.6(28)	4.0(22)	5.4(19)
OK86215	70.4(5)	12.3(7)	57.3(15)	7.9(3)	4.5(17)	5.7(9)
OK86216	69.8(6)	11.8(25)	55.8(24)	4.6(27)	4.0(25)	5.0(29)
OK87558	68.2(7)	12.3(10)	58.6(6)	5.1(25)	5.0(11)	5.5(18)
Mesa	68.1(8)	12.1(13)	59.1(4)	5.4(24)	3.5(28)	5.5(16)
OK84286	66.9(9)	12.1(16)	58.2(9)	6.7(15)	3.5(26)	5.3(25)
Karl	66.0(10)	12.8(2)	58.6(7)	7.1(10)	4.5(21)	5.4(20)
OK84287	65.8(11)	11.7(27)	60.0(1)	7.4(5)	5.5(6)	5.6(12)
OK87555	61.7(12)	12.9(1)	58.2(11)	7.6(4)	4.5(18)	5.4(22)
TAM200	61.4(13)	11.9(21)	55.0(28)	6.0(17)	5.0(14)	5.5(15)
TAMW-101	60.3(14)	12.3(9)	55.8(25)	5.4(22)	4.5(20)	5.7(11)
OK87575	58.2(15)	12.2(11)	59.1(3)	6.9(12)	5.0(12)	5.5(17)
Siouxland	58.0(16)	12.0(17)	58.9(5)	5.6(19)	4.0(23)	5.3(23)
OK87672	56.7(17)	11.8(26)	56.5(21)	7.4(8)	7.0(1)	6.0(2)
CO820026	56.6(18)	12.5(5)	56.6(20)	7.4(9)	6.5(3)	5.5(14)
OK87675	55.7(19)	12.5(4)	57.2(16)	5.6(18)	4.5(15)	5.3(26)
OK87557	55.7(20)	11.9(22)	55.9(23)	8.0(2)	6.0(4)	5.9(3)
OK84343	54.9(21)	12.3(8)	55.1(27)	3.6(30)	2.5(30)	4.9(30)
OK86223	54.6(22)	12.0(18)	56.6(19)	5.4(23)	4.0(24)	5.5(13)
OK87W667	53.6(23)	12.2(12)	57.1(17)	7.4(7)	5.5(8)	5.7(8)
Chisholm	53.5(24)	11.6(28)	58.5(8)	5.6(20)	4.5(19)	5.3(24)
OK87542	53.3(25)	11.9(20)	57.4(14)	6.6(13)	5.5(9)	5.8(6)
TX84V1336	53.3(26)	11.6(29)	59.4(2)	7.1(11)	6.0(5)	5.9(5)
OK87W663	51.2(27)	12.1(15)	57.4(13)	7.4(6)	5.5(10)	5.8(7)
OK87507	50.2(28)	12.6(3)	55.4(26)	4.0(29)	3.0(29)	5.0(28)
OK87630	50.0(29)	11.9(23)	57.7(12)	6.5(14)	4.5(16)	5.9(4)
TX84V1317	42.8(30)	11.4(30)	54.9(29)	8.9(1)	7.0(2)	6.3(1)
Mean	60.83	12.13	57.20	6.23	4.78	5.56
C.V.	10.80	2.08	2.83	8.50	18.41	4.08
L.S.D.(.05)	13.44	0.51	3.32	1.08	1.80	0.47

TABLE 17

MEAN PERFORMANCE FOR SIX VARIABLES OF 30 GENOTYPES IN THE IWPN GROWN AT LAHOMA AND STILLWATER, OK IN 1989. RANKED ACCORDING TO KERNEL HARDNESS.

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)
2180	93.2(1)	12.5(3)	53.2(29)	4.6(29)	3.5(26)	5.1(28)
OK88829	82.3(2)	12.2(14)	57.2(19)	4.0(30)	3.0(28)	5.4(26)
Mesa	78.7(3)	12.0(23)	59.4(7)	4.8(25)	3.0(27)	5.6(19)
OK88813	77.9(4)	12.4(8)	59.7(4)	4.9(24)	3.5(24)	5.5(22)
Siouxland	70.1(5)	12.3(12)	59.5(6)	7.5(6)	4.0(22)	5.1(29)
OK88735	69.9(6)	12.2(16)	56.3(24)	6.1(11)	6.0(1)	5.7(10)
TAMW-101	65.6(7)	12.2(13)	57.8(14)	4.9(27)	3.5(25)	5.7(12)
OK88773	65.2(8)	12.2(19)	59.8(3)	5.8(14)	5.5(8)	5.7(14)
OK88775	65.0(9)	12.4(5)	56.2(26)	5.5(19)	5.5(6)	5.2(27)
OK88701	62.4(10)	12.0(24)	55.4(27)	5.2(20)	4.5(14)	5.6(20)
OK88810	62.1(11)	12.1(21)	60.9(1)	5.2(21)	4.5(15)	5.8(5)
OK88753	62.0(12)	12.5(4)	59.6(5)	7.5(5)	5.0(10)	5.5(25)
OK88803	60.1(13)	12.6(2)	59.3(8)	5.1(23)	3.0(29)	5.6(21)
OK88721	58.7(14)	11.6(28)	60.8(2)	4.6(28)	4.0(19)	5.7(16)
OK88727	58.4(15)	12.4(6)	57.1(20)	5.2(22)	5.0(9)	5.7(13)
TAM200	58.1(16)	11.8(25)	57.9(13)	6.7(8)	5.0(12)	5.5(23)
OK88853	57.6(17)	12.4(10)	52.1(30)	4.9(26)	3.0(30)	4.7(30)
OK88718	56.2(18)	11.7(27)	58.5(9)	6.0(12)	4.0(17)	6.0(2)
OK88776	53.3(19)	12.4(7)	54.5(28)	5.7(17)	4.0(21)	5.5(24)
OK88822	53.0(20)	12.4(9)	58.0(11)	5.7(16)	4.0(23)	5.8(8)
Chisholm	52.8(21)	12.2(18)	56.7(23)	9.2(1)	6.0(3)	5.8(7)
OK88750	52.5(22)	12.2(17)	58.4(10)	8.7(3)	5.5(5)	5.8(6)
OK88796	51.7(23)	12.2(15)	57.1(21)	7.8(4)	5.0(11)	5.7(15)
OK88729	51.3(24)	12.7(1)	57.6(16)	8.8(2)	5.5(7)	5.6(18)
OK88767	50.4(25)	12.1(20)	57.8(15)	6.0(13)	5.0(13)	5.7(17)
OK88745	50.0(26)	12.0(22)	58.0(12)	6.8(7)	5.5(4)	5.9(4)
OK88W833	48.0(27)	11.8(26)	56.8(22)	6.4(9)	4.0(20)	5.9(3)
OK88744	47.2(28)	12.3(11)	57.6(17)	6.2(10)	6.0(2)	5.8(9)
OK88712	46.6(29)	11.1(30)	57.3(18)	5.5(18)	4.0(18)	6.1(1)
OK88W836	45.6(30)	11.5(29)	56.2(25)	5.9(15)	4.5(16)	5.7(11)
Mean	60.22	12.17	57.58	6.07	4.48	5.63
C.V.	5.84	2.64	3.96	18.76	24.20	2.73
L.S.D. 0.05	7.19	0.66	4.66	2.33	2.22	0.32

TABLE 18

MEAN PERFORMANCE FOR SIX VARIABLES OF 18 GENOTYPES IN THE AWPN GROWN AT LAHOMA AND STILLWATER, OK IN 1990. RANKED ACCORDING TO KERNEL HARDNESS.

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)
2180	94.8(1)	12.3(4)	59.4(9)	3.2(18)	3.0(17)	4.0(17)
OK88775	76.1(2)	12.0(7)	58.3(14)	3.5(16)	4.0(9)	3.7(18)
Cimarron	74.4(3)	11.6(14)	60.1(8)	5.4(3)	5.5(2)	4.7(8)
Karl	72.1(4)	12.6(1)	60.5(6)	5.2(5)	4.5(3)	5.2(2)
OK87575	70.4(5)	12.4(2)	61.5(4)	4.6(13)	3.5(15)	4.5(12)
OK84286	69.2(6)	11.6(15)	60.7(5)	5.1(7)	4.5(5)	4.6(10)
Mesa	67.6(7)	11.6(17)	58.4(13)	5.0(10)	6.0(1)	4.3(14)
Delange7846	66.2(8)	12.2(5)	58.1(16)	3.4(17)	3.5(16)	4.2(15)
OK87555	63.7(9)	12.4(3)	61.6(3)	5.7(1)	4.0(11)	5.0(4)
TAM200	61.2(10)	11.8(11)	54.3(18)	4.1(15)	3.0(18)	4.1(16)
OK88701	60.8(11)	11.7(12)	60.2(7)	4.7(11)	4.0(6)	4.3(13)
OK88745	60.4(12)	11.9(8)	62.5(1)	4.7(12)	4.0(8)	5.1(3)
OK87542	58.7(13)	11.9(9)	58.3(15)	5.0(9)	4.0(7)	5.3(1)
OK88750	56.2(14)	11.7(13)	62.3(2)	5.0(8)	4.5(4)	4.8(7)
OK87W663	56.1(15)	11.4(18)	58.9(11)	5.4(2)	3.5(13)	4.6(9)
OK88W833	55.0(16)	11.8(10)	58.7(12)	5.4(4)	3.5(12)	4.8(5)
OK88767	54.8(17)	12.0(6)	57.4(17)	4.1(14)	4.0(10)	4.8(6)
Chisholm	50.6(18)	11.6(16)	59.1(10)	5.1(6)	3.5(14)	4.6(11)
Mean	64.92	11.94	59.50	4.70	4.00	4.62
C.V.	5.16	1.56	3.01	12.48	20.70	5.40
L.S.D. 0.05	7.20	0.40	3.77	1.24	1.76	0.53

TABLE 19

MEAN PERFORMANCE FOR SIX VARIABLES OF 15 GENOTYPES IN THE IWPN GROWN AT LAHOMA AND STILLWATER, OK IN 1990. RANKED ACCORDING TO KERNEL HARDNESS.

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)
2180	97.5(1)	12.6(3)	58.1(13)	3.2(11)	3.5(11)	3.6(10)
OK89499	90.1(2)	12.7(2)	62.2(2)	2.6(14)	2.5(12)	3.4(11)
OK89399	84.7(3)	12.3(6)	58.9(10)	2.8(13)	2.5(13)	3.4(12)
OK85276-49	77.8(4)	11.9(7)	58.8(11)	3.1(12)	3.5(9)	3.3(14)
Siouxland	76.6(5)	11.8(9)	59.2(8)	3.5(10)	2.5(14)	3.4(13)
OK89328	74.0(6)	12.6(4)	57.7(14)	2.4(15)	2.5(15)	3.0(15)
OK85182-61	70.4(7)	12.5(5)	58.2(12)	3.7(8)	3.5(10)	3.8(8)
Mesa	70.0(8)	11.5(13)	59.2(7)	3.6(9)	4.0(7)	3.9(6)
OK89428	69.9(9)	11.2(15)	61.1(4)	4.6(4)	4.5(6)	4.0(4)
OK89421	67.6(10)	11.7(11)	59.7(5)	4.7(3)	4.5(5)	4.3(2)
OK89451	63.3(11)	11.8(8)	61.4(3)	5.4(1)	5.0(1)	4.1(3)
Karl	61.1(12)	13.0(1)	59.4(6)	4.2(6)	4.0(8)	4.5(1)
OK89449	57.8(13)	11.4(14)	62.2(1)	4.7(2)	4.5(2)	3.7(9)
TAM200	57.2(14)	11.7(12)	55.6(15)	4.1(7)	4.5(3)	3.9(7)
Chisholm	52.6(15)	11.8(10)	59.0(9)	4.2(5)	4.5(4)	4.0(5)
Mean	71.40	12.04	59.40	3.82	3.73	3.87
C.V.	6.53	2.63	3.14	10.13	16.74	4.78
L.S.D.(.05)	10.00	0.68	4.00	0.83	1.34	0.39

TABLE 20

MEAN PERFORMANCE FOR SIX VARIABLES OF 30 GENOTYPES IN THE IWPN GROWN AT LAHOMA AND STILLWATER, OK IN 1989. RANKED ACCORDING TO KERNEL HARDNESS.

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)
2180	87.5(1)	12.4(12)	53.9(38)	4.9(20)	4.5(23)	5.0(33)
TX86V1109	80.7(2)	12.9(5)	58.0(17)	3.4(42)	4.0(36)	5.3(18)
TX86V1110	79.3(3)	12.9(4)	56.8(26)	2.6(45)	4.0(33)	5.3(16)
T15-2	78.5(4)	11.9(30)	51.9(43)	3.4(40)	4.5(28)	4.8(41)
TXGH12588	76.5(5)	10.7(45)	56.7(28)	5.6(9)	6.0(4)	5.5(3)
TX85V1326	76.1(6)	12.3(16)	58.4(16)	4.1(33)	5.0(18)	5.3(20)
RL845472	75.8(7)	11.4(42)	55.7(33)	3.4(39)	3.5(43)	4.1(45)
T1-2	74.9(8)	11.3(43)	55.3(34)	5.0(18)	6.0(3)	5.5(8)
NE83498	74.6(9)	12.3(14)	59.7(7)	6.2(5)	4.5(26)	5.1(31)
Scout 66	73.0(10)	12.3(15)	58.7(12)	4.4(31)	4.5(29)	5.4(14)
CLP#6	72.7(11)	13.5(1)	60.6(3)	4.7(25)	3.5(37)	4.9(36)
TX87V1233	72.2(12)	12.0(26)	51.8(44)	4.3(32)	4.5(27)	5.1(28)
TX86V1405	71.4(13)	12.2(18)	56.3(29)	5.2(14)	5.0(15)	5.5(6)
WH32362	70.7(14)	12.9(6)	59.6(9)	3.6(37)	4.0(31)	5.1(29)
NE86582	70.7(15)	12.0(28)	60.6(4)	7.2(2)	5.5(7)	5.5(9)
TAM105	70.6(16)	11.6(39)	55.8(32)	4.4(29)	5.5(11)	5.3(22)
NE84557	70.2(17)	12.9(3)	61.1(1)	4.9(21)	4.0(32)	5.0(35)
OK84287	70.0(18)	11.8(37)	59.6(8)	6.6(4)	5.0(17)	5.5(7)
TX84V1307	69.8(19)	11.5(40)	53.4(40)	5.4(11)	6.5(1)	5.4(15)
NE83407	68.9(20)	11.9(35)	59.8(5)	4.9(19)	4.5(25)	5.5(4)
XH900	68.5(21)	12.2(21)	57.0(21)	4.7(26)	5.5(5)	5.1(30)
OK86216	68.5(22)	12.2(19)	53.5(39)	6.1(6)	5.5(9)	5.4(12)
NE86606	68.1(23)	12.1(22)	59.8(6)	6.6(3)	5.0(16)	5.3(21)
TX87V1316	67.9(24)	12.4(13)	55.3(35)	3.2(43)	3.0(45)	4.6(43)
OK84286	67.8(25)	11.9(34)	56.8(25)	6.1(7)	5.5(8)	5.4(13)
2163	67.6(26)	11.9(31)	56.9(24)	4.4(30)	5.0(14)	5.2(24)
KS8010-142	67.1(27)	12.3(17)	57.5(19)	3.4(41)	3.5(41)	4.5(44)
CLP#3	66.8(28)	13.0(2)	58.7(13)	3.0(44)	3.5(40)	4.9(37)
XH736	66.4(29)	12.6(9)	58.6(14)	4.7(23)	5.0(12)	5.0(32)
RL844677	66.1(30)	11.0(44)	60.6(2)	4.4(28)	4.5(22)	4.8(42)
WH52498	64.7(31)	12.7(8)	56.8(27)	4.1(34)	4.5(21)	5.1(27)
NAW84-229	64.4(32)	12.4(11)	59.0(10)	3.7(36)	3.5(42)	5.2(25)
KS8010-72	64.4(33)	12.1(25)	58.5(15)	5.2(13)	4.0(35)	4.9(38)
NAW83-256	63.6(34)	11.8(38)	57.0(22)	4.0(35)	4.5(20)	4.9(39)
OK86215	62.9(35)	12.2(20)	54.3(37)	8.4(1)	5.5(10)	5.3(19)
CO830014	62.8(36)	12.0(27)	56.9(23)	5.2(16)	4.0(30)	5.6(2)
XH884	62.5(37)	11.9(33)	57.8(18)	5.9(8)	6.5(2)	5.5(5)
TX86A8072	58.1(38)	11.4(41)	52.2(41)	4.7(24)	5.0(13)	5.7(1)
T21-1	55.3(39)	12.1(24)	59.0(11)	3.5(38)	4.0(34)	5.2(26)
2157	53.1(40)	12.5(10)	57.1(20)	5.4(12)	4.5(24)	5.5(11)
WH180001	50.6(41)	12.7(7)	55.9(31)	5.0(17)	4.5(19)	5.2(23)

TABLE 20 (Continued)

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)
OK86223	50.5(42)	11.9(32)	56.3(30)	5.6(10)	5.5(6)	5.5(10)
TX86A7041	49.5(43)	11.8(36)	52.0(42)	4.5(27)	3.5(39)	5.3(17)
Kharkof	48.2(44)	12.1(23)	54.5(36)	4.8(22)	3.5(44)	5.0(34)
TX84V2036	29.6(45)	12.0(29)	48.7(45)	5.2(15)	3.5(38)	4.9(40)
Mean	66.67	12.16	59.80	4.81	4.60	5.20
C.V.	6.04	3.35	2.87	15.76	15.37	5.96
L.S.D.(.05)	8.13	0.82	3.29	1.53	1.43	0.63

TABLE 21

MEAN PERFORMANCE FOR SIX VARIABLES OF 38 GENOTYPES IN THE SRPN GROWN AT LAHOMA AND STILLWATER, OK IN 1990. RANKED ACCORDING TO KERNEL HARDNESS.

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)
NE87403	92.8(1)	12.5(14)	58.5(16)	4.0(17)	5.5(4)	3.8(21)
NE86582	90.1(2)	12.3(20)	61.2(5)	5.1(4)	6.0(3)	4.2(8)
TX86D1310	89.3(3)	12.9(7)	57.6(23)	3.4(28)	4.0(24)	4.8(3)
2163	85.9(4)	12.6(11)	58.1(20)	4.1(16)	4.5(15)	4.0(14)
NE87615	85.6(5)	12.4(17)	60.5(8)	5.2(3)	6.0(2)	4.1(9)
TAM107	84.4(6)	12.2(21)	58.3(19)	3.0(35)	4.0(16)	3.9(17)
KS8010-142	84.2(7)	12.8(8)	59.6(11)	3.2(30)	1.5(38)	2.8(38)
CO850034	83.3(8)	12.6(10)	57.7(22)	3.9(18)	5.0(11)	3.7(26)
XH1176	83.0(9)	12.2(23)	58.6(15)	4.4(9)	4.0(26)	3.6(30)
TX87V1316	82.6(10)	12.2(22)	61.2(3)	2.7(38)	2.0(37)	3.2(35)
NE86606	81.4(11)	11.6(34)	64.0(1)	4.4(10)	5.0(12)	4.1(12)
KS87H6	80.7(12)	12.4(16)	59.2(13)	5.1(6)	5.0(8)	4.6(5)
KLEO-W	80.4(13)	12.9(6)	60.2(10)	2.9(37)	2.5(36)	3.5(32)
NE83498	80.3(14)	12.1(28)	61.2(4)	5.0(7)	5.0(5)	3.6(29)
KLEO-R	79.6(15)	13.3(1)	60.2(9)	3.4(27)	3.0(31)	3.7(24)
XH1209	79.3(16)	12.3(19)	59.0(14)	4.5(8)	4.0(20)	4.1(15)
TX86D1332	79.2(17)	13.0(4)	58.4(18)	4.2(13)	5.0(10)	5.1(2)
CO850260	78.4(18)	11.5(36)	55.0(31)	4.2(11)	5.0(7)	3.6(28)
TX86V1405	78.2(19)	11.8(31)	55.0(32)	3.7(19)	4.5(13)	3.8(20)
XH1017	75.8(20)	12.1(25)	57.8(21)	3.6(20)	3.0(33)	3.4(33)
TX87V1233	75.5(21)	11.5(37)	54.3(35)	3.2(29)	4.0(22)	3.6(27)
TAM105	75.4(22)	12.2(24)	56.5(27)	3.4(26)	3.5(27)	3.5(31)
Scout 66	74.1(23)	13.3(2)	59.3(12)	3.0(33)	3.5(30)	3.7(23)
KS8010-72	73.6(24)	13.0(5)	62.4(2)	3.6(23)	2.5(35)	2.9(37)
TXGH12588	72.9(25)	11.6(35)	55.4(30)	3.2(31)	4.0(17)	4.1(11)
TX85V1326	71.8(26)	12.5(13)	58.5(17)	3.0(34)	4.0(23)	3.9(18)
TX84V1307	71.4(27)	12.5(12)	55.5(29)	3.4(25)	5.0(9)	4.0(16)
CO850267	69.2(28)	12.6(9)	54.7(34)	3.4(24)	3.0(32)	3.3(34)
CO850061	67.0(29)	11.7(32)	54.3(36)	4.1(14)	6.0(1)	4.1(10)
TX86A8072	65.6(30)	12.1(26)	54.7(33)	3.0(36)	4.0(19)	3.9(19)
2158	62.5(31)	12.3(18)	57.3(25)	3.6(21)	3.5(28)	4.3(7)
Kharkof	60.2(32)	13.1(3)	53.5(37)	3.1(32)	2.5(34)	3.2(36)
XH1235	57.7(33)	12.4(15)	56.1(28)	3.6(22)	4.5(14)	3.7(25)
OK86223	56.9(34)	11.9(30)	57.4(24)	4.1(15)	4.0(18)	4.1(13)
OK87542	55.6(35)	12.1(27)	60.7(7)	5.5(1)	4.0(25)	4.7(4)
OK87W663	55.3(36)	11.7(33)	60.7(6)	5.1(5)	4.0(21)	4.3(6)

TABLE 21

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)
OK87630	49.7(37)	11.9(29)	56.6(26)	5.5(2)	5.0(6)	5.4(1)
TX84V2036	34.7(38)	11.4(38)	52.4(38)	4.2(12)	3.5(29)	3.8(22)
Mean	73.80	12.30	58.00	3.90	4.10	3.20
C.V.	5.18	3.19	2.06	10.00	18.70	6.00
L.S.D. (.05)	7.71	0.79	2.42	0.79	1.54	0.48

TABLE 22

MEAN PERFORMANCE FOR SIX VARIABLES OF 40 GENOTYPES IN THE IWPN GROWN AT LAHOMA AND STILLWATER, OK IN 1989. RANKED ACCORDING TO KERNEL HARDNESS.

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)
2180	90.5(1)	12.4(13)	52.4(38)	4.7(28)	4.5(29)	5.0(36)
Lamar	88.3(2)	12.4(14)	59.4(4)	6.0(10)	5.5(13)	5.3(25)
Thunderbird	79.6(3)	12.6(7)	60.7(1)	4.2(37)	4.5(34)	5.4(23)
Mesa	77.6(4)	11.9(29)	56.6(21)	4.2(36)	4.5(33)	5.1(34)
Cody	75.8(5)	11.7(33)	57.0(20)	6.4(6)	6.0(7)	5.3(27)
Hawk	75.4(6)	11.9(30)	59.5(3)	5.8(15)	6.0(9)	5.6(7)
TAM107	74.4(7)	11.1(40)	54.9(27)	6.1(8)	6.0(4)	5.9(3)
Scout 66	73.3(8)	12.5(9)	57.3(18)	4.5(30)	4.5(36)	5.4(20)
Arapaho	72.7(9)	12.1(23)	58.7(5)	4.9(26)	5.0(21)	5.1(32)
Redland	72.4(10)	11.3(39)	60.0(2)	6.1(9)	6.5(1)	5.7(6)
Abilene	72.3(11)	12.5(8)	57.7(13)	5.7(16)	5.5(14)	5.6(8)
Mustang	71.7(12)	11.9(27)	58.6(6)	4.4(33)	5.0(24)	5.2(29)
Stallion	70.4(13)	12.7(6)	57.8(11)	5.9(14)	4.5(35)	5.4(22)
WH32362	70.3(14)	12.4(18)	57.1(19)	4.1(38)	4.5(28)	5.3(26)
QT554	70.2(15)	12.2(22)	56.4(23)	4.6(29)	5.0(25)	5.1(33)
Century	69.6(16)	12.0(26)	49.0(40)	6.7(4)	5.5(15)	5.4(17)
TAM 105	68.3(17)	11.4(37)	54.8(28)	4.7(27)	6.5(12)	5.9(2)
Arkan	68.0(18)	12.4(15)	57.4(14)	6.0(11)	4.5(32)	5.4(16)
Payne	66.4(19)	12.4(17)	53.9(33)	6.0(12)	5.5(16)	5.5(10)
TAM201	65.4(20)	11.6(36)	52.9(35)	5.1(22)	6.0(3)	6.0(1)
Siouxland	65.3(21)	11.6(35)	57.9(8)	4.5(31)	4.0(37)	4.5(40)
W84-229	64.7(22)	12.3(19)	57.8(12)	4.4(35)	4.0(38)	5.2(30)
TAM200	64.6(23)	11.3(38)	54.0(32)	5.6(17)	6.0(8)	5.4(15)
Dodge	64.5(24)	13.5(1)	57.4(15)	6.2(7)	5.0(19)	4.8(38)
Osage	64.3(25)	12.3(20)	57.4(16)	3.5(40)	4.5(31)	5.4(18)
Karl	63.0(26)	12.9(3)	57.8(10)	7.0(2)	5.5(11)	5.4(19)
QT578	62.1(27)	12.5(10)	54.5(29)	4.4(32)	5.0(22)	4.7(39)
RHS7837	61.8(28)	12.7(5)	55.8(24)	8.0(1)	5.5(10)	5.4(14)
Vona	61.7(29)	11.7(34)	54.1(30)	5.6(18)	6.0(6)	5.5(9)
Triumph 64	61.5(30)	12.9(2)	57.8(9)	5.1(23)	4.0(39)	5.4(24)
WH52498	61.2(31)	12.5(11)	55.0(26)	4.4(34)	4.5(27)	4.8(37)
QT574	60.4(32)	12.4(16)	52.6(37)	5.2(21)	5.5(17)	5.3(28)
TAMW-101	59.8(33)	12.1(24)	54.1(31)	4.0(39)	5.0(20)	5.7(4)
RHS7846	58.5(34)	12.0(25)	56.6(22)	5.4(20)	4.5(30)	5.0(35)
WH18000	55.8(35)	11.9(28)	53.3(34)	5.0(24)	5.0(23)	5.4(21)
Newton	55.7(36)	12.2(21)	57.4(17)	5.5(19)	5.5(18)	5.5(12)
2157	53.9(37)	12.8(4)	58.1(7)	6.9(3)	4.5(26)	5.5(11)
2157	46.8(38)	12.5(12)	52.9(36)	5.0(25)	3.5(40)	5.5(13)

TABLE 22 (Continued)

Genotype	Kernel Hard. (0-100)	Flour Prot. (%)	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)
Chisholm	46.6(39)	11.9(31)	55.6(25)	6.5(5)	6.0(5)	5.7(5)
Collin	30.4(40)	11.8(32)	50.3(39)	5.9(13)	6.0(2)	5.2(31)
Mean	65.9	12.21	56.1	5.37	5.10	5.37
C.V.	7.25	3.25	3.13	14.02	12.16	4.32
L.S.D (.05)	9.65	0.80	3.54	1.52	1.25	0.47

TABLE 23

MEAN SQUARES AND F VALUES FROM THE ANALYSIS OF VARIANCE FOR THE CHARACTERISTICS FLOUR PROTEIN CONTENT, FLOUR YIELD, MIXING TIME MIXING TOLERANCE, SPECIFIC SEDIMENTATION AND NIR HARDNESS SCORES FOR FOUR NURSERIES GROWN IN 1989 AT LAHOMA AND STILLWATER, OK.

		Flour Prot. (%)		Flour Yield (%)		Mix. Time (min)		Mix. Tol. (1-10)		Spec. Sed. (Units)		Kernel Hard (0-100)	
Source	DF	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value
IWPN													
Loc	1	11.267	109.15**	744.128	143.0**	36.613	28.24**	1.350	1.15	1.734	73.30**	1.067	0.09
Genotype	29	0.240	2.32*	8.163	1.57	3.560	2.75**	1.844	1.57	0.163	6.90**	263.940	21.36**
Error	29	0.103		5.203		1.300		1.178		0.024		12.357	
C.V.		2.64%		3.96%		18.76%		24.20%		2.73%		5.84%	
AWPN													
Loc	1	12.881	203.08**	681.414	259.41**	47.704	170.16**	6.017	7.76**	1.040	20.18**	75.040	1.74
Genotype	29	0.249	3.92**	4.998	1.90*	3.273	11.67**	2.403	3.10**	0.194	3.77**	187.989	4.35**
Error	29	0.063		2.627		0.280		0.775		0.052		43.186	
C.V.		2.08%		2.83%		8.50%		18.41%		4.08%		10.80%	
VHPN													
Loc	1	12.013	76.33**	761.995	247.9**	43.145	76.23**	20.00	52.00**	2.592	48.18**	394.272	17.29**
Genotype	39	0.488	3.10**	13.601	4.4**	1.901	3.36**	1.031	2.68**	0.196	3.64**	234.365	10.28**
Error	39	0.157		3.074		0.566		0.385		0.054		22.804	
C.V.		3.25%		3.13%		14.02%		12.16%		4.32%		7.25%	
SRPN													
Loc	1	10.609	64.07**	42.849	16.15**	9.506	16.51**	0.000	0.00	0.278	2.89	4.900	0.30
Genotype	44	0.563	3.40**	15.448	5.82**	2.744	4.76**	1.491	2.98**	0.205	2.13**	206.427	12.72**
Error	44	0.166		2.654		0.576		0.500		0.096		16.227	
C.V.		3.35%		2.87%		15.76%		15.37%		5.96%		6.04%	

TABLE 24

MEAN SQUARES AND F VALUES FROM THE ANALYSIS OF VARIANCE FOR THE CHARACTERISTICS FLOUR PROTEIN CONTENT, FLOUR YIELD, MIXING TIME, MIXING TOLERANCE, SPECIFIC SEDIMENTATION AND NIR HARDNESS SCORES FOR THREE NURSERIES GROWN IN 1990 AT LAHOMA AND STILLWATER, OK.

		Flour Prot. (%)		Flour Yield (%)		Mix. Time (min)		Mix. Tol. (1-10)		Spec. Sed. (Units)		Kernel Hard (0-100)	
Source	DF	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value
IWPN													
Loc	1	2.952	29.41**	13.333	3.83	0.533	3.57	0.533	1.37	0.012	0.37	34.347	1.58
Genotype	14	0.596	5.94**	6.206	1.78	1.517	10.16**	1.562	4.00**	0.323	9.88**	315.821	14.54**
Error	14	0.100		3.485		0.149		0.390		0.033		21.723	
C.V.		2.63%		3.14%		10.13%		16.74%		4.78%		6.53%	
AWPN													
Loc	1	1.357	38.97**	1.361	0.43	0.141	0.41	4.694	6.76*	0.614	9.74**	4.694	0.42
Genotype	17	0.247	7.10**	7.976	2.49*	1.102	3.18**	1.204	1.73	0.360	5.71**	220.133	19.62**
Error	17	0.035		3.199		0.347		0.694		0.063		11.632	
C.V		1.56%		3.01%		12.48%		20.69%		5.43%		5.16%	
SRPN													
Loc	1	0.061	0.39	0.005	0.00	1.451	9.46**	0.474	0.081	0.043	0.77	208.563	14.30**
Genotype	37	0.526	3.41**	14.410	10.07**	1.253	8.17**	2.366	4.07**	0.582	10.47**	310.458	21.29**
Error	37	0.154		1.431		0.153		0.582		0.056		14.585	
C.V.		3.19%		2.06%		10.02%		18.70%		6.01%		5.18%	

TABLE 25

SIMPLE CORRELATION COEFFICIENTS OF 6 VARIABLES FOR 30 WHEAT GENOTYPES (IWPN), AT LAHOMA AND STILLWATER, OK IN 1989.

	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)	Kernel Hards. (0-100)
Flour Prot. (%)	-0.625**	0.420**	0.151	-0.607**	0.168
Flour Yield (%)		-0.282*	0.007	0.596**	-0.014
Mix. Time (min)			0.592**	-0.018	-0.326**
Mix. Tol (0-10)				0.231	-0.321**
Spec. Sed. (Units)					-0.404**

TABLE 26

SIMPLE CORRELATION COEFFICIENTS OF 6 VARIABLES FOR 15 WHEAT GENOTYPES (IWPN), AT LAHOMA AND STILLWATER, OK IN 1990.

	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)	Kernel Hard. (0-100)
Flour Prot. (%)	-0.231	-0.346	-0.442*	-0.106	0.304
Flour Yield (%)		0.208	0.072	0.124	0.073
Mix. Time (min)			0.806**	0.749**	-0.645**
Mix. Tol. (1-10)				0.678**	-0.635**
Spec. Sed. (Units)					-0.556**

*, ** = Significance at 0.05 and 0.01 levels of probability with 58 and 28 d.f. in 1989 and 1990 respectively.

TABLE 27

SIMPLE CORRELATION COEFFICIENTS OF 6 VARIABLES FOR 30 WHEAT GENOTYPES (AWPN), AT LAHOMA AND STILLWATER, OK IN 1989.

	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)	Kernel Hards. (0-100)
Flour Prot. (%)	-0.673**	0.346**	-0.055	-0.575**	0.183
Flour Yield (%)		-0.433**	-0.195	0.360**	-0.065
Mix. Time (min)			0.650**	0.282*	-0.146
Mix. Tol. (1-10)				0.539**	-0.208
Spec. Sed. (Units)					-0.317**

TABLE 28

SIMPLE CORRELATION COEFFICIENTS OF 6 VARIABLES FOR 18 WHEAT GENOTYPES (AWPN), AT LAHOMA AND STILLWATER, OK IN 1990.

	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)	Kernel Hards. (0-100)
Flour Prot. (%)	0.147	-0.151	-0.406*	-0.029	0.336*
Flour Yield (%)		0.308	0.130	0.364*	0.053
Mix. Time (min)			0.365*	0.585**	-0.418**
Mix. Tol. (1-10)				0.375*	0.008
Spec. Sed. (Units)					-0.413**

*,** = Significance at 0.05 and 0.01 levels of probability with 58 and 34 d.f in 1989 and 1990 respectively.

TABLE 29

SIMPLE CORRELATION COEFFICIENTS OF 6 VARIABLES FOR 40 WHEAT GENOTYPES (VHPN), AT LAHOMA AND STILLWATER, OK IN 1989.

	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)	Kernel Hards. (0-100)
Flour Prot. (%)	-0.358**	0.436**	0.063	-0.446**	0.099
Flour Yield (%)		-0.464**	-0.484**	0.257*	0.129
Mix. Time (min)			0.626**	-0.080	0.002
Mix. Tol. (1-10)				0.060	0.091
Spec. Sed. (Units)					-0.117

TABLE 30

SIMPLE CORRELATION COEFFICIENTS OF 6 VARIABLES FOR 40 WHEAT GENOTYPES (VHPN), AT STILLWATER, OK IN 1990.

	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)	Kernel Hards. (0-100)
Flour Prot. (%)	0.273	-0.040	-0.120	0.550**	0.162
Flour Yield (%)		0.139	-0.153	0.181	0.411**
Mix. Time (min)			0.547**	0.295	0.021
Mix. Tol. (1-10)				0.144	-0.140
Spec. Sed. (Units)					0.144

*,** = Significance at 0.05 and 0.01 levels of probability with 78 d.f in 1989 and 1990 respectively.

TABLE 31

SIMPLE CORRELATION COEFFICIENTS OF 6 VARIABLES FOR 45 WHEAT GENOTYPES (SRPN), AT LAHOMA AND STILLWATER, OK IN 1989.

	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)	Kernel Hards. (0-100)
Flour Prot. (%)	0.031	-0.049	-0.333**	-0.223*	0.041
Flour Yield (%)		-0.024	-0.086	0.090	0.289**
Mix. Time (min)			0.472**	0.270**	-0.142
Mix. Tol. (1-10)				0.463**	0.124
Spec. Sed. (Units)					-0.041

TABLE 32

SIMPLE CORRELATION COEFFICIENTS OF 6 VARIABLES FOR 38 WHEAT GENOTYPES (SRPN), AT LAHOMA AND STILLWATER, OK IN 1990.

	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)	Kernel Hards. (0-100)
Flour Prot. (%)	0.193	-0.298**	-0.237*	-0.047	0.285*
Fflour Yield (%)		0.237*	-0.049	0.005	0.394**
Mix. Time (min)			0.549**	0.511**	-0.170
Mix. Tol. (1-10)				0.508**	0.118
Spec. Sed. (Units)					-0.170

*,** = Significance at 0.05 and 0.01 levels of probability with 88 and 74 d.f. in 1989 and 1990 respectively.

TABLE 33

SIMPLE CORRELATION COEFFICIENTS OF 6 VARIABLES FOR THE COMBINATION OF FOUR WINTER WHEAT NURSERIES (145 GENOTYPES) AT LAHOMA AND STILLWATER, OK IN 1989.

	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)	Kernel Hards. (0-100)
Flour Prot. (%)	-0.369**	0.241**	-0.056	-0.388**	0.111
Flour Yield (%)		-0.253**	-0.212**	0.310**	0.059
Mix. Time (min)			0.527**	0.242**	-0.224**
Mix. Tol. (1-10)				0.277**	-0.047
Spec. Sed. (Units)					-0.267**

TABLE 34

SIMPLE CORRELATION COEFFICIENTS OF 6 VARIABLES FOR THE COMBINATION OF FOUR WINTER WHEAT NURSERIES (111 GENOTYPES) AT LAHOMA AND STILLWATER, OK IN 1990.

	Flour Yield (%)	Mix. Time (min)	Mix. Tol. (1-10)	Spec. Sed. (Units)	Kernel Hards. (0-100)
Flour Prot. (%)	-0.031	-0.169*	-0.152*	-0.026	0.092
Flour Yield (%)		0.271**	-0.019	0.188*	0.230**
Mix. Time (min)			0.539**	0.582**	-0.283**
Mix. Tol. (1-10)				0.374**	-0.050
Spec. Sed. (Units)					-0.273**

*,** = Significance at 0.05 and 0.01 levels of probability with 143 and 109 d.f. in 1989 and 1990 respectively.

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