1969

# A Study of Some Physical and Chemical Properties of Hard Red Spring and Hard Red Winter Wheat in South Dakota

Richard A. Pence

# A STUDY OF SOME PHYSICAL AND CHEMICAL PROPERTIES OF HARD RED SPRING AND HARD RED WINTER WHEAT IN SOUTH DAKOTA

BY

RICHARD A. PENCE

A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Major in
Agronomy, South Dakota
State University

1969

A STUDY OF SOME PHYSICAL AND CHEMICAL PROPERTIES

OF HARD RED SPRING AND HARD RED WINTER

WHEAT IN SOUTH DAKOTA

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser Date

Head, Agronomy Department Date

# ACKNOWLEDGMENTS

The author wishes to express his appreciation to Dr. L. O. Fine, Head of the Agronomy Department, South Dakota State University, and Mr. R. C. Kinch, Professor of Agronomy, in charge of the Agronomy Seed Laboratory, for their encouragement and supervision in conducting this study.

Thanks are extended to the South Dakota Wheat Commission for their guidance and financial support of the project and to the Agronomy Seed Laboratory for the use of facilities and equipment.

The help of Dr. W. L. Tucker, Associate Professor of Statistics; Dr. D. G. Wells, Professor of Agronomy; Dr. C. A. Watson, Cereal Chemist U.S.D.A. - A.R.S., Beltsville, Maryland; Mr. W. C. Shuey, Research Technologist, Spring Wheat Quality Laboratory, Fargo, North Dakota; Mr. Roy Potas, Agricultural Statistician, South Dakota Crop and Livestock Reporting Service; Mr. J. A. Schroder, Chief Grain Inspector, Aberdeen, South Dakota; and Doty Laboratory of Kansas City, Missouri, is greatly acknowledged.

Thanks are also due to my wife for her moral support.

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# INTRODUCTION

South Dakota is located in a transition zone between the winter wheat area to the south and the spring wheat area to the north. The summers seem to be too warm to produce the later maturing spring wheat of good test weight and of good milling quality that is in demand by consumers. Yet South Dakota remains primarily a spring wheat state because varieties and farming practices have not yet been perfected enough to overcome the problem of winter killing of winter wheat. Indications from several sources (27, 30) are that South Dakota's wheat, especially the spring wheat, is of questionable quality.

In the past years, world wheat production has increased significantly resulting in a world surplus of wheat. The world's wheat buyers now enjoy a very competitive market not only in terms of price, but also in terms of quality. Those states, provinces, or countries who choose to ignore the quality of their wheat will face the possibility of losing their market.

"A wheat exporting state such as South Dakota can justify producing wheat only if it produces a quality commodity that is in real demand by wheat buyers " (13). In 1963, a joint project was initiated between the South Dakota Wheat Commission and the South Dakota State University Agronomy Department to obtain information on the quality of wheat produced in South Dakota.

This study was undertaken (a) to determine as specifically as possible the quality of wheat produced and delivered to shipping points in South Dakota, (b) to compare the quality of wheat being delivered to the country elevator to the quality of the wheat being shipped to the terminal markets, (c) to compare quality factors of spring and winter wheat and to consider the comparative advantages of both classes of wheat in South Dakota, (d) to analyze the quality of wheat going into different elevators and to observe area differences, (e) to determine the milling and baking quality of South Dakota grown wheat and to compare it to wheat grown in other areas. It is hoped that these investigations will reveal the particular quality factors that lower the quality of wheat entering the market and help point out where changes can be made to make South Dakota's wheat more competitive in the terminal market.

# REVIEW OF LITERATURE

## Physical Quality

For many years wheat has been merchandised on the basis of physical quality. Many grading factors such as test weight, foreign material, and defects, jointly determine grade which eventually influences price. In recent years buyers and local producers have complained that the physical quality of wheat being received by the processor was not as good as that being produced on the farm (30). In spite of the importance placed on the physical quality of wheat, very little literature pertinent to this study was found.

One of the most important components of physical quality is test weight. Test weight has long been considered an estimate of flour extraction (10). Discounts for lower bushel weight are based on estimated loss in flour yield (28).

In recent research Shuey (24) found a very poor relationship between test weight and flour yield. Tests showed that wheats may have as much as nine pounds per bushel difference in test weight and show the same flour extraction.

Results obtained from a new wheat kernel sizing technique developed by Shuey (24) seem promising. Percentages of large, medium and small kernels were determined and by use of a mathematical equation, converted to a figure known as "Potential Yield." A correlation coefficient of +.957 was found between

potential yield and flour yield.

A review of the literature revealed some interrelation of quality factors. McGregor (14) found that the red flour beetle, (Tribolium castaneum Herbst), showed a preference for wheat containing a high percent of dockage. The largest increase in insect number occurred when dockage increased from 0.3% to 4.5%. Shuey (25) found that insect damaged wheat and heat or moisture damaged wheat have a lower flour extraction. High moisture was more conducive to insect and heat damage. However, Balanki (1) demonstrated that impact damage increased as moisture level decreased.

## Fertilizer Effects

It has long been recognized that the protein content of wheat is important to the milling and baking properties of wheat flour. Shuey (27) stated that while high protein does not necessarily assure a high milling and baking score, it is nearly impossible to maintain high scores without high protein. Much research has been conducted to determine the effect of nitrogen fertilization on protein content. More recently the effects of other nutrients on quality have been considered.

Hill (9) found in Canada that addition of 30 pounds of nitrogen significantly increased the protein content of wheat. The addition of nitrogen and phosphorus increased protein but not as much as nitrogen used alone. Smith (29) found that phosphorus and

potassium are important to the wheat plant but neither of them singly or in combination with nitrogen will affect wheat yields and quality as much as will nitrogen alone. However, results in South Dakota (4) indicated that small amounts of phosphorus are beneficial along with nitrogen.

In Ohio (18) plots where nitrogen was used alone produced wheat giving the best loaf volume. However, nitrogen alone decreased test weight. Phosphorus used alone increased kernel size but decreased protein content. Adding phosphorus also increased the phosphorus in the seed. This is of interest because phosphorus is a basic constituent of flour ash. Singh and Lamb (28) found in Ohio that ash content was increased by the addition of phosphorus and decreased by the use of nitrogen.

It was the opinion of Hutcheon and Paul (11) that it is possible to increase protein content of spring wheat to 16% while maintaining or increasing yields. Protein contents above 16% were obtained only when a growth factor such as moisture was below optimum for maximum yields.

Bauer, Young, and Vassey (3) stated that it probably does not pay to add nitrogen just to increase the protein content of spring wheat if elevators buy on station averages. (Buying on the basis of station averages, infers that all producers delivering wheat to an elevator receive a price based on the average protein of all of the wheat delivered to the elevators. The producer who brings in high protein wheat receives no extra compensation.)

Research on time and method of nitrogen application carried out by Smith (29) indicated that time of application does not affect yield. However, protein content was maximized by applying nitrogen as a urea spray at flowering time. Thirty pounds of actual nitrogen as urea increased protein content by 2.5%.

Moisture use studies in North Dakota (16) indicated that use of fertilizers increased the total or absolute draft on soil moisture very little, and commonly increased the efficiency of moisture use substantially. This author suggested that a farmer can improve his management by considering available moisture at seeding time and by considering rainfall probability in making decisions relative to fertilizer use.

## Chemical Quality

In reviewing the voluminous literature on the milling and baking quality of wheat, this author decided to concentrate this discussion primarily on one of the most troublesome problems of South Dakota's wheat -- that of ash content.

Singh and Lamb (28) were of the opinion that ash in the flour is one of the most inflexible of the specifications set up by bakers. Meeting ash requirements limits the pounds of flour a miller can extract from 100 pounds of wheat.

Watson (34) and Shuey (27) stated that, usually as flour ash increases by one point, (0.01%) flour extraction must be decreased by 2% in order to maintain a constant flour ash content.

Shuey (25) reported frost damaged wheat will give a higher ash flour than undamaged wheat.

Schrenk and King (23) found in Kansas that localities producing high ash wheat did so consistently. Areas of high nutrient availability coincided with those producing the wheat of highest ash and protein content. Areas of high ash also tended to be high in protein content. Increases in ash were not due to any one element but were the combined result of increases in each of the major constituents which are potassium, phosphorus, magnesium and calcium in that order. These four elements were found to compose 90% of ash content of wheat.

Temperatures above 90°F. during the last 15 days of kernel formation may cause kernel shrinkage and are detrimental to gluten quality in wheat. The results are shorter "dough development time" and smaller loaves of bread (21).

# MATERIALS AND METHODS

## Physical Quality of South Dakota's Wheat

The most basic portion of this study was a survey of the wheat delivered by producers to local elevators. During the five year period 1963-67, 2820 samples--1689 of spring wheat and 1131 of winter wheat--were taken and graded. In 1967, 516 samples were taken in twenty-six counties from the wheat area. Samples of about one pound were taken from the trucks as they came into the elevators. Samples were sealed in plastic lined bags and taken to the Agronomy Seed Laboratory in Brookings, where dockage, moisture, test weight, protein content, damaged kernels, foreign material, shrunken and broken kernels, contrasting classes, total defects and thousand kernel weight were determined. Dockage was determined by the use of the Carter Dockage machine. Moisture was determined by use of a Burrows moisture recorder. Protein content was determined by the Kjeldahl method in the Soil Testing Laboratory. All other factors were determined as outlined in the U.S.D.A. Grain Inspection Manual (32). Appendix Table 1 lists allowable limits for all grading factors. When indicating official grade, it is only necessary to list the percentage of that factor that determined the grade. Dockage need only be listed in whole and half percents. However, all determinations in this study were listed exactly as found.

## Comparison of Wheat Coming into Elevators with Wheat Being Shipped Out of Elevators

For the past three years the South Dakota Crop and Livestock Reporting Service has conducted a quality survey on South Dakota grown wheat as it arrived at the major terminals. Quality data were taken from grading cards on car lot samples that were sampled, and graded at terminal grading points (31). This information was punched onto computer cards. In order to compare 1967 data on the wheat coming into elevators (as shown by the S.D.S.U. survey) to the wheat being shipped out of those same elevators (as shown on the Crop and Livestock data cards), it was necessary to obtain a list of the car numbers shipped from each elevator. The data cards showing these car numbers were sorted out and used for the analysis. Only cars graded in Aberdeen were used because it was known that Aberdeen listed the quality factors exactly. Comparisons were made on six quality factors at twenty-five elevators. The least squares analysis was performed on the university's computer. All data were transformed logarithmically to analyze these low percentage figures.

## Quality Factors of Spring and Winter Wheat [1]

The quality of spring and winter wheat was compared in eleven South Dakota counties. Seven quality factors were compared to indicate which class of wheat showed the best quality. Data from the Crop and Livestock Reporting Service were used. Transformed data on carload samples graded in Aberdeen were used for the least squares analysis. To compare the test weights of spring and winter wheat, one pound was added to all spring wheat test weights and one pound subtracted from all winter wheat samples. This was done to allow for the difference in test weight requirements for grading the two classes. Some data from the S.D.S.U. survey were used in the discussion, but not for the statistical analysis. All comparisons were made using data from the 1967 crop.

## Comparison of the Quality of Wheat Received at Different Elevators

An analysis of variance was run to compare the quality of wheat being delivered to different elevators throughout the state. Samples from the S.D.S.U. 1967 survey were used for this comparison. Eight quality factors were compared at nineteen elevators for winter wheat and twenty-four elevators for spring wheat. The Duncan's

[1] Hereafter, S.D.S.U. shall refer to the survey data compiled by the South Dakota State University Agronomy Department. C and L shall refer to the survey data as compiled on car lot samples by the Crop and Livestock Reporting Service.

New Multiple Range Test was used for each quality factor to point out elevator differences at the one percent level. General trends are referred to in the discussion section.

## Milling and Baking Quality

Data for this section were obtained from the Doty Laboratories in Kansas City, Missouri (6). Each year this laboratory evaluates wheat samples for several wheat states. State averages have been figured by adding together area averages in each state. The averages have not been weighted for production within areas.

The quality of South Dakota's spring and winter wheat is compared to the quality of wheat grown in other major wheat producing areas. Six quality factors are compared for both classes of wheat using data for the years 1965-1967.

# RESULTS AND DISCUSSION

## Physical Quality of South Dakota's Wheat

For years, buyers have purchased grain on the basis of physical quality. Some people have failed to realize that each of the twelve quality factors represents an important economic consideration in the buyers'business.

This section deals with the physical quality of South Dakota wheat studied over the period 1963 to 1967. The factors to be discussed are: moisture, dockage, thousand kernel weight, test weight, protein content, damaged kernels, foreign material, shrunken and broken kernels, total defects, contrasting classes, sub-classes, and numerical grade.

### Moisture

Moisture is expressed as percent by weight. It is indicated as percent on the grading ticket unless it exceeds 13.5% in which case the special grade designation "tough" is shown. If moisture is too high, spoilage and heating may occur resulting in loss of quality in the wheat and the risk of fire loss to storage facilities. High moisture is also conducive to higher levels of insect infestations (14). High moisture is expensive to buyer and seller alike. The seller must ship the extra weight. "To the buyer the difference in the value of a 55 ton car load of wheat at 8% moisture versus one at 14% moisture is about $250. Unfortunately such

differences in intrinsic value are seldom reflected in actual market price" (10). Low moisture grain is more subject to cracking in the handling process. From this, it seems that the producer is ahead to sell wheat in the upper ranges of allowable moisture.

Moisture content of South Dakota's wheat varied from year to year but the averages were always well below 13.5% (Table 1). Most of the elevators observed were very strict about moisture. Wheat above 13.5% moisture was usually either artificially dried or turned away. The small amount of high moisture wheat that was taken in was carefully blended with dry wheat.

Table 1. S.D.S.U. wheat samples classified according to moisture content.

| Range in % of Moisture | 1963 | 1964 | 1965 | 1966 | 1967 |
|---|---|---|---|---|---|
| | | | Hard Red Spring Wheat | | |
| 0 through 13.5 | 86% | 97% | 96% | 95% | 88% |
| 13.6 and up | 14% | 3% | 4% | 5% | 12% |
| Number of Samples | 485 | 483 | 340 | 113 | 268 |
| Yearly Average | 12.5% | 11.4% | 11.2% | 11.7% | 11.5% |
| | | | Hard Red Winter Wheat | | |
| 0 through 13.5 | 85% | 97% | 90% | 92% | 94% |
| 13.6 and up | 15% | 3% | 10% | 8% | 6% |
| Number of Samples | 230 | 288 | 179 | 186 | 248 |
| Yearly Average | 12.4% | 11.4% | 12.0% | 10.6% | 11.3% |

## Dockage

Dockage is expressed as percent by weight and consists of all material that can be readily removed by appropriate cleaning devices. It consists primarily of dirt, chaff, fragments of wheat heads, coarse grains and weed seed. To the buyer dockage represents material that must be removed before grading and milling. To the elevator manager it means either a higher freight bill or an added cost of cleaning before shipping. The dockage of South Dakota's wheat varied considerably from year to year (Table 2). Average dockage seemed to depend upon the type of season in which the crop matured and was harvested. In 1963 stem rust was severe in the spring wheat and dockage was high. In 1965 stem rust hit again, this time in winter wheat and dockage was more than twice as high as the five year average. The high dockage content of wheat arriving at country elevators indicated that dockage was a real problem in South Dakota's wheat. The dockage content of winter wheat showed a downward trend over the five year period except for 1965.

It seemed that farmers in the winter wheat area placed much more emphasis on delivering dockage free wheat than did farmers in the spring wheat area. However, the elevators did more cleaning in the spring wheat area, due partially to the fact that the need for cleaning was greater.

The seeds of wild buckwheat (Polygonum convolvolus L.) and wild oats (Avena fatua L.) account for much of the dockage in South Dakota's wheat. The eradication of these two weeds would

eliminate a great portion of the dockage in many areas of the state.

Table 2. S.D.S.U. wheat samples classified according to dockage content.

| % Dockage | 1963 | 1964 | 1965 | 1966 | 1967 |
|---|---|---|---|---|---|
| | | | Spring Wheat | | |
| Average | 4.14% | 3.82% | 2.15% | 4.67% | 1.71% |
| | | | Winter Wheat | | |
| Average | 2.84% | 1.52% | 3.90% | 1.22% | .72% |

## Thousand Kernel Weight

Thousand kernel weight is simply the weight in grams of 1000 kernels of wheat. It is a function of kernel size and density. Inasmuch as large dense kernels normally have a higher ratio of endosperm to nonendosperm components than do smaller less dense kernels, it is a good index of percent of flour yield. The average thousand kernel weight of U. S. hard red spring and hard red winter wheat is about 28 grams--with spring wheat averaging slightly lighter (10). Data on thousand kernel weight of South Dakota's wheat were limited to the 1967 crop which was above average. In 1967 the weight per thousand kernels averaged 28.60 grams for hard red spring wheat and 30.45 grams for hard red winter wheat. This would be considered excellent as far as wheat quality is concerned.

## Test Weight

Test weight is determined on the basis of dockage free wheat and is a measure of the weight per bushel. Test weight is another indication of flour extraction. However, above 57 pounds per bushel the test weight of wheat has relatively little influence on flour milling yield. At weights below 57 pounds, flour yields usually fall off rapidly (10). The test weight of South Dakota's spring wheat varied greatly from year to year (Table 3) and averaged below 57 pounds per bushel in two of the last five years. Stem rust epidemics cut sharply into the test weight of spring wheat in 1963 and winter wheat in 1965. Early season drought conditions combined with abnormally hot weather caused the spring wheat crop to show a low test weight in 1966. The test weight of winter wheat also varied considerably from year to year but the five year average was acceptable for number one wheat (Table 4).

## Protein Content

Protein content is an indication to the buyer of what the baking performance of the wheat will be. Protein content is not a grading factor but is an important factor to the miller. Though only three years of data were available, it is evident that the protein content of South Dakota's wheat varied considerably from year to year (Table 5).

Table 3. S.D.S.U. spring wheat samples classified according to test weight per bushel.

| Pounds per bushel | Theoretical grade [1] | % of Samples in each grade by year | | | | |
|---|---|---|---|---|---|---|
| | | 1963 | 1964 | 1965 | 1966 | 1967 |
| 60 or better | 1 heavy | 8.3 | 15.9 | 13.5 | 1.8 | 63.8 |
| 58 thru 59.9 | 1 | 20.0 | 36.4 | 32.1 | 19.5 | 23.1 |
| 57 thru 57.9 | 2 | 9.5 | 15.2 | 18.5 | 15.0 | 6.7 |
| 55 thru 56.9 | 3 | 17.7 | 17.4 | 23.3 | 27.4 | 5.2 |
| 53 thru 54.9 | 4 | 24.8 | 8.3 | 8.8 | 16.8 | 0.8 |
| 50 thru 52.9 | 5 | 16.0 | 5.6 | 3.2 | 16.8 | 0.4 |
| Below 50 | Sample grade | 3.7 | 1.2 | 0.6 | 2.7 | 0.0 |
| Yearly average in pounds per bushel | | 55.5 | 57.5 | 57.5 | 55.5 | 60.0 |

[1] Hereafter theoretical grade shall be the grade as affected only by the grading factor being discussed.

Table 4. S.D.S.U. winter wheat samples classified according to test weight per bushel.

| Pounds per bushel | Theoretical grade | % of Samples in each grade by year | | | | |
|---|---|---|---|---|---|---|
| | | 1963 | 1964 | 1965 | 1966 | 1967 |
| 62 or better | 1 heavy | 37.0 | 51.4 | 1.7 | 47.8 | 73.4 |
| 60 thru 61.9 | 1 | 30.4 | 29.9 | 12.3 | 36.6 | 21.0 |
| 58 thru 59.9 | 2 | 14.3 | 16.3 | 21.2 | 11.8 | 3.6 |
| 56 thru 57.9 | 3 | 10.4 | 1.7 | 21.2 | 3.8 | 1.2 |
| 54 thru 55.9 | 4 | 6.9 | 0.7 | 14.0 | 0.0 | 0.4 |
| 51 thru 53.9 | 5 | 0.9 | 0.0 | 15.1 | 0.0 | 0.0 |
| Below 51 | Sample grade | 0.0 | 0.0 | 14.5 | 0.0 | 0.4 |
| Yearly average in pounds per bushel | | 60.5 | 61.7 | 55.96 | 61.68 | 62.5 |

Table 5. S.D.S.U. survey of state averages of percent protein content for spring and winter wheat from 1965 to 1967.

| Year | Protein % of Hard Red Spring | Protein % of Hard Red Winter |
|---|---|---|
| 1965 | 13.57 | 10.69 |
| 1966 | 16.44 | 14.69 |
| 1967 | 13.29 | 12.77 |

## Damaged Kernels

Damaged kernels are composed primarily of sprouted kernels, fungus damaged kernels, and immature green colored kernels. They represent material that is of low baking value or material that will be removed in cleaning. Neither damaged kernels nor heat damaged kernels were found to affect the grade of South Dakota's wheat except for such a small number of samples that they would not readily be shown in a table.

## Foreign Material

Foreign material is determined as percent of the sample by weight after the removal of dockage. It consists of all matter other than wheat which is not separated in the proper determination of dockage (33). This material is of concern to the processor because it will be milled with the wheat. The foreign material in South Dakota's wheat is composed largely of wild buckwheat seed

and the caryopsis of wild oats. Rye was also found in a few samples. In 1967, 8% of the samples would not have met the requirements for number one wheat because foreign material was too high. This is not to say that foreign material was the "factor that determined grade" in eight percent of the samples. (The grading factor that puts the sample into the lowest grade is said to be the "factor that determines grade." For example, if a sample contains 0.60% foreign material and 6.0% shrunken and broken kernels, the latter determines the grade because it would cause the sample to grade number three wheat while 0.6% foreign material would only cause the sample to grade number two wheat) (See Appendix Table 1). Table 6 indicates that the foreign material content varies somewhat from year to year but generally stays below the limits for number one wheat.

These data would indicate that although foreign material cannot be ignored, it is not a major problem in South Dakota's wheat.

Table 6. S.D.S.U. state averages of percent foreign material for spring and winter wheat.

| Year | Hard Red Spring | Hard Red Winter |
|---|---|---|
| 1963 | 0.39% | 0.46% |
| 1964 | 0.30% | 0.37% |
| 1965 | 0.52% | 0.65% |
| 1966 | 0.48% | 0.12% |
| 1967 | 0.42% | 0.32% |

## Shrunken and Broken Kernels

Shrunken and broken kernels are determined on the basis of dockage free wheat. They are shown as percent by weight, and consist primarily of broken and shriveled wheat that will pass through a 0.064 x 3/8 inch oblong hole sieve (33). Shrunken and broken kernels are generally removed by cleaning before wheat is milled.

Data in Table 7 indicated that South Dakota's wheat was high in percent of shrunken and broken kernels and the averages fluctuated considerably from year to year. Shriveled kernels were especially high when disease or drought prevailed during the filling period. Cracking and breaking of kernels results from handling wheat at low moisture content and from improper setting of the combine (5, 35).

Shrunken and broken kernels was the factor that most often determined the grade of South Dakota's wheat. Much more research is needed to overcome this loss to the wheat producer.

## Total Defects

Total defects is determined by adding together the total of the three grading factors: (1) damage, (2) foreign material, and (3) shrunken and broken kernels. Total defects sets a limit for these factors added together. In 1967 total defects was the factor that determined grade in 20% of the samples that did not grade number one. Percent of total defects varied greatly from year to year as seen in Table 8.

Table 7. S.D.S.U. wheat samples classified according to percent of shrunken and broken kernels.

| % of shrunken and broken | Theoretical grade | % of Samples by year | | | | |
|---|---|---|---|---|---|---|
| | | 1963 | 1964 | 1965 | 1966 | 1967 |
| | | | Hard Red Spring Wheat | | | |
| 0 thru 3 | 1 | 93.2 | 49.3 | 74.1 | 78.8 | 58.6 |
| 3.1 thru 5 | 2 | 6.2 | 27.1 | 19.4 | 12.4 | 25.4 |
| 5.1 and above | 3 to sample grade | 0.6 | 23.6 | 6.5 | 8.8 | 16.0 |
| Yearly average | | 1.41 | 3.83 | 2.29 | 2.26 | 3.1 |
| | | | Hard Red Winter Wheat | | | |
| 0 thru 3 | 1 | 95.2 | 90.3 | 65.4 | 95.7 | 78.2 |
| 3.1 thru 5 | 2 | 4.4 | 7.3 | 13.4 | 3.2 | 17.7 |
| 5.1 and above | 3 to sample grade | 0.4 | 2.4 | 21.2 | 1.1 | 4.1 |
| Yearly average | | 1.31 | 2.37 | 3.37 | 0.83 | 2.2 |

Table 8. S.D.S.U. wheat samples classified according to percent of total defects--state averages.

| Year | Hard Red Spring % of total defects | Hard Red Winter % of total defects |
|---|---|---|
| 1964 | 4.20 | 2.68 |
| 1965 | 2.92 | 4.19 |
| 1966 | 2.86 | 1.01 |
| 1967 | 3.64 | 2.75 |
| Four year average | 2.72 | 2.12 |

## Contrasting Classes

Contrasting classes refers to the mixing of other classes of wheat with the class being graded. Durum constitutes a contrasting class in the bread wheat classes. Over the five year average, only 2% of the spring wheat contained contrasting classes in sufficient amounts to affect grade. No contrasting classes were found in the winter wheat.

## Subclass

Subclasses indicate percent of dark hard and vitreous kernels which are most desirable for milling. Dark Northern Spring Wheat, for example, must contain 75% or more of dark hard and vitreous kernels. Kernel vitreousness is the grain inspector's estimate of milling performance or high protein content (2). Wheat subject to high moisture at harvest or grown on land low in nitrogen will often have a low percentage of vitreous kernels. Vitreous kernel content of the South Dakota wheat varied considerably from year to year (Table 9).

## Numerical Grade

A numerical grade is placed on each wheat sample. It represents the minimum in market quality at a grade level because of one or more grading factors. As seen in Table 10 the percent falling into each grade varied from year to year. Inconsistency in

Table 9. S.D.S.U. wheat samples classified according to subclass.

| Subclass | 1963 | 1964 | 1965 | 1966 | 1967 |
|---|---|---|---|---|---|
| | | | Hard Red Spring | | |
| Dark Northern Spring | 40% | 74% | 85% | 79% | 96% |
| Northern Spring | 26% | 16% | 11% | 15% | 4% |
| Red Spring | 34% | 10% | 4% | 6% | 0% |
| | | | Hard Red Winter | | |
| Dark Hard Winter | 59% | 72% | 49% | 95% | 78% |
| Hard Winter | 28% | 21% | 30% | 4% | 19% |
| Yellow Hard Winter | 13% | 7% | 21% | 1% | 3% |

grade is readily explained by the large variation from year to year in the factors that determine grade.

Table 10. S.D.S.U. wheat samples classified according to grade.

| Grade | 1963 | 1964 | 1965 | 1966 | 1967 |
|---|---|---|---|---|---|
| | | | Hard Red Spring Wheat | | |
| 1 heavy | * | 9.7% | * | 0.9% | 28.6% |
| 1 | 23.8% | 20.3% | 25.5% | 11.5% | 11.8% |
| 2 heavy | * | * | * | 0.0% | 23.1% |
| 2 | 12.2% | 25.9% | 27.4% | 11.7% | 12.2% |
| 3 heavy | * | * | * | 0.9% | 8.1% |
| 3 | 18.9% | 25.5% | 30.1% | 28.3% | 9.6% |
| 4 | 24.3% | 9.9% | 11.7% | 20.5% | 6.0% |
| 5 | 16.3% | 7.3% | 3.5% | 16.7% | 0.3% |
| Sample grade | 4.5% | 1.4% | 1.8% | 3.5% | 0.3% |
| | | | Hard Red Winter Wheat | | |
| 1 heavy | * | * | * | 44.6% | 47.6% |
| 1 | 60.9% | 68.1% | 10.6% | 32.8% | 16.1% |
| 2 heavy | * | * | * | 0.5% | 19.4% |
| 2 | 15.2% | 18.3% | 20.7% | 12.4% | 6.5% |
| 3 heavy | * | * | * | 0.6% | 3.6% |
| 3 | 13.5% | 8.7% | 22.3% | 5.9% | 3.2% |
| 4 | 7.8% | 3.8% | 15.1% | 2.7% | 2.8% |
| 5 | 0.9% | 0.7% | 14.0% | 0.5% | 0.0% |
| Sample grade | 1.7% | 0.4% | 17.3% | 0.0% | 0.8% |

* Data not available.

Data presented thus far have indicated that quality factors in South Dakota's wheat varied from year to year. Perhaps more important is the comparison of South Dakota's wheat to that grown in other areas. Data in Table 11 show 1967 state averages of eight

factors and grade for North and South Dakota spring wheat. The North Dakota data were compiled by the North Dakota Department of Agriculture from samples taken at elevators and from farm bins. The South Dakota Crop and Livestock Reporting Service data were used in this comparison.

These data revealed that North Dakota's spring wheat graded higher, contained less dockage, fewer shrunken and broken kernels, and a smaller percentage of foreign material than did the spring wheat produced in South Dakota in 1967.

Table 11. Comparison of the physical quality of the 1967 spring wheat crops from North and South Dakota.

| Factor | North Dakota [1] State Averages | South Dakota [2] State Averages |
|---|---|---|
| Grade | | |
| No. 1 | 71.9% | 45.5% |
| No. 2 | 24.1% | 42.6% |
| Under No. 2 | 4.0% | 11.9% |
| Test Weight | 59.7 lbs. per bushel | 59.4 lbs. per bushel |
| Moisture | 11.3% | 11.2% |
| Protein | 15.0% | 14.6% |
| Shrunken and Broken | 2.3% | 2.8% |
| Damaged Kernels | 0.2% | 0.1% |
| Foreign Material | 0.2% | 0.5% |
| Total Defects | 2.7% | 3.3% |
| Dockage | | |
| Less than 0.5% | 53.7% | 8.0% |
| 0.5% - 0.9% | 19.0% | 29.0% |
| 1.0% - or over | 27.3% | 63.0% |

[1] These data were furnished through the courtesy of the North Dakota Department of Agriculture (Arne Dahl, Commissioner), Bismarck, North Dakota, and are not for publication.

[2] Data from the South Dakota Crop and Livestock Reporting Service.

Davis (5), and Zeman and Johnson (35), have suggested several ways to improve the quality of the wheat. The following suggestions include several of their recommendations:

1. Reduce wheat of other classes by:
   A. Planting clean seed.
   B. Keeping the cleaning equipment and bins free of wheat of other classes.
   C. Do not "Patch" killed out winter wheat with spring wheat unless you cut the patches out separately.
2. Reduce the moisture content to about 12%.
   A. Swath to hasten maturity and drying.
   B. Start the combine later each morning and stop earlier in the evening.
3. Reduce the total defects by:
   A. Running the cylinder only fast enough to effectively separate the grain. High cylinder speeds cause a high percent of broken kernels.
   B. Use the proper sieve openings and air volume to avoid overloading the straw walker and sieves.
   C. Adjust the combine not only for each crop but also for each field.
   D. Adjust the concaves as temperature and humidity changes occur.
   E. Handle the grain as little as possible to reduce kernel breakage. Augers should not have excessive clearance between the screw and housing.
   F. Do not attempt to get every kernel. Finding about one kernel in every fifteen heads on a dry year and one in every five heads on a wet year indicates that cylinder loss is about

right. However, in well standing clean grain, losses should not exceed 2%.

G. Use "pre-cleaners" to reduce foreign material and shrunken and broken kernels.

H. Practice good weed control.

4. Maximize test weight and yield by harvesting at the proper time. After a field reaches maturity, test weight drops about ¼ pound per bushel per day and shattering increases about twelve pounds daily per acre.

5. Reduce storage damage (if stored on the farm).

A. Spray storage areas to reduce insect levels.

B. Do not store dirty wheat. The red flour beetle (Triboluim castaneum) increases rapidly as dockage increases from 0.3% to 4.5% (14).

C. Do not store wheat that is above 13.5% moisture.

If these recommendations are closely followed, the producer may realize a higher grade and price.

## Comparisons of Wheat Coming Into Elevators With Wheat Being Shipped Out of Elevators

In this portion of the study, an attempt was made to find changes in wheat quality that occurred during handling. Wheat being delivered to elevators by farmers (referred to as wheat coming in) was compared to wheat being shipped from the same elevators (referred to as outgoing wheat). Only twenty-five elevators were used in this analysis which differed from the comparisons in which state averages were used.

The analysis indicated that the dockage of wheat coming into the elevators was significantly higher than that being shipped out by rail (Table 12). It is possible that the elevators considered in the analysis did more cleaning thus removing more dockage than did the average elevator.

The test weight of the wheat going into elevators was significantly higher than the test weight of wheat going out (Table 12). Under current conditions wheat comes in so rapidly during the harvest that many elevators cannot keep wheat of widely different qualities separate. Consequently, wheat of different test weights are mixed. However, the difference in test weight between wheat coming in and going out remains largely unexplained. In comparing the S.D.S.U. and the C & L state averages (Table 13), it can be seen that incoming wheat is higher in test weight. This is consistent with the analysis.

Table 12. Results of the analysis of variance of six quality factors comparing wheat coming in versus wheat being shipped out of twenty-five elevators in South Dakota during the 1967 crop year.

| | Quality Factor | Mean of [1] Incoming Wheat | Mean of Outgoing Wheat | Statistical Comparison of Mean |
|---|---|---|---|---|
| 1. | Dockage | 1.20% | 1.06% | ** |
| 2. | Test Weight | 61.23 lbs/bu | 60.73 lbs/bu | ** |
| 3. | Damaged Kernels | 0.13% | 0.07% | ** |
| 4. | Foreign Material | 0.30% | 0.47% | ** |
| 5. | Shrunken and Broken | 1.78% | 1.74% | ** |
| 6. | Total Defects | 3.15% | 3.16% | NS |

[1] These means are in the original units of measure and all tests of significance were carried out using transformed data.

** - significantly different at the 1% level.

NS - not significantly different.

Table 13. Comparison of 1967 state averages for the S.D.S.U. Survey representing wheat coming into the elevators and the Crop and Livestock Reporting Service Survey representing wheat being shipped out of elevators.

| | Spring Wheat | | Winter Wheat | |
|---|---|---|---|---|
| | S.D.S.U. | Crop & Livestock | S.D.S.U. | Crop & Livestock |
| Test Weight | 60.0 lbs/bu | 59.4 lbs/bu | 62.5 lbs/bu | 61.5 lbs/bu |
| Moisture % | 11.5% | 11.2% | 11.3% | 11.5% |
| Protein % | 13.3% | 14.6% | 12.8% | 12.7% |
| Grade: No. 1 | 40% | 45% | 63% | 76% |
| No. 2 | 35% | 43% | 26% | 19% |
| No. 3 | 18% | 10% | 7% | 4% |
| No. 4 & 5 & Sample Grade | 7% | 2% | 4% | 3% |
| Dockage: 0.0 - 0.50 | 15% | 8% | 54% | 41% |
| 0.51 - 0.99 | 24% | 29% | 28% | 43% |
| 1.0 & above | 61% | 63% | 18% | 16% |
| Damaged Kernels: | 0.13% | 0.1% | 0.23% | 0.1% |
| Foreign Material: | 0.42% | 0.5% | 0.32% | 0.5% |
| Shrunken & Broken: | 3.1% | 2.7% | 2.2% | 2.0% |
| Total Defects: | 3.64% | 3.3% | 2.75% | 2.6% |
| Subclass: | | | | |
| Dark Northern Spring | 96.27% | 99% | 78.22% | 75% |
| Northern Spring | 3.73% | 1% | 19.35% | 22% |
| Red Spring | 0.00% | 0% | 2.42% | 3% |

Wheat coming into elevators was shown to be significantly higher in shrunken and broken kernels than that leaving the elevators (Table 12). This is consistent with comparisons of state averages of the S.D.S.U. and the C & L surveys. The lower percentage of shrunken and broken kernels in wheat coming out of the elevators served as further evidence that cleaning did occur before shipment at many elevators. The degree of cleaning depended upon the standards set by the elevator operators. Several elevator managers have expressed the opinion that their cleaners were getting the wheat "too clean".

There was a significantly smaller percentage of damaged kernels in the wheat being shipped from the elevators than that received from farmers (Table 12). This suggested that some damaged kernels were removed in cleaning.

There was a reversal in the trend when foreign material was observed. The amount of foreign material being shipped out was significantly higher than in wheat received by the elevators (Table 12). The results of this analysis were much the same as the comparison of the S.D.S.U. and the C & L state averages (Table 13). Foreign material is all matter other than wheat which is not removed in the proper determination of dockage. It represents what remains in the wheat after the wheat has been cleaned and is ready for milling. It is possible that in taking in several kinds of grain, elevators could be inadvertently mixing a small amount of rye, for example, into the wheat.

No significant difference between incoming and outgoing wheat in the percent of total defects was noted. Total defects are composed of damaged kernels, foreign material, and shrunken and broken kernels. Here it seems that these factors have balanced each other to show no significance.

Comparisons of grades of samples used in the analysis indicate that a greater percentage of the wheat being shipped out graded number two or higher, than did the wheat coming into elevators. Ninety-five percent of the spring wheat and ninety-eight percent of the winter wheat being shipped out graded number two or higher while only 74.7% of the spring wheat and 89.7% of the winter wheat coming in graded number two or higher (Table 14). The trends observed in this comparison are much the same as those of state averages for incoming and outgoing wheat. The fact that the wheat being shipped out graded higher may be attributed primarily to the higher percentage of shrunken and broken kernels in the incoming wheat. It has been the experience of this author that shrunken and broken kernels is the grading factor that most frequently affects grade. Cleaning will remove a portion of the shrunken and broken kernels, thus explaining the difference indicated in the analysis.

Protein content was not analyzed. State averages shown by the C & L and the S.D.S.U. reports indicate no definite trend (Table 13).

The comparison of the incoming versus outgoing wheat would vary with the time the survey was taken during harvest. Managers say that when they get behind they are unable to clean the grain before

shipping it.

Table 14. Grade distribution of samples used for analysis of incoming and outgoing wheat for the 1967 wheat crop.

| Grade | Incoming Wheat | | Outgoing Wheat | |
|---|---|---|---|---|
| | Spring | Winter | Spring | Winter |
| 1 | 38.8% | 67.7% | 41.7% | 79.8% |
| 2 | 34.9% | 22.0% | 53.9% | 18.6% |
| 3 | 18.4% | 8.7% | 4.4% | 1.7% |
| 4 | 6.8% | 0.8% | 0.0% | 0.0% |
| 5 | 0.48% | 0.0% | 0.5% | 0.0% |
| Sample Grade | 0.48% | 0.8% | 0.0% | 0.0% |

In general, this study indicated that the overall quality of the wheat being shipped out of elevators is higher than the quality of wheat received from the growers. Much of this difference is believed to be due to the cleaning that occurs in the elevators sampled.

## Comparison of the Quality of Spring and Winter Wheat

The recent introduction of more winter hardy varieties of winter wheat coupled with new ideas in cultural practices have improved the potential of winter wheat in South Dakota. Basic to the decision of whether to grow spring or winter wheat is the question of quality. A distinct quality advantage for one class of wheat over the other could be the deciding factor.

A comparison of the quality of spring and winter wheat using state averages from the 1967 data as compiled at S.D.S.U. (Table 15), showed that spring wheat contained one percent more dockage than did winter wheat. The cost of hauling this extra one percent of the 39 million bushel spring wheat crop to the elevator (at five cents per bushel) was $197,610. More important is the cost of cleaning this high dockage wheat and shipping that portion of the dockage that is not removed. The difference of 0.1% in foreign material is important, because foreign material represents matter other than wheat that will be milled for flour.

Spring wheat averaged 0.9% higher in shrunken and broken kernels than did winter wheat. This is enough to make the difference between grade number one and number two grade wheat. Although both classes of wheat will average heavy, the winter wheat at 62.5 pounds per bushel again has an edge over spring wheat at 60 pounds. (Spring wheat need only show 58 pounds per bushel to grade number one, while winter wheat must weigh 60 pounds.)

Table 15. Comparison of spring and winter wheat for six quality factors and grade using state averages from the 1967 S.D.S.U. Survey.

| | Hard Red Spring Wheat | Hard Red Winter Wheat |
|---|---|---|
| Dockage | 1.7% | 0.72% |
| Foreign Material | 0.42% | 0.32% |
| Shrunken and Broken Kernels | 3.10% | 2.2% |
| Test Weight | 60.0 lbs/bu | 62.5 lbs/bu |
| Damaged Kernels | 0.13% | 0.23% |
| Protein | 13.29% | 12.77% |

| Grade | % in Each Grade | % in Each Grade |
|---|---|---|
| No. 1 | 40.67 | 63.71 |
| No. 2 | 34.45 | 25.81 |
| No. 3 | 17.91 | 6.85 |
| No. 4 | 5.97 | 2.82 |
| No. 5 | 0.37 | 0.00 |
| Sample grade | 0.37 | 0.81 |

Spring wheat showed 0.1% fewer damaged kernels than winter wheat. Although damaged kernels can be important, they are seldom the factor that determines grade in South Dakota wheat. Up to 2% damaged kernels can be present before the wheat drops a grade. Neither the state average of spring wheat at 0.13% nor winter wheat at 0.23% damaged kernels would be considered serious.

Together, the above mentioned factors account for 23% more of the winter wheat grading number one than the spring wheat.

The results of this survey showed that spring wheat was higher in protein than winter wheat by 0.52%. High protein is one of the most important quality aspects. The higher protein in spring wheat is the reason for its receiving a premium in the cash market. Data compiled by the Doty Laboratories (6) as presented in Tables 24 and 25 show the protein content of spring and winter wheat from several states for the years of 1965 through 1967. The protein content of South Dakota's spring wheat averaged below the protein content of spring wheat grown in North Dakota and Montana when wheats of equal test weight were compared. The average protein content of South Dakota's winter wheat was above the three year averages shown for Montana, Kansas, and Nebraska.

In the foregoing comparisons of spring and winter wheat, using data from the S.D.S.U. survey, there is one recognized fallacy. It is realized that the spring and winter wheat being compared may not be grown in the same area. To overcome this fallacy a comparative analysis was carried out between the quality of spring and winter

wheat grown within certain counties in South Dakota. Seven quality factors were compared in eleven counties. The counties included were Spink, Hand, Faulk, Potter, Perkins, Butte, Sully, Hyde, Hughes, Stanley, and Haakon. Data on car load lots from the C & L were used for the comparison.

Dockage was higher in the spring wheat in all counties and was significantly higher in Spink, Hand, Perkins, Butte, Sully, Hughes, Stanley, and Haakon counties (Table 16).

Winter wheat was significantly higher in test weight in Haakon, Hand, Butte, Stanley, Sully, Hughes, and Hyde counties (Table 17). Spink County showed a higher test weight for winter wheat than for spring wheat but the difference was not significant.

The percentage of shrunken and broken kernels was higher in spring wheat than in winter wheat in all counties. This difference was statistically significant in all counties except Faulk (Table 18).

Winter wheat was generally higher in damaged kernels than spring wheat but the difference was only significant in Spink, Stanley, and Hughes counties (Table 19).

Foreign material content was generally higher in the winter wheat than in the spring wheat (Table 20). Differences were significant in Spink, Haakon, Hand and Sully counties. This is the only reversal from trends indicated by state averages (Table 15). In the state averages spring wheat is higher in foreign material.

The percentage of total defects (Table 21) is higher in the spring wheat in all counties. This difference is significant in

Table 16. Comparative analysis of the percent of dockage found in spring and winter wheat in eleven South Dakota counties.

| | County | Mean of Winter Wheat | Mean of Spring Wheat | Statistical Comparison of Means |
|---|---|---|---|---|
| 1. | Spink | 1.015% | 1.559% | ** |
| 2. | Haakon | 0.534% | 1.693% | ** |
| 3. | Hand | 0.668% | 1.762% | ** |
| 4. | Potter | 0.964% | 1.008% | NS |
| 5. | Faulk | 0.356% | 0.588% | NS |
| 6. | Perkins | 0.053% | 0.710% | ** |
| 7. | Butte | 0.962% | 1.664% | * |
| 8. | Stanley | 0.542% | 1.349% | ** |
| 9. | Sully | 0.561% | 1.237% | ** |
| 10. | Hughes | 0.745% | 1.471% | ** |
| 11. | Hyde | 2.092% | 2.583% | NS |

* - significantly different at the 5% level.

** - significantly different at the 1% level.

NS - not significantly different.

Table 17. Comparative analysis of the test weight of spring and winter wheat in eleven South Dakota counties.

| | County | Mean of Winter Wheat | Mean of Spring Wheat | Statistical Comparison of Means |
|---|---|---|---|---|
| 1. | Spink | 60.91 lbs/bu | 60.55 lbs/bu | NS |
| 2. | Haakon | 60.91 lbs/bu | 59.21 lbs/bu | ** |
| 3. | Hand | 60.93 lbs/bu | 59.31 lbs/bu | ** |
| 4. | Potter | 59.61 lbs/bu | 60.31 lbs/bu | NS |
| 5. | Faulk | 59.60 lbs/bu | 60.10 lbs/bu | NS |
| 6. | Perkins | 60.00 lbs/bu | 60.18 lbs/bu | NS |
| 7. | Butte | 61.68 lbs/bu | 59.98 lbs/bu | ** |
| 8. | Stanley | 61.28 lbs/bu | 59.68 lbs/bu | ** |
| 9. | Sully | 60.26 lbs/bu | 58.84 lbs/bu | ** |
| 10. | Hughes | 61.20 lbs/bu | 58.58 lbs/bu | ** |
| 11. | Hyde | 60.67 lbs/bu | 59.27 lbs/bu | * |

* - significantly different at the 5% level.

** - significantly different at the 1% level.

NS - not significant.

Table 18. Comparative analysis of the percent of shrunken and broken kernels found in spring and winter wheat in eleven South Dakota counties.

| | County | Mean of Winter Wheat | Mean of Spring Wheat | Statistical Comparison of Means |
|---|---|---|---|---|
| 1. | Spink | 2.279% | 2.707% | * |
| 2. | Haakon | 2.082% | 3.206% | ** |
| 3. | Hand | 1.574% | 3.756% | ** |
| 4. | Potter | 2.342% | 3.225% | ** |
| 5. | Faulk | 2.173% | 2.400% | NS |
| 6. | Perkins | 2.272% | 2.831% | * |
| 7. | Butte | 2.893% | 4.028% | ** |
| 8. | Stanley | 2.157% | 3.548% | ** |
| 9. | Sully | 2.206% | 3.385% | ** |
| 10. | Hughes | 1.974% | 3.923% | ** |
| 11. | Hyde | 1.409% | 3.004% | ** |

* - significantly different at the 5% level.

** - significantly different at the 1% level.

NS - not significantly different.

Table 19. Comparative analysis of the percent of damaged kernels found in spring and winter wheat in eleven South Dakota counties.

| | County | Mean of Winter Wheat | Mean of Spring Wheat | Statistical Comparison of Means |
|---|---|---|---|---|
| 1. | Spink | 0.019% | 0.011% | ** |
| 2. | Haakon | 0.017% | 0.013% | NS |
| 3. | Hand | 0.018% | 0.013% | NS |
| 4. | Potter | 0.0002% | 0.003% | NS |
| 5. | Faulk | 0.010% | 0.018% | NS |
| 6. | Perkins | 0.014% | 0.008% | NS |
| 7. | Butte | 0.004% | 0.004% | NS |
| 8. | Stanley | 0.017% | 0.003% | ** |
| 9. | Sully | 0.007% | 0.004% | NS |
| 10. | Hughes | 0.018% | 0.004% | ** |
| 11. | Hyde | 0.013% | 0.007% | NS |

** - significantly different at the 1% level.

NS - not significantly different.

Table 20. Comparative analysis of the percent of foreign material found in spring and winter wheat in eleven South Dakota counties.

| | County | Mean of Winter Wheat | Mean of Spring Wheat | Statistical Comparison of Means |
|---|---|---|---|---|
| 1. | Spink | 0.609% | 0.506% | * |
| 2. | Haakon | 0.370% | 0.273% | * |
| 3. | Hand | 0.899% | 0.502% | ** |
| 4. | Potter | 0.389% | 0.382% | NS |
| 5. | Faulk | 0.673% | 0.524% | NS |
| 6. | Perkins | 0.374% | 0.367% | NS |
| 7. | Butte | 0.673% | 0.526% | NS |
| 8. | Stanley | 0.378% | 0.359% | NS |
| 9. | Sully | 0.435% | 0.356% | ** |
| 10. | Hughes | 0.419% | 0.385% | NS |
| 11. | Hyde | 0.474% | 0.621% | NS |

* - significantly different at the 5% level.

** - significantly different at the 1% level.

NS - not significantly different.

Table 21. Comparative analysis of the percent of total defects found in spring and winter wheat in eleven South Dakota counties.

| | County | Mean of Winter Wheat | Mean of Spring Wheat | Statistical Comparison of Means |
|---|---|---|---|---|
| 1. | Spink | 3.129% | 3.329% | NS |
| 2. | Haakon | 2.651% | 3.584% | ** |
| 3. | Hand | 2.740% | 4.464% | ** |
| 4. | Potter | 2.754% | 3.678% | ** |
| 5. | Faulk | 2.871% | 3.140% | NS |
| 6. | Perkins | 2.798% | 3.279% | NS |
| 7. | Butte | 3.666% | 4.621% | * |
| 8. | Stanley | 2.740% | 3.961% | ** |
| 9. | Sully | 2.733% | 3.818% | ** |
| 10. | Hughes | 2.608% | 4.370% | ** |
| 11. | Hyde | 2.047% | 3.735% | ** |

* - significantly different at the 5% level.

** - significantly different at the 1% level.

NS - not significantly different

Haakon, Hand, Potter, Butte, Stanley, Sully, Hughes, and Hyde counties.

As expected, the protein content (Table 22) was significantly higher in the spring wheat in all counties.

Table 23 shows a comparison of spring and winter wheat at four locations using S.D.S.U. data. The results of this comparison were much the same as the comparison of state averages made earlier.

After considering all comparisons it seems that the overall quality of the winter wheat is higher than that of spring wheat--test weight, dockage, and shrunken and broken kernels being the primary factors considered in physical wheat quality. Comparisons of figures 1 and 2 may help to explain some of the differences. Winter wheat is filling during the period of maximum precipitation but before the period of maximum temperatures, while spring wheat is filling during the period when temperatures are highest (15, 17). High temperatures would keep the kernels in the lower portion of the head from filling properly, resulting in more shrunken kernels. Test weight could also be lowered by the hot weather.

It is important that the reader realize that the foregoing statements and conclusions on the comparison of spring and winter wheat quality are based primarily upon one year's data. Much more data would have to be evaluated before final conclusions could be drawn.

Table 22. Comparative analysis of the protein content of spring and winter wheat in eleven South Dakota counties.

| | County | Mean of Winter Wheat | Mean of Spring Wheat | Statistical Comparison of Means |
|---|---|---|---|---|
| 1. | Spink | 13.01% | 13.86% | ** |
| 2. | Haakon | 12.67% | 15.02% | ** |
| 3. | Hand | 13.62% | 14.29% | ** |
| 4. | Potter | 13.30% | 14.36% | ** |
| 5. | Faulk | 12.61% | 14.59% | ** |
| 6. | Perkins | 13.21% | 15.39% | ** |
| 7. | Butte | 11.97% | 14.87% | ** |
| 8. | Stanley | 12.96% | 14.56% | ** |
| 9. | Sully | 12.88% | 14.60% | ** |
| 10. | Hughes | 13.05% | 14.30% | ** |
| 11. | Hyde | 12.65% | 13.67% | ** |

** - significantly different at the 1% level.

Table 23. Comparisons of station averages of eight grading factors in spring and winter wheat at four locations using data from the 1967 S.D.S.U. Survey.

| Station | % Dockage | Test Weight in lbs/bu | % Shrunken and Broken | % Foreign Materials | % Damaged Kernels | 1000 Kernel Weight | % Protein |
|---|---|---|---|---|---|---|---|
| LEMMON | | | | | | | |
| Spring | 1.06 | 56.8 | 6.45 | 0.89 | 0.43 | 23.09 g. | 13.91 |
| Winter | 2.83 | 61.55 | 3.36 | 0.61 | 0.27 | 27.44 g. | 12.24 |
| ONIDA | | | | | | | |
| Spring | 1.22 | 58.46 | 4.04 | 0.26 | 0.17 | 26.77 g. | 13.94 |
| Winter | 0.42 | 62.80 | 2.29 | 0.19 | 0.15 | 29.62 g. | 12.38 |
| ORIENT | | | | | | | |
| Spring | 1.17 | 60.01 | 2.2 | 0.30 | 0.16 | 29.74 g. | 12.53 |
| Winter | 0.66 | 61.80 | 3.69 | 0.33 | 0.25 | 29.40 g. | 11.98 |
| FT. PIERRE | | | | | | | |
| Spring | 2.2 | 60.62 | 3.0 | 0.52 | 0.10 | 27.96 g. | 13.92 |
| Winter | 0.81 | 62.43 | 2.0 | 0.18 | 0.32 | 34.05 g. | 12.32 |
| AVERAGES | | | | | | | |
| Spring | 1.41 | 58.97 | 3.92 | 0.49 | 0.22 | 26.89 g. | 13.57 |
| Winter | 1.18 | 62.12 | 2.83 | 0.33 | 0.25 | 30.12 g. | 12.23 |

Figure 1. Filling and harvesting periods of winter wheat as related to mean monthly precipitation and temperature in South Dakota(15,17).

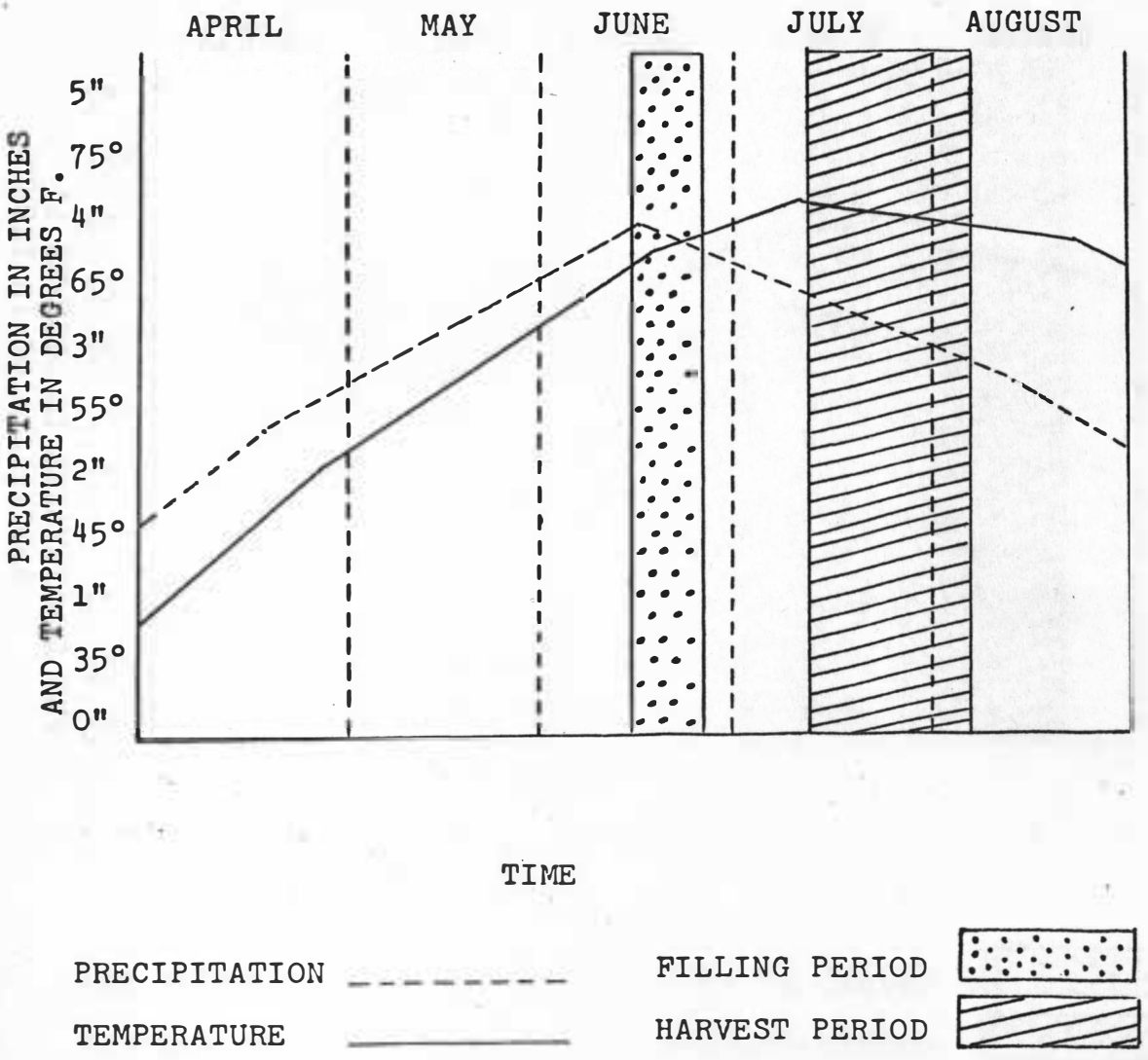
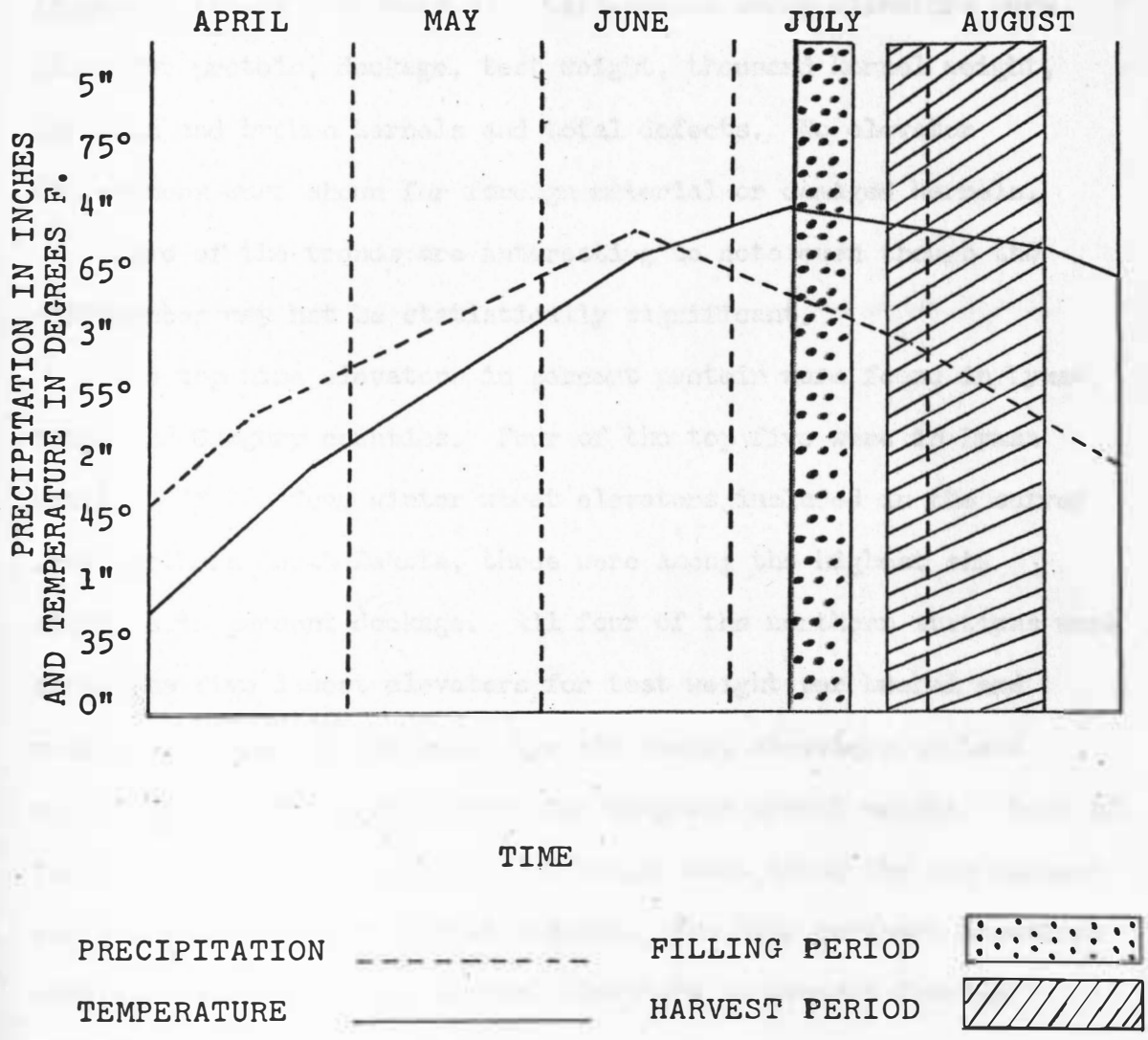


Figure 2. Filling and harvesting periods of spring wheat as related to mean monthly precipitation and temperature in South Dakota (15, 17).



Comparison of the Quality of Wheat Received at Different Elevators

WINTER WHEAT:

The results of this analysis indicate that there was a significant difference among elevators for six of the eight factors (Appendix tables 2 through 9). Differences among elevators were shown for protein, dockage, test weight, thousand kernel weight, shrunken and broken kernels and total defects. No elevator differences were shown for foreign material or damaged kernels.

Some of the trends are interesting to note even though the differences may not be statistically significant.

The top nine elevators in percent protein were found in Lyman, Tripp and Gregory counties. Four of the top five were in Lyman County. Of the four winter wheat elevators included in the survey from northern South Dakota, three were among the highest six stations in percent dockage. All four of the northern stations were among the five lowest elevators for test weight per bushel and weight per thousand kernels. The six lowest elevators in test weight were also the six lowest for thousand kernel weight. Four of the six highest elevators in test weight were among the six highest elevators for thousand kernel weights. The four northern locations were also among the five highest elevators in percent foreign material.

Four of the six lowest elevators in percent of shrunken and broken kernels were located in Lyman County. The northern locations

showed the four highest averages of shrunken and broken kernels.

The above comparisons show some consistencies in the elevator differences. Of the six elevators showing the lowest percent of shrunken and broken kernels, four are also in the lowest six in percent of damaged kernels. Four of the lowest elevators in dockage are in the low six for damaged kernels.

SPRING WHEAT:

A significant difference among elevators was shown for all eight factors with spring wheat (See Appendix tables 10 through 17).

Again it is interesting to note trends. Five of the eight elevators highest in protein content were in the north central part of the state. These same elevators comprise the lowest five averages in test weight. Four of them are also in the lowest five in weight per thousand kernels.

The top six elevators in test weight were located in the northeastern portion of the state.

As with winter wheat, consistencies begin to show up within elevator differences. Four of the eight elevators highest in percent dockage were also among the eight highest in shrunken and broken kernels. Likewise, four of the eight elevators lowest in dockage were also among the eight lowest in shrunken and broken kernels.

These data indicated that for several of the grading factors, there were some elevators taking in wheat of higher quality. It

is important to remember that only the 1967 crop is represented. It is possible that in another year, under different weather conditions, another set of elevators would show up better.

## Milling and Baking Quality

Nearly all of the hard red wheat grown in South Dakota is milled into flour for use by the baking industry. For this reason, the milling and baking evaluation of South Dakota wheat is of primary importance. As mentioned earlier, several of the physical quality factors are merely tools used by the grain merchant to estimate the final milling and baking quality. In this section, six factors are discussed in an attempt to compare the quality of South Dakota's wheat to that grown in other major wheat areas. Data are given for the comparisons in Tables 24 and 25.

SPRING WHEAT:

A. Test Weight

South Dakota's spring wheat was consistently lower in test weight than either North Dakota's or Montana's (Table 24). South Dakota's three year average was two pounds per bushel lower than either of the other two states.

B. Protein

The three year average for protein content of South Dakota's spring wheat was much the same as for North Dakota's and Montana's spring wheat. As mentioned in the previous section, the protein content of South Dakota's spring wheat was low relative to its test weight. As a general rule, protein content will increase as test weight decreases. High protein content is considered a necessary, but not a sufficient condition for good milling and baking

Table 24. State averages of six physical and chemical quality factors of hard red spring wheat from three states for the years of 1965-1967.[1]

| State | Year | T.W.[2] | % Protein | Yield-% Flour | % Flour Ash | F.V.[3] | Bake Evaluate[4] |
|---|---|---|---|---|---|---|---|
| South Dakota | 1965 | 56.9 | 14.1 | 68.3 | .498 | 69.6 | Excellent |
| | 1966 | 53.5 | 16.1 | 67.7 | .505 | 69.8 | V. Good |
| | 1967 | 58.5 | 13.8 | 70.9 | .455 | 79.4 | Good + |
| Average | | 56.3 | 14.7 | 69.0 | .486 | 72.9 | V. Good |
| Montana | 1965 | 58.1 | 14.0 | 69.7 | .477 | 68.2 | V. Good + |
| | 1966 | 58.8 | 14.8 | 70.9 | .475 | 70.3 | V. Good + |
| | 1967 | 59.2 | 15.0 | 71.7 | .455 | 80.0 | Good |
| Average | | 58.7 | 14.6 | 70.8 | .469 | 72.8 | V. Good |
| North Dakota | 1965 | 58.1 | 14.8 | 69.3 | .494 | 83.1 | Excellent |
| | 1966 | 57.3 | 15.5 | 69.8 | .487 | 76.2 | V. Good + |
| | 1967 | 59.5 | 14.7 | 71.5 | .454 | 80.6 | Good + |
| Average | | 58.3 | 15.0 | 70.2 | .478 | 80.0 | V. Good + |

[1] Data for this table were obtained through the courtesy of the Doty Laboratories Incorporated, Kansas City, Missouri, and are not for publication.

[2] Test weight in pounds per bushel.

[3] Farinograph Valorimeter Score.

[4] V. Good = Very Good; + = plus.

quality (27). The protein test is used to predict the quantity of gluten and not the quality (12).

C. Flour Yield

Percent flour yield is a measure of the amount of flour that can be extracted from a given volume of wheat (12). When dealing in large quantities of wheat, it is easy to see how a small difference in extraction can be economically important to the miller.

South Dakota's extraction was consistently lower than either Montana's or North Dakota's. The three year average showed a difference in excess of one percent. This could well be an important difference.

D. Ash Content

The importance of flour ash content is a very controversial subject. There seems to be little doubt among cereal chemists that high flour ash can be a serious problem. It becomes of prime importance when values are set as to what is acceptable and what is undesirable (27). Large differences in flour ash, especially in the upper range of acceptability, can affect the baking properties of wheat (8). Although standards vary from year to year depending upon the ash content of the wheat being marketed, flour ash content is one of the most inflexible standards set by the bakers (28).

The flour ash content of South Dakota's 1967 spring wheat compared favorably to the flour ash content of wheat grown in Montana and North Dakota (Table 24). The three year average showed South Dakota to be 0.008% higher than North Dakota and 0.017% higher

than Montana.[1] This difference may or may not affect the baking quality. However, the fact that extraction has to be decreased in South Dakota's wheat in order to meet ash requirements could be important to the miller. South Dakota's 1966 spring wheat would have been at a definite disadvantage with respect to ash content.

E. Farinograph Valorimeter Score[2]

The farinograph is an instrument used in testing the baking properties of wheat flour. The F.V. Score is but one of six values derived from a farinogram curve. In simple terms, F.V. Score is an indication of the overall strength of a flour. High scores generally indicate strong flour and low scores indicate weak flour. Strong wheats are desirable for baking (12).

The F.V. Scores of South Dakota's spring wheats were very similar to those shown for Montana's spring wheats, but generally below the North Dakota scores. Kansas State University has indicated that a "bakers mill mix" should have a F.V. Score of about 66 (12). The three year average F.V. Score for South Dakota's spring wheat was 72.9. This indicated that South Dakota's spring wheat was strong in these years.

F. Bake Evaluation

Evaluations shown for the last three years indicated that the overall baking evaluation of South Dakota's spring wheat was very much like North Dakota's and Montana's.

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[1] As a rule of thumb when flour ash increases by 0.01% flour extraction, at a constant ash content, will decrease by 2%.

[2] Hereafter, Farinograph Valorimeter will be shown as F.V.

WINTER WHEAT:

A. Test Weight and Protein

The test weight and protein content of South Dakota's winter wheat were good for the three year average. The protein content was above the averages shown for Montana, Kansas, and Nebraska (Table 25).

B. Flour Yield

The flour yield of South Dakota's winter wheat was very close to the averages shown for the other states.

C. Ash Content

South Dakota's winter wheat showed a consistently higher ash content than did the wheat from other states. This held not only for the three year average, but also for each year. The difference in ash content over a three year average showed South Dakota's winter wheat to be 0.012% higher than Kansas'. Using the rule of thumb mentioned earlier, this would mean a loss in extraction of more than 2% to those millers using South Dakota winter wheat.

D. Farinograph Valorimeter Score

Three year averages of the F.V. Score indicated that South Dakota's winter wheat was stronger than Kansas' and Nebraska's wheat, but not nearly as strong as Montana's. The F.V. Score for a "bakers mill mix" should be about 66 (12). South Dakota's winter wheat score of 62.3 indicated that it would have been necessary to blend it with wheat showing a higher score. This is reflected in the premiums paid for Montana's wheat.

Table 25. State averages of six physical and chemical quality factors of hard red winter wheat from four states for the years of 1965-67.[1]

| State | Year | T.W.[2] | % Protein | Yield-% Flour | % Flour Ash | F.V.[3] | Bake Evaluate[4] |
|---|---|---|---|---|---|---|---|
| South Dakota | 1965 | 58.7 | 11.7 | 69.7 | .460 | 61.1 | Good |
| | 1966 | 60.3 | 14.0 | 70.8 | .461 | 62.6 | V. Good |
| | 1967 | 60.4 | 13.0 | 71.9 | .453 | 63.2 | Good |
| Average | | 59.8 | 12.9 | 70.8 | .458 | 62.3 | Good + |
| Kansas | 1965 | 59.8 | 11.4 | 71.0 | .450 | 58.8 | Good - |
| | 1966 | 61.0 | 12.6 | 71.6 | .454 | 60.6 | Good - |
| | 1967 | 58.9 | 12.9 | 70.8 | .435 | 65.4 | Good |
| Average | | 59.9 | 12.3 | 71.1 | .446 | 61.6 | Good - |
| Montana | 1965 | 58.8 | 11.5 | 69.3 | .435 | 58.8 | Good |
| | 1966 | 62.0 | 12.8 | 72.1 | .440 | 71.3 | V. Good |
| | 1967 | 61.8 | 12.7 | 72.0 | .438 | 79.8 | Good |
| Average | | 60.9 | 12.2 | 71.1 | .437 | 70.9 | Good + |
| Nebraska | 1965 | 55.2 | 10.4 | 68.5 | .455 | 52.9 | Poor + |
| | 1966 | 61.8 | 12.6 | 71.9 | .456 | 61.1 | Good - |
| | 1967 | 58.9 | 12.1 | 70.4 | .436 | 58.4 | Fair |
| Average | | 58.6 | 11.7 | 70.3 | .449 | 57.5 | Fair |

[1] Data for this table were obtained through the courtesy of the Doty Laboratories Incorporated, Kansas City, Missouri, and are not for publication.

[2] Test weight in pounds per bushel.

[3] Farinograph Valorimeter Score.

[4] V. Good = Very Good; + = plus; - = minus.

E. Bake Evaluation

The baking evaluation of South Dakota's winter wheat was above average.

In summary, it seems that the overall quality of South Dakota's spring wheat was slightly below North Dakota's and Montana's. Winter wheat produced in South Dakota compared more favorably to winter wheat produced in other areas. High ash tends to be a problem with both classes of wheat in South Dakota.

Some Needed Changes in the Method of Reporting Grain Grades

In recent years there has been a tendency for inspection points to list on the grading card only those factors that affect grade. In addition, dockage--not a grading factor--is rounded down and reported on the grading card in whole and half percentages (22). An example may help to illustrate the difference. Suppose a sample contains 1.3% dockage, 2.9% shrunken and broken kernels, 0.6% foreign material, 1.9% damaged kernels, 5.4% total defects, and weighs 54 pounds per bushel. The sample would grade number four on the basis of test weight. None of the other factors would be listed except dockage which would be rounded down and listed at 1.0%. (Reference to appendix Table 1 may help those who are unfamiliar with wheat grading.) Distortions that can occur from this method were demonstrated by taking the averages of seven grading factors using exact percentages and comparing them to averages of the same data when only the factor affecting grade was listed and dockage was listed in whole and half percentages (Table 26). 1967 data compiled at S.D.S.U. from the Aberdeen elevator was used for this comparison. When dockage was rounded down to whole and half percents, 0.26% less dockage was shown than was actually present. This difference may seem unimportant, but from a buyer's standpoint it can be very important. With wheat valued at $1.50 per bushel, a 180,000 bushel ship load would be worth $270,000.00. If the buyer had loaded with this Aberdeen wheat he would have paid for over $700.00 worth of wheat that was

Table 26. Comparison of 1967 S.D.S.U. data from Aberdeen showing averages of dockage and six grading factors as tabulated exactly and as they would be taken from an official grading card where only the factor that affects grade and dockage in whole and half percents are shown.

| Method of Figuring Averages | Dockage | Test Weight | Shrunken and Broken | Foreign Material | Damaged Kernels | Total Defect | Contrasting Classes |
|---|---|---|---|---|---|---|---|
| Data as Listed in Exact Percentages | 1.82% | 60.77 lbs/bu | 3.07% | 0.52% | 0.05% | 3.27% | 0.01% |
| Data as It Would Be Listed on Grading Cards | 1.56% | 60.77 lbs/bu | 1.67% | 0.35% | 0.00% | 2.20% | 0.00% |

actually dockage, as compared to the dockage listed on the selling contract.

The decrease in shrunken and broken kernels as shown on Table 26 would mean the difference between number one and two wheat. Notice that nearly twice as many shrunken and broken kernels, than would be shown, are present. Shrunken and broken kernels are of little value in wheat being used for flour production, because most of them are removed in the cleaning process prior to milling. If only 50% of the shrunken and broken kernels were removed in cleaning, the miller would lose another $1,900.00 on the ship load of wheat.

These data would indicate a need for stricter controls over what must be listed on the grading ticket. Per capita consumption of wheat in the U.S. has remained relatively constant for a number of years. Therefore, the potential to sell increasing quantities of wheat lies primarily in the export markets. For this reason particularly close attention must be paid to quality. Gilles stated that "One of the quickest ways for the Upper Great Plains region to lose its wheat market will be to lose sight of the need for quality." (7)

In comparing surveys of wheat quality, one must be extremely careful to see that the data for both surveys are compiled and reported in the same way. As can be seen on Table 26, great differences are found in the two methods.

One further comment on the present grading system seems in order. Foreign material and shrunken and broken kernels often

affect grade either separately or together as total defects. Under the present system, these two factors are determined on separate samples of grain. Much of the material that passes through the sieve and is counted as shrunken and broken kernels will also be picked out of the second sample and be counted as foreign material. This means that the producer can be docked twice for a portion of the undesirable material in wheat. This was especially evident in the 1967 South Dakota spring wheat crop. Immature wild oats passed readily through the sieve and were counted as shrunken and broken kernels. The same material was picked from the foreign material sample resulting in double counting.

The double counting that occurs with shrunken and broken kernels and foreign material could be overcome by the following procedure:

1. Separate a representative sample.
2. Run the sample over the proper screen for determining shrunken and broken kernels.
3. Count the material that passes through the screen as shrunken and broken kernels and pick the remaining material in the screen for foreign material.
4. Calculate both on a weight basis.

In the final analysis, it is difficult to be sure who reaps the benefit of this inconcise reporting. Suffice it to say that if factors were listed in exact terms, it would surely be more just to all concerned.

## Need for Relocation of Experimental Plots

In reviewing data from South Dakota experiment stations, several facts have come to the attention of this author. These facts raise a question as to the location of these stations for the best evaluation of wheat--the state's leading cash crop.

In 1967, Brown and Spink counties produced nearly 25% of South Dakota's spring wheat crop (19,20). However, there is not a yearly milling and baking quality analysis for any site in either of these counties.

In 1964, quality analysis for spring wheat was made using wheat from Cottonwood, Newell, Watertown, Brookings, Centerville, Highmore and Eureka (26). Of these stations, only Eureka was in a heavy hard red spring wheat producing area. Eureka was also the only station that showed acceptable flour ash (Table 27).

Table 27. Ash content of spring wheat at seven locations in South Dakota for the 1964 crop[1].

| Locations | Flour Ash | Locations | Flour Ash |
|---|---|---|---|
| Cottonwood | 0.60% | Watertown | 0.53% |
| Newell | 0.56% | Brookings | 0.50% |
| Highmore | 0.55% | Centerville | 0.49% |
| --- | | Eureka | 0.43% |

[1] All of these locations have a test weight average of 59 lbs. or better.

Further investigation revealed that the only stations included every year in the Uniform Regional Nursery trials for spring wheat were Highmore and Watertown (26). In 1967, Codington County--in which Watertown is located--produced 1.38% of the state's spring wheat crop. Highmore is located in Hyde County which produced 0.46% of the 1967 spring wheat. Data from Table 28 indicate that both stations, especially Highmore, are high in flour ash content. In 1967, spring wheat samples from sixteen elevators showed an average flour ash content of 0.40%--well below the 0.43% at Watertown or the 0.51% at Highmore[1].

Table 28. Comparison of test weight and flour ash for two locations in South Dakota and comparison of North and South Dakota averages.*

| Year | Station | | | | State | | | |
|---|---|---|---|---|---|---|---|---|
| | Watertown | | Highmore | | South Dakota | | North Dakota | |
| | Test Weight | Flour Ash | Test Weight | Flour Ash | Test Weight | Flour Ash | Test Weight | Flour Ash |
| 1965 | 57.6 | 0.49% | 59.3 | 0.56% | 58.5 | 0.53% | 60.7 | 0.46% |
| 1966 | 56.8 | 0.47% | 52.8 | 0.69% | 54.8 | 0.58% | 59.4 | 0.46% |
| 1967 | 58.5 | 0.43% | 60.0 | 0.60% | 59.3 | 0.51% | 60.4 | 0.42% |
| Average | 57.6 | 0.46% | 57.4% | 0.62% | 57.5 | 0.54% | 60.2 | 0.45% |

* Data is from Hard Red Spring Wheat Quality Reports 1965-66-67 U.S.D.A. -- A.R.S. -- North Dakota State University. Uniform Region Nursery trials.

[1] Data on the ash content of the 1967 South Dakota spring wheat crop was taken from the unpublished results of a complete milling and baking analysis of samples taken from elevators in South Dakota.

These figures indicate that South Dakota's spring wheat evaluation points are poorly located and may not be representative of the state's spring wheat or spring wheat growing conditions.

## SUMMARY AND CONCLUSION

The physical quality of South Dakota's wheat appeared to vary considerably from year to year.

Dockage was more of a problem in spring wheat than in winter wheat. The five year average for the period 1963 to 1967 showed winter wheat at 2.04% dockage and spring wheat at 3.30% dockage. Dockage above 1% is considered high by some people.

Moisture was seldom a problem in either hard red spring or hard red winter wheat. Spring wheat averaged 11.6% moisture and winter wheat averaged 11.5% moisture for the five year period. Moisture content below 13.5% is acceptable.

Test weight was often the factor that determined grade in both classes of wheat although it was more of a problem in spring wheat. In order to grade number one, spring wheat must weigh 58 pounds or more per bushel and winter wheat must weigh 60 pounds or more. Spring wheat has averaged less than 58 pounds per bushel in four of the last five years. Only in 1965 did winter wheat average less than 60 per bushel. Stem rust epidemics and hot dry weather were the main causes of low test weight.

Damaged kernels were seldom found in large enough quantities to affect the grade of either class of wheat. In 1967, for example, spring wheat showed an average of 0.13% damaged kernels and winter wheat showed an average of 0.23%. Damaged kernels can make up as much as 2% of the sample before grade is affected.

The foreign material found in South Dakota wheat was composed primarily of wild buckwheat seed and the caryopses of wild oats. In 1967, 8% of the samples contained greater than 0.5% foreign material. The five year average showed 0.38% foreign material in the winter wheat and 0.42% in the spring wheat. Number one wheat can contain as much as 0.5% foreign material for both classes.

Shrunken and broken kernels was the factor that most often determined the grade of South Dakota wheat. Over the period 1963 to 1967, 29% of the spring wheat and 14% of the winter wheat did not meet the standards set on shrunken and broken kernels for number one wheat.

Total defects affected the grade of both classes of wheat a good percentage of the time. In 1967, for example, total defects was the factor that determined grade in 20% of the samples that did not grade number one. Number one wheat can contain up to 3% of total defects. The five year state averages were 2.72% total defects for spring wheat and 2.12% for winter wheat.

Contrasting classes was very seldom a grading factor in wheat produced in South Dakota. Only 2% of the spring wheat and none of the winter wheat contained a large enough percentage of contrasting classes to affect grade.

Subclass, which is an indication of the percentage of dark hard and vitreous kernels, varied greatly from year to year. Over the five year period from 1963 to 1967, 74% of the spring wheat and 71% of the <u>winter</u> wheat graded Dark Northern Spring and Dark Hard

Winter respectively.

In comparing the 1967 spring wheat crops from North and South Dakota, it is evident that the wheat produced in North Dakota was cleaner and graded higher than that produced in South Dakota. In 1967, 72% of the North Dakota spring wheat graded number one while only 46% of South Dakota's spring wheat graded number one. North Dakota's spring wheat showed 0.5% less shrunken and broken kernels and 0.3% less foreign material. Fifty three percent of North Dakota's wheat showed less than 0.5% dockage as compared to 8% of South Dakota's wheat.

An analysis of data from twenty five elevators revealed that the overall quality of the wheat being shipped out of elevators was better than that being delivered to the elevators by farmers. The wheat shipped from these elevators was significantly lower in dockage, damaged kernels and shrunken and broken kernels than the wheat taken in. This difference can be attributed to the cleaning that occurred in the elevators prior to shipping. There was a significantly lower percentage of foreign material in the wheat moving to elevators which could be due to contamination of the wheat in the elevators.

A comparison of state averages of the quality of spring and winter wheat combined with a statistical comparison of the two classes of wheat in eleven counties was completed. The results of both comparisons indicated that the overall quality of winter wheat was better than that of spring wheat. Spring wheat was generally

lower in test weight, higher in dockage and higher in shrunken and broken kernels than was winter wheat. Foreign material and damaged kernels were higher in winter wheat, but these factors seldom affected grade. The differences between spring and winter wheat quality shown in these comparisons may be partially explained by the difference in filling periods of the two classes relative to maximum precipitation and temperature periods.

A comparison of the quality of wheat taken in at different elevators indicated that there were differences in the quality of wheat being delivered to these elevators. The test weight of winter wheat appeared to be lower in the Northern stations and the percent of shrunken and broken kernels was higher. Some of the elevators that showed the lowest percentages of shrunken and broken kernels also showed the least dockage. This was true in both spring and winter wheat.

The results of three years of milling and baking tests indicated that the overall quality of South Dakota's spring wheat was slightly lower than that of spring wheat grown in Montana and North Dakota. The test weight and flour yields of South Dakota's spring wheat were lower than those shown for Montana and North Dakota. The protein content of South Dakota's wheat was below that of wheat from other states when comparing wheat of equal test weight. The baking strength of both spring and winter wheat from South Dakota was good. The ash content of both classes of wheat was consistently higher in South Dakota than in wheat from other states.

The test weight and flour yields of South Dakota's winter wheat were very similar to figures shown for winter wheat produced in Kansas, Nebraska, and Montana. South Dakota's winter wheat averaged higher in protein content than the wheat from the other states. Of the states compared, only Montana appeared to surpass South Dakota in overall winter wheat quality in the years of 1965 through 1967.

In order to point out hidden discrepancies that may be encountered in methods of reporting wheat grades, wheat was graded in two ways. Data from samples taken in 1967 at the Aberdeen elevator were used for this comparison. First, dockage and all grading factors were listed in exact percentages. Figures were then listed for only those factors that determined grade. Dockage was listed in whole and half percents. Results indicated that when dockage is shown in whole and half percents, 0.26% less dockage will be shown than is actually present. By listing only the factors that affect grade, an average of only half as many shrunken and broken kernels and 0.17% less foreign material would be shown.

In the last section, it is pointed out that the location of South Dakota's wheat evaluation experiment stations may not be representative of the spring wheat or of spring wheat growing areas of the state. Together, Brown and Spink counties produced nearly 25% of the 1967 spring wheat crop. However, there is not a yearly milling and baking quality analysis for any site in either of these counties. The only two sites included yearly in the Uniform Regional Nursery trials for spring wheat are in Codington and Hyde

counties. Together these two counties produced less than 2% of the state's 1967 spring wheat crop.

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Table 1. **Numerical grades and Sample grade and grade requirements**

## Wheat (33)

(a) *Numerical grades and Sample grade and grade requirements for all classes of Wheat except Mixed Wheat.*

| Grade | Minimum test weight per bushel | | Maximum limits of– | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Defects | | | | | Wheat of other classes [1] | |
| | Hard Red Spring Wheat | All other classes | Heat-damaged kernels | Damaged kernels (total) | Foreign material | Shrunken and broken kernels | Defects (total) | Contrasting classes | Wheat of other classes (total) |
| | *Pounds* | *Pounds* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| 1 | 58.0 | 60.0 | 0.1 | 2.0 | 0.5 | 3.0 | 3.0 | 1.0 | 3.0 |
| 2 | 57.0 | 58.0 | 0.2 | 4.0 | 1.0 | 5.0 | 5.0 | 2.0 | 5.0 |
| 3 | 55.0 | 56.0 | 0.5 | 7.0 | 2.0 | 8.0 | 8.0 | 3.0 | 10.0 |
| 4 | 53.0 | 54.0 | 1.0 | 10.0 | 3.0 | 12.0 | 12.0 | 10.0 | 10.0 |
| 5 | 50.0 | 51.0 | 3.0 | 15.0 | 5.0 | 20.0 | 20.0 | 10.0 | 10.0 |

Sample grade: Sample grade shall be wheat which does not meet the requirements for any of the grades from No. 1 to No. 5, inclusive; or which contains stones; or which is musty, or sour, or heating; or which has any commercially objectionable foreign odor except of smut or garlic; or which contains a quantity of smut so great that any one or more of the grade requirements cannot be applied accurately; or which is otherwise of distinctly low quality.

[1] Red Durum Wheat of any grade may contain not more than 10.0 percent of wheat of other classes.

Table 2. Comparison of the percent protein content of winter wheat at nineteen elevators in South Dakota using the Duncan's Multiple Range Test.

| Elevator Number | Means | Statistical * Significance |
|---|---|---|
| 9 | 11.6% | a |
| 13 | 11.8% | ab |
| 3 | 11.9% | ab |
| 11 | 11.9% | abc |
| 12 | 11.9% | abc |
| 8 | 12.2% | abcd |
| 4 | 12.2% | abcde |
| 10 | 12.3% | abcdef |
| 5 | 12.7% | abcdefg |
| 1 | 12.7% | abcdefg |
| 18 | 12.8% | abcdefg |
| 19 | 12.8% | abcdefg |
| 17 | 13.1% | bcdefg |
| 2 | 13.1% | bcdefg |
| 7 | 13.3% | cdefg |
| 14 | 13.6% | defg |
| 16 | 13.6% | efg |
| 6 | 13.7% | fg |
| 15 | 13.9% | g |

* Means accompanied by the same lower case letters are not statistically different at the highly significant level.

Table 3. Comparison of the percent dockage of winter wheat at nineteen elevators in South Dakota using the Duncan's Multiple Range Test.

| Elevator Number | Means | Statistical Significance * |
|---|---|---|
| 12 | 0.24% | a |
| 14 | 0.41% | b |
| 7 | 0.44% | b |
| 15 | 0.49% | b |
| 13 | 0.50% | b |
| 16 | 0.50% | b |
| 18 | 0.51% | b |
| 19 | 0.51% | b |
| 9 | 0.51% | b |
| 10 | 0.53% | b |
| 5 | 0.60% | b |
| 6 | 0.65% | b |
| 17 | 0.65% | b |
| 1 | 0.74% | bc |
| 4 | 0.77% | bc |
| 2 | 0.78% | bc |
| 11 | 0.96% | bc |
| 3 | 1.55% | cd |
| 8 | 1.90% | d |

* Means accompanied by the same lower case letters are not statistically different at the highly significant level.

Table 4. Comparison of the test weight of winter wheat at nineteen elevators in South Dakota using the Duncan's Multiple Range Test.

| Elevator Number | Means in lbs/bu. | Statistical * Significance |
|---|---|---|
| 9 | 60.1 | a |
| 5 | 61.4 | ab |
| 8 | 61.6 | ab |
| 3 | 61.6 | ab |
| 11 | 61.8 | ab |
| 16 | 61.8 | ab |
| 2 | 61.9 | ab |
| 17 | 62.0 | ab |
| 6 | 62.1 | abc |
| 4 | 62.3 | abc |
| 15 | 62.7 | abc |
| 18 | 62.7 | abc |
| 10 | 62.8 | abc |
| 19 | 62.9 | abcd |
| 7 | 63.1 | abcd |
| 14 | 63.2 | abcd |
| 12 | 63.4 | bcd |
| 13 | 64.2 | cd |
| 1 | 64.8 | d |

* Means accompanied by the same lower case letters are not statistically different at the highly significant level.

Table 5. Comparison of weight per thousand kernels of winter wheat at nineteen elevators in South Dakota using the Duncan's Multiple Range Test.

| Elevator Number | Means | Statistical * Significance |
|---|---|---|
| 3 | 26.5 g. | a |
| 5 | 27.0 g. | ab |
| 8 | 27.4 g. | abc |
| 10 | 29.3 g. | abcd |
| 11 | 29.4 g. | abcd |
| 9 | 29.5 g. | abcd |
| 2 | 29.6 g. | abcd |
| 6 | 29.7 g. | abcd |
| 16 | 29.9 g. | abcde |
| 14 | 30.3 g. | abcde |
| 18 | 30.6 g. | abcde |
| 17 | 30.6 g. | abcde |
| 7 | 30.8 g. | abcde |
| 19 | 30.9 g. | abcde |
| 15 | 31.3 g. | bcde |
| 13 | 31.6 g. | cde |
| 1 | 32.1 g. | de |
| 12 | 32.8 g. | de |
| 4 | 34.0 g. | e |

* Means accompanied by the same lower case letters are not statistically different at the highly significant level.

Table 6. Comparison of percent of shrunken and broken kernels found in the winter wheat in South Dakota at nineteen elevators using the Duncan's Multiple Range Test.

| Elevator Number | Means | Statistical * Significance |
|---|---|---|
| 15 | 1.11% | a |
| 9 | 1.37% | a |
| 1 | 1.41% | a |
| 14 | 1.73% | ab |
| 17 | 1.82% | abc |
| 7 | 1.83% | abc |
| 4 | 1.83% | abc |
| 19 | 1.88% | abc |
| 12 | 1.90% | abc |
| 18 | 1.94% | abc |
| 16 | 1.95% | abc |
| 13 | 2.05% | abc |
| 10 | 2.20% | abc |
| 2 | 2.27% | abcd |
| 6 | 2.32% | abcd |
| 3 | 2.82% | abcd |
| 8 | 3.22% | abcde |
| 11 | 3.62% | de |
| 5 | 4.30% | e |

* Means accompanied by the same lower case letters are not statistically different at the highly significant level.

Table 7. Comparison of percent of foreign materials found in winter wheat at nineteen elevators in South Dakota using the Duncan's Multiple Range Test.

| Elevator Number | Means | Statistical * Significance |
|---|---|---|
| 1 | 0.126% | a |
| 12 | 0.146% | a |
| 13 | 0.149% | a |
| 2 | 0.172% | a |
| 4 | 0.174% | a |
| 10 | 0.177% | a |
| 15 | 0.192% | a |
| 14 | 0.201% | a |
| 19 | 0.210% | a |
| 9 | 0.224% | a |
| 7 | 0.233% | a |
| 6 | 0.267% | a |
| 17 | 0.273% | a |
| 18 | 0.278% | a |
| 11 | 0.285% | a |
| 16 | 0.350% | a |
| 5 | 0.370% | a |
| 8 | 0.470% | a |
| 3 | 0.476% | a |

* Means accompanied by the same lower case letters are not statistically different at the highly significant level.

Table 8. Comparison of percent of damaged kernels found in winter wheat in South Dakota at nineteen elevators using the Duncan's Multiple Range Test.

| Elevator Number | Means | Statistical * Significance |
|---|---|---|
| 9 | 0.101% | a |
| 14 | 0.107% | a |
| 7 | 0.108% | a |
| 12 | 0.118% | a |
| 15 | 0.124% | a |
| 17 | 0.142% | a |
| 10 | 0.146% | a |
| 16 | 0.166% | a |
| 18 | 0.171% | a |
| 19 | 0.181% | a |
| 1 | 0.181% | a |
| 5 | 0.192% | a |
| 13 | 0.212% | a |
| 11 | 0.241% | a |
| 4 | 0.285% | a |
| 2 | 0.294% | a |
| 3 | 0.359% | a |
| 8 | 0.367% | a |
| 6 | 0.440% | a |

* Means accompanied by the same lower case letter are not statistically different at the highly significant level.

Table 9. Comparison of percent of total defects found in winter wheat in South Dakota at nineteen elevators using the Duncan's Multiple Range Test.

| Elevator Number | Means | Statistical * Significance |
|---|---|---|
| 15 | 1.32% | a |
| 9 | 1.68% | a |
| 1 | 1.73% | a |
| 14 | 2.05% | a |
| 12 | 2.15% | a |
| 19 | 2.30% | ab |
| 7 | 2.30% | ab |
| 16 | 2.38% | ab |
| 13 | 2.40% | ab |
| 4 | 2.45% | ab |
| 18 | 2.45% | ab |
| 17 | 2.46% | ab |
| 10 | 2.53% | abc |
| 2 | 2.65% | abcd |
| 6 | 2.81% | abcd |
| 11 | 4.22% | abcde |
| 3 | 4.32% | cde |
| 8 | 4.52% | de |
| 5 | 4.87% | e |

* Means accompanied by the same lower case letters are not statistically different at the highly significant level.

Table 10. Comparison of percent protein content of spring wheat at twenty-two elevators in South Dakota using the Duncan's Multiple Range Test.

| Elevator Numbers** | Means | Statistical * Significance |
|---|---|---|
| 9 | 12.1% | a |
| 4 | 12.2% | ab |
| 3 | 12.4% | ab |
| 21 | 12.5% | abc |
| 16 | 12.8% | abcd |
| 2 | 12.8% | abcd |
| 1 | 12.9% | abcd |
| 8 | 12.9% | abcd |
| 19 | 12.9% | abcd |
| 22 | 13.0% | abcd |
| 5 | 13.4% | abcd |
| 23 | 13.4% | abcd |
| 11 | 13.5% | abcd |
| 18 | 13.6% | abcd |
| 10 | 13.8% | abcd |
| 20 | 13.8% | abcd |
| 15 | 13.8% | abcd |
| 6 | 14.0% | bcd |
| 14 | 14.0% | bcd |
| 17 | 14.2% | cd |
| 24 | 14.4% | d |
| 7 | 14.5% | d |

* Means accompanied by the same lower case letters are not statistically different at the highly significant level.

** Protein data for numbers 12 and 13 were not available.

Table 11. Comparison of the percent of dockage of spring wheat at twenty-four elevators in South Dakota using the Duncan's Multiple Range Test.

| Elevator Number | Means | Statistical * Significance |
|---|---|---|
| 1 | 0.451% | a |
| 11 | 0.472% | ab |
| 22 | 0.553% | abc |
| 17 | 0.855% | abcd |
| 8 | 0.890% | abcd |
| 14 | 0.959% | abcd |
| 21 | 1.02% | abcd |
| 5 | 1.03% | abcd |
| 15 | 1.04% | abcd |
| 20 | 1.15% | abcd |
| 18 | 1.25% | abcd |
| 6 | 1.41% | abcd |
| 2 | 1.59% | abcd |
| 12 | 1.78% | abcd |
| 3 | 1.90% | bcd |
| 13 | 1.91% | bcd |
| 9 | 1.95% | cd |
| 16 | 1.96% | cd |
| 24 | 1.96% | cd |
| 7 | 1.96% | cd |
| 10 | 2.08% | d |
| 4 | 2.36% | d |
| 19 | 2.40% | d |
| 23 | 2.53% | d |

* Means accompanied by the same lower case letters are not statistically different at the highly significant level.

Table 12. Comparison of the test weight of spring wheat at twenty-four elevators in South Dakota using the Duncan's Multiple Range Test.

| Elevator Number | Means in lbs/bu. | Statistical * Significance |
|---|---|---|
| 15 | 56.8 | a |
| 20 | 58.4 | ab |
| 7 | 58.7 | abc |
| 17 | 59.0 | abcd |
| 24 | 59.2 | bcde |
| 6 | 59.4 | bcde |
| 16 | 59.5 | bcde |
| 18 | 59.5 | bcde |
| 21 | 60.0 | bcde |
| 19 | 60.2 | bcde |
| 11 | 60.2 | bcde |
| 8 | 60.3 | bcde |
| 3 | 60.5 | bcde |
| 22 | 60.6 | bcde |
| 13 | 60.6 | bcde |
| 10 | 60.7 | bcde |
| 23 | 60.7 | bcde |
| 12 | 60.7 | bcde |
| 2 | 60.8 | bcde |
| 5 | 60.9 | cde |
| 14 | 61.1 | cde |
| 4 | 61.2 | de |
| 1 | 61.5 | e |
| 9 | 61.6 | e |

* Means accompanied by the same lower case letter are not statistically different at the highly significant level.

Table 13. Comparison of the weight per thousand kernels of spring wheat at twenty-four elevators using the Duncan's Multiple Range Test.

| Elevator Number | Means | Statistical * Significance |
|---|---|---|
| 15 | 23.0 g. | a |
| 17 | 26.0 g. | b |
| 24 | 26.2 g. | bc |
| 18 | 26.6 g. | bcd |
| 20 | 26.7 g. | bcde |
| 16 | 27.8 g. | bcdef |
| 10 | 27.9 g. | bcdef |
| 6 | 28.0 g. | bcdef |
| 11 | 28.0 g. | bcdef |
| 9 | 28.2 g. | bcdef |
| 8 | 28.3 g. | bcdef |
| 7 | 28.4 g. | bcdef |
| 12 | 28.6 g. | bcdef |
| 14 | 29.2 g. | bcdef |
| 19 | 29.3 g. | cdef |
| 5 | 29.5 g. | def |
| 21 | 29.7 g. | def |
| 13 | 29.7 g. | def |
| 2 | 29.8 g. | def |
| 3 | 30.0 g. | ef |
| 23 | 30.0 g. | ef |
| 22 | 30.4 g. | f |
| 4 | 30.5 g. | f |
| 1 | 30.5 g. | f |

* Means accompanied by the same lower case letters are not statistically different at the highly significant level.

Table 14. Comparison of percent of shrunken and broken kernels found in the spring wheat at twenty-four elevators in South Dakota using the Duncan's Multiple Range Test.

| Elevator Number | Means | Statistical * Significance |
|---|---|---|
| 22 | 1.75% | a |
| 8 | 1.84% | a |
| 3 | 1.88% | a |
| 21 | 1.93% | a |
| 11 | 1.98% | a |
| 12 | 2.42% | a |
| 13 | 2.51% | a |
| 9 | 2.55% | a |
| 18 | 2.64% | a |
| 1 | 2.73% | a |
| 2 | 2.77% | a |
| 14 | 2.96% | a |
| 10 | 2.97% | a |
| 7 | 3.01% | a |
| 4 | 3.01% | a |
| 5 | 3.04% | a |
| 6 | 3.04% | a |
| 23 | 3.04% | a |
| 19 | 3.06% | a |
| 17 | 3.09% | a |
| 24 | 3.51% | a |
| 20 | 3.85% | ab |
| 16 | 3.94% | ab |
| 15 | 6.34% | b |

* Means accompanied by the same lower case letters are not statistically different at the highly significant level.

Table 15. Comparison of percent of foreign material found in spring wheat at twenty-four elevators in South Dakota using the Duncan's Multiple Range Test.

| Elevator Number | Means | Statistical * Significance |
|---|---|---|
| 24 | 0.127% | a |
| 1 | 0.181% | ab |
| 14 | 0.192% | ab |
| 17 | 0.229% | abc |
| 20 | 0.241% | abc |
| 5 | 0.251% | abc |
| 6 | 0.285% | abc |
| 12 | 0.293% | abc |
| 21 | 0.294% | abc |
| 11 | 0.297% | abc |
| 7 | 0.301% | abc |
| 18 | 0.301% | abc |
| 9 | 0.303% | abc |
| 13 | 0.359% | abc |
| 8 | 0.378% | abc |
| 22 | 0.429% | abc |
| 15 | 0.442% | abc |
| 16 | 0.449% | abc |
| 2 | 0.480% | abc |
| 10 | 0.500% | abc |
| 3 | 0.589% | abc |
| 19 | 0.611% | bc |
| 4 | 0.632% | bc |
| 23 | 0.690% | c |

* Means accompanied by the same lower case letters are not statistically different at the highly significant level.

Table 16. Comparison of the percent of damaged kernels found in spring wheat in South Dakota at twenty-four elevators using Duncan's Multiple Range Test.

| Elevator Number | Means | Statistical * Significance |
|---|---|---|
| 24 | 0.020% | a |
| 14 | 0.033% | a |
| 5 | 0.034% | a |
| 9 | 0.040% | ab |
| 18 | 0.042% | ab |
| 13 | 0.045% | ab |
| 2 | 0.046% | abc |
| 7 | 0.068% | abcd |
| 23 | 0.073% | abcd |
| 16 | 0.082% | abcd |
| 4 | 0.088% | abcde |
| 17 | 0.091% | abcde |
| 10 | 0.097% | abcde |
| 6 | 0.101% | abcde |
| 12 | 0.118% | abcde |
| 1 | 0.150% | abcde |
| 21 | 0.159% | abcde |
| 20 | 0.164% | abcde |
| 22 | 0.192% | abcdef |
| 3 | 0.271% | bcdef |
| 8 | 0.276% | cdef |
| 19 | 0.290% | def |
| 15 | 0.323% | ef |
| 11 | 0.425% | f |

* Means accompanied by the same lower case letters are not statistically different at the highly significant level.

Table 17. Comparison of percent of total defects found in spring wheat at twenty-four elevators in South Dakota using the Duncan's Multiple Range Test.

| Elevator Number | Means | Statistical * Significance |
|---|---|---|
| 21 | 2.42% | a |
| 3 | 2.44% | a |
| 22 | 2.46% | a |
| 11 | 2.71% | a |
| 5 | 2.73% | a |
| 8 | 2.80% | a |
| 12 | 2.86% | a |
| 9 | 2.90% | a |
| 18 | 2.97% | a |
| 2 | 3.04% | a |
| 13 | 3.18% | a |
| 7 | 3.32% | a |
| 1 | 3.40% | a |
| 6 | 3.43% | a |
| 17 | 3.44% | a |
| 10 | 3.59% | a |
| 4 | 3.73% | a |
| 24 | 3.90% | a |
| 23 | 3.94% | a |
| 19 | 4.01% | a |
| 14 | 4.32% | ab |
| 16 | 4.42% | ab |
| 20 | 4.69% | ab |
| 15 | 7.07% | b |

* Means accompanied by the same lower case letters are not statistically different at the highly significant level.