

LORADO



3) Bulletin

July, 1918

4) No. 247

2) The Agricultural Experiment Station  
OF THE  
Colorado Agricultural College

# A STUDY OF COLORADO WHEAT

A Resume of Bulletins Nos. 205, 208, 217, 219, 237  
and 244

By W. P. HEADDEN



PUBLISHED BY THE EXPERIMENT STATION  
FORT COLLINS, COLORADO,  
1918

# The Colorado Agricultural College

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# A STUDY OF COLORADO WHEAT

A Resume of Bulletins Nos. 205, 208, 217, 219, 237,  
and 244

By W.P. HEADDEN

A study of Colorado wheats was suggested by two popular notions. First, that Colorado wheat is soft and produces a poor flour for bread-making; second, that hard wheat deteriorates into soft wheat when grown under our conditions. There was another reason for the work, namely, the close relation that we had found to exist between the soil conditions and the deterioration in the quality of sugar beets grown in certain sections of the State.

It was asserted that Colorado conditions produce soft wheat. The term "Colorado conditions" is understood to mean climatic conditions. This was not always definitely stated but it was generally accepted. The prevalence of this general idea was a quite natural result of the teachings regarding this subject. This was the explanation offered by persons in whose knowledge and judgment the people had confidence, and it became very prevalent.

The millers claimed that the flour produced from this wheat contained too little gluten for bread-making. The bakers said that it made too little bread and the housewives had come to the same conclusion, but all knew that it made fine biscuit. If I am correctly informed, Colorado flour was put upon the market as a biscuit and pastry flour.

The purpose of this study was to ascertain whether these ideas, which I believe are still current, were justified by the facts, and to ascertain, if possible, the causes which converted the hard wheats imported as seed into soft wheats.

The study was begun in 1912 and extended over a period of six years, terminating in 1918.

The results, of which this bulletin is a recapitulation, were published in six separate bulletins. They are Colorado Experiment Station bulletins Nos. 205, 208, 217, 219, 237, and 244, respectively.

## ***DOUBTED CLIMATIC CONDITIONS WERE CAUSE OF SOFT WHEAT***

It seemed to me doubtful that our climatic conditions, which have been praised as being almost ideal, should be in fact the cause of the change in the quality of our wheat. Further, as I had succeeded in producing deterioration in beets by modifying the soil conditions, it appeared probable that soil conditions, not only may,

but probably actually play a big part in this question. In the beet problem we always found many lots of beets of most excellent quality grown in the same section and during the same season in which beets of very poor quality were produced. I had scarcely more than begun the study of the wheat problem before my attention was called to the same fact in regard to wheat, namely, that two crops grown from the same lot of seed, in the same district and under the same general system of cultivation were of very different character and quality. This difference could not be attributed to climatic conditions, as these crops were produced within one-half or three-quarters of a mile of one another.

Such differences in crops are not confined to Colorado. I secured samples of wheat from a number of our experiment stations, from Canada, and from some European countries. These samples were of different varieties, but showed by their physical properties that they were, almost without exception, more or less mealy, that is, they were softer than the same varieties ought to be to correspond to our ideals of good samples of the varieties. Only a few of all the samples that I succeeded in obtaining were plump and flinty. These samples of what we may designate the best grains, came from Canada, Montana, Minnesota and Colorado. Soft or mealy samples of all varieties are of universal occurrence. The Irish, Swedish, Dutch, and French wheats that I obtained were very plump and mealy wheats. The Russian wheat obtained was mixed.

All of the writers on this subject with whose works I am acquainted have attributed this condition to the effects of climatic conditions. Lawes and Gilbert do not specifically mention this condition, but insist upon the influence of the climate upon the quality of the grain. Schindler and also Kosutany are very emphatic in attributing the mealiness or softness of wheats to climate. Schindler discusses Hungarian wheats and shows that they become softer as one goes from the plains to the mountain regions. He points out that France, England, Denmark and countries in general that have coastal climates produce soft wheats.

Colorado has a semi-arid climate and produces a soft wheat. This statement, as will be seen later, needs modification, but this is still a prevailing opinion. These facts are not easily reconciled with the general teachings on this subject.

In order to meet this discrepancy between our climatic conditions and the character of the wheat produced, we often interpose our practice of irrigation, which may more than counter-balance the aridity of our climate. One often hears this question raised

and it is possible to find the assertion that irrigation produces soft wheat.

### **CLIMATIC CONDITIONS, IRRIGATION, AND SOIL CONDITIONS CONSIDERED**

The purpose of this study was to ascertain which factor in our conditions produces the softening of Colorado wheat. The factors had in mind were: First, that group designated as climatic conditions; second, irrigation; third, the soil conditions.

It was a question from the very beginning whether irrigation should be separated from the soil on the one hand and from climatic conditions, especially rainfall, on the other. It is evident that plants must have water and a sufficiency of it, in order to grow and mature normally, but it was not evident whether a difference should be made between rainfall and irrigating water.

Many things may be included under soil conditions. I had the supply of nitric nitrogen, potassium and phosphorus specifically in view and believed that in these factors of the soil we would find the solution to our problem. I considered it probable that we would find in the nitrogen supply the key to this solution. The great part played by nitric nitrogen in determining the quality of the beet crop led me to believe this. I already knew that our soils very generally possess a high efficiency in fixing atmospheric nitrogen and in nitrifying it. It became a matter of interest to ascertain what part, if any, these biological factors might play.

The land chosen on which to raise our wheat was land on which we had made some of our beet experiments and we knew at the outset that it was only moderately well supplied with nitrogen but that the bacterial activity of the soil was very pronounced and that both fixation and nitrification proceeded rapidly, at least at times. We had found nitric nitrogen in samples of the surface soil corresponding to nearly 500 parts of sodic nitrate to the million parts of soil. Direct experiment, i. e., incubation of this soil without the addition of anything except ammonia-free distilled water, had given various results for the amount of nitrogen fixed. The minimum degree of fixation observed was in a sample kept in a large bottle. The time of observation was 27 days. The amount of nitrogen fixed corresponded to 192.8 pounds of nitrogen to the acre-foot of soil, which, calculated as sodic nitrate, corresponded to 1,157 pounds to the acre-foot.

In regard to potassium, analyses had shown that there was an ample supply present in an easily soluble form.

The soil is not excessively rich in phosphorus but it contains an ample supply for the time being.

The physical condition of the land is good and our supply of irrigating water is adequate.

The claim that our conditions cause the softening of wheat has never been applied to any particular variety. The earlier claims probably pertained to varieties of spring wheat rather than to winter wheat, but it is just as applicable to the latter.

These are, in the main, the conditions under which we began this study.

### ***DEFIANCE, RED FIFE AND KUBANKA, VARIETIES USED***

We chose three varieties of spring wheat with which to experiment, Defiance, Red Fife\*, and Kubanka. We chose spring wheats because their growing period is continuous without any resting period and is comparatively short. The characteristics of these varieties are very different, both in the growth of the plants and in the characteristics and properties of the grains. The Defiance is a light-colored, soft wheat with a longer growing period by 8 or 10 days than the others. The Red Fife is a dark-colored hard wheat, ripening the earliest of the three. The Kubanka seed was supposed to be the best strain of this variety, probably the most desirable of the durum wheats.

The Defiance is a variety which was originated at this station and which has been grown very generally throughout the State. There was no question of softening this variety; it is thoroughly at home under our conditions. Different samples of it, however, show as great extremes in flintiness and mealiness as any other variety, but it is always a light-colored and soft wheat. These are two of its variety characteristics which are not variable. The other varieties also have their characteristics but the hardness and softness or flintiness and mealiness vary greatly. Our object in this study was to ascertain what factor or factors in our conditions may cause these differences.

### ***FACTORS THAT COULD BE CONTROLLED***

The only factors in our conditions that we could effectively modify or control was the supply of nitrogen, phosphorus, potassium, and water. It is evident that we could modify the supply of the first three by increasing it, and of the last one, as the rainfall is seldom sufficient to mature the spring wheat, we can either add too little, enough, or an excess.

We endeavored to ascertain the specific effects of the elements

\*This Red Fife was purchased from the South Dakota Experiment Station. They subsequently learned that they were mistaken in regard to the variety and so notified me. I had, however, already published three bulletins as the result of our study and deemed it wiser to retain this name than to introduce the correct variety name which is Preston.

in question by applying them alone and in such quantities as would produce exaggerated effects that might be easily recognized. We applied the same principle in the case of water. We hoped to find the effects of an insufficient supply of water in the study of dry-land wheat.

The experiments with each of the elements involved have been repeated 45 times, not counting any subsidiary experiments. The results were the same in every case and were very clear and decisive from the first to the last experiments.

### ***APPLICATION OF PHOSPHORUS AND POTASSIUM PRODUCE NO DISCERNIBLE EFFECTS***

The applications of phosphorus and potassium in any amounts that we used produced no discernible effects upon the development of the plants or the yields obtained. The application of 60 pounds of available phosphorus to the acre at the time of planting failed to produce any of the effects upon the growth of the plants that is usually ascribed to it; for instance, it had no effect upon the date of ripening. Potassium, applied at the rate of 200 pounds per acre, had some effect upon the rate of the development of the plant. This effect was discernible for a few days but disappeared in every case, after which no difference could be detected between the stage of development of the plots that had been dressed with potassium and the others. The physical properties of the grains, however, showed that the potassium had exercised a specific influence, for the grain had a lighter color, and starchy or mealy kernels were more abundant than in the wheat grown on the check plots, or in that grown with the application of phosphorus.

These two last-mentioned wheats were so nearly alike in all cases that we concluded that phosphorus applied to our soil produces no effect upon the character of the wheat produced, but that potassium increases the number of yellow, starchy, or mealy kernels. This was clearly a partial answer to the problem we had set out to solve, i. e., that potassium causes the mealiness or softness of our wheats. There were mealy kernels in the wheat grown on the check plots, as well as in that grown with the application of phosphorus, but there were more mealy berries and the whole sample was lighter in color and showed the characteristics of soft wheat in a higher degree where we had increased the amount of potassium. We had another and a still more decided answer to our inquiry in the effect of sodic nitrate upon the wheat produced. This wheat contained practically no mealy or starchy kernels. It was all darker in color, translucent, and flinty or hard.

These two elements, potassium and nitrogen, have produced these antagonistic results in every set of experiments made; potassium has made the wheat soft and the nitrogen in the form of nitrates has made it hard.

### ***NITRATE WHEATS FLINTY, POTASSIUM WHEATS MEALY***

During the five years that our field experiments continued, there were favorable and unfavorable years. The year of 1915 was particularly unfavorable in that we had much cloudy weather and frequent, light rains, which, with the heavy dews that were caused by these conditions, kept the plants dripping wet for much the greater part of the time. The plants were large and leafy and nearly all of the plots lodged badly so that in only a few cases did we have good ventilation. These conditions induced an abundant development of rust. Our grain was badly shrunken and the yield from some of the plots was very light. This was especially true of the Defiance wheat. This was a very bad season for the crop but a most fortunate one for our study. All of these bad conditions combined did not obscure the characteristic effects of the fertilizers in the least; the nitrate wheats were flinty and the potassium wheats were mealy.

What the effects, due alone to the unusual wetness of the season, might have been upon the composition and character of the grain produced was wholly obscured by the development of rust.

### ***EFFECT OF WEATHER CONDITIONS***

The composition of the plants had been followed throughout the season of 1913 and again in 1915 so we have the data obtained in the two seasons which show the differences in the plants due to the differences in the weather conditions. The plants were almost constantly wet in 1915. The water applied to the plants as light rains and heavy dews appeared to remove by actual leaching both nitrogen and the ash constituents, but did not, up to the appearance of the rust, obscure the effects of the respective fertilizers. What part the cloudiness of the season and the poor ventilation of the wheat played was not determined.

The changes which took place in the plants in 1913 as they approached maturity were very marked, but in 1915 these changes practically stopped upon the appearance of the rust. The transference of the substance of the plant to the kernels was so limited that the kernels filled out very poorly; they were for the most part badly shrunken. We laid particular stress upon the nitrogen content of the plant throughout its development as the datum of special interest to us. In 1913 we found it to be very largely trans-



ferred from the plant to the head within a few days at the time of ripening, so that the stems and leaves of the ripe plants contained about one-fourth the percentage of total nitrogen that the heads contained, and from one-tenth to one-fifth as much proteid nitrogen. In 1915 we found that the stems and leaves of the ripe plants contained from one-third to nearly one-half the percentage of total nitrogen that the heads contained and from one-fourth to one-third as much proteid nitrogen. In other words, the nitrogen had not been transferred from the plant to the head. The material in the plant intended to be used in filling out the grain remained in the plant or was used up by the rust. The weight of these wheats per 1,000 kernels showed the differences between the two crops. In 1913 the weight of 1,000 kernels of Defiance wheat varied from 35.5 to 38.2 grams; in 1915 it varied from 19.0 to 23.6 grams. The variations in the weight of 1,000 kernels of Red Fife in 1913 was from 30.8 to 33.8; in 1915 it was from 20.9 to 26.9 grams. The weight of 1,000 kernels of Kubanka in 1913 varied from 42.1 to 43.2 grams and in 1915 from 35.6 to 39.1 grams.

There is no reason for assuming that there is any other cause for this difference in the weight per 1,000 kernels than the degree to which they were filled out. The skeleton of the kernel had already been formed by the plant on just as generous a scale probably as in 1913 but it was never filled out. As the crude fibre occurs largely in bran of the wheat, this constituent may be used as a measure of the probability that this is the case. We found that the ratio of the crude fibre in the crop of 1913 to that in the crop of 1915 was approximately as 5 to 7. The material which should have filled out these kernels was in some way stopped by the rust. The difference in the amount of protein contained in these respective crops was fully as striking. In 1913 the general average of protein for all of the plots and varieties was 12.53 percent, while the general average in 1915 was 8.95 percent.

There might have been a difference in the amount of protein in these two crops due to the wet and cloudy season even if the rust had not developed, but it certainly would have been much less than the difference shown by these percentages. The assumption is tacitly made in presenting this subject that the same relative difference would have been found in the nitrogen content of the grain that we found in the various parts of the plants. If this assumption be justified by the facts, then the grain would have been inferior to that of 1913, but I do not know that this assumption is justified. It is possible that the supply of nitrogen would have proved sufficient to produce good wheat had the plants remained

free from rust and been able to utilize in a normal manner the nitrogen actually at its disposal.

It was clearly not the amount of water that fell on the land that made the differences noted, for the total amount applied to the land during the respective seasons was the same, 19 inches. In 1915 the rainfall did not reach the land till it had run down the plants and produced a certain amount of washing. This, together with the lack of sunshine and of ventilation, is the factor to which we must attribute these differences.

### ***EFFECT OF RAINFALL AND IRRIGATING WATER IS DIFFERENT***

A very much larger amount of water applied to the soil as irrigating water does not produce these results. We have the results of eleven experiments as the basis of this conclusion. In eight of these experiments we considered the plants as well as the grain and in three of them we considered the grain only. As the rainfall was a factor common to each set of experiments there is no need to mention it each time. In two series we applied 1 foot of water at one application to all of the plots, and later another foot to four of the plots. This series was repeated the following year. We could not find that the application of the second foot of water affected the composition of the plants or the grain. In another series of three experiments, 1, 2, and 3 feet of water in three, five and seven applications were applied within a period of about 112 days. One foot of water was sufficient moisture for the production of as large a crop as the land would ordinarily yield, and the additional amounts produced only a small additional amount of grain and straw. The significant fact in the case was that there was no difference in the composition of the wheats produced. The inferior quality of our 1915 crop was not due to the quantity of water that it received but to the manner of its application.

### ***NITROGEN MUST BE IN FORM OF NITRATES TO PRODUCE HARD WHEAT***

Emphasis has been placed upon the importance of nitrogen in the form of nitrates in the production of hard or flinty wheat. The amount of total nitrogen in the soil does not determine the character of the wheat. This assertion, too, is based upon the result of direct experiment. We found that the application of nitrogen as sodic nitrate at the time of planting, equal to ten parts per million, was sufficient—I am satisfied that it was more than sufficient—to produce hard wheat. The addition of twelve times as much nitrogen in the form of farmyard manure did not affect the character or composition of the wheat produced but it affected the

yield of straw and grain to some extent, results which may have been due as much to other effects of the manure as to the nitrogen that it contained. If the soil had possessed the power to convert this organic nitrogen into the form of nitrates or had it been given time enough to accomplish this with the nitrifying efficiency that it possessed, it would undoubtedly have produced flinty or hard wheat, whereas, the wheat that was actually produced was practically all spotted, half mealy, or mealy wheat.

#### **WHY DRY-LAND WHEATS ARE FREQUENTLY HARD**

It is a current notion that our dry-land wheats are hard, and this condition is attributed to the fact that it is grown without irrigation. The preceding paragraphs bear upon this matter, as they point out that irrigation has practically no influence upon the hardness or softness of the wheat grown, but that the hardness is produced by another factor in our conditions. Besides, the fundamental assumption in this case, that dry-land wheat is necessarily hard wheat, is erroneous. Some samples of dry-land wheat have as high a degree of mealiness as we find in irrigated wheat. Dry-land culture aims at the conservation of moisture by fallowing, which effects not only the conservation of moisture but facilitates the production and conservation of the nitrates for the coming year. When dry land is cropped to wheat after wheat for a few years it produces mealy wheat. The flinty character so often met with in dry-land wheats is due to the available nitrates and not to the scanty supply of moisture. The fact that kernels of dry-land wheat are sometimes smaller than those of the same variety grown under irrigation may be due to early ripening, a result due to a scanty moisture supply, but it is not a fact that the kernels of dry-land wheat are always smaller than those of irrigated wheat. A liberal supply of nitrates with an abundant supply of water will produce small-grained, dark-colored, flinty wheat. Dry-land wheat may be small-grained but is not necessarily dark-colored and flinty. The small size of the kernels may be due in the two cases to different causes. Why a disproportionately large supply of nitrates produces a smaller kernel than usual I do not know, but I can understand why an insufficient supply of moisture near the period of ripening, as often occurs in the case of dry-land wheat, should cut the filling process short and cause the kernels to remain only partially filled. The flour made from such wheat may be of good quality but it is not necessarily better than that of irrigated wheat, in fact, the same wheat would produce more flour of equally good quality if it could have had a supply of moisture sufficient to have brought it to a fuller maturity. These statements are based upon our observations, analyses, milling, and baking tests. The milling

results obtained with dry-land wheat resemble those obtained with somewhat shrunken, irrigated wheat. The characteristic milling result is a high yield of bran and the baking qualities of the flour are no better than those of flour from the same variety of wheat grown with irrigation. In this case, as in the cases which we shall subsequently present, the baking qualities are doubtlessly correlated with the composition of the grain.

We have analyzed both spring and winter dry-land wheats and find their composition to vary from that of irrigated wheat no more than samples of irrigated wheat of the same variety vary from one another. In fact, we have found greater variation in the nitrogen content of the latter class of wheat than we have found between the dry-land and irrigated wheats.

### ***EFFECT OF RUST***

The effects of excessive amounts of fertilizers used singly, of varying quantities of irrigating water applied to the soil, and of rainfall, upon the physical properties of the wheat have been given. In this connection we were unable to determine the part to be attributed to rust in producing the effects observed as the results of the continued wet weather. The very marked stoppage in the transference of the nitrogen from the leaves and stems to the head on the appearance of the rust indicated that a very large part of the total effect should be attributed to this cause.

The effects of these causes upon the composition of the grain are, for our study, of far more importance than the effects on the physical properties. It happens that there is a very close relation between the physical properties and the composition of wheat, the milling qualities of the wheat, and the baking qualities of the flour. This relation is evident in regard to the milling qualities of the wheat but less so than in the two other respects. In this connection again we can omit all mention of the samples grown with the application of phosphorus and those grown on the check plots, and consider only those grown with the application of nitrogen as sodic nitrate and of potassium. All that might be said of the samples grown with the application of phosphorus will be applicable in almost the same degree to check-plot samples.

### ***WHEAT GROWN WITH NITRATES RICHER IN NITROGEN***

We have found without exception that the samples grown with the application of the nitrate are richer in nitrogen than those grown with potassium. The fact that some of our samples were badly shrunken did not affect this characteristic in the least; it was just as pronounced in plump grains as in shrunken ones. The

samples grown with the nitrate produce more flour as a rule and this invariably of better quality; it required as much, often more, water to produce a dough of good consistency as the other flour; and uniformly produced a larger loaf.

The differences in the amount of nitrogen contained in the wheat proved to be an entirely safe criterion by which to judge of its qualities both in regard to milling and baking. These differences found expression in the flintiness of the kernels, the amount of wet and dry gluten, its color and character. The only point of inferiority shown by the wheats grown with the application of nitrate was in the color of the gluten, which was decidedly darker than that from the other samples. This fact was also observable in the bread baked from it. This gluten of the nitrate wheat is softer than that of the potassium wheat but this did not prove to be a disadvantageous property in any respect. The dough from this flour was as easily manipulated as other doughs and the loaf was at least as good in texture and better in size.

These results were both persistent and uniform throughout the experiments and proved to be independent of the water applied, the rainfall, and even the action of the rust which affected some of our crops, particularly that of 1915.

#### ***RATIO BETWEEN NITRATES AND POTASSIUM DETERMINES QUALITY***

The main conclusion drawn from these experiments is that the important factor in our conditions that determines the quality of our wheat as hard or soft is the ratio existing between the hydrogen present in the soil as nitrates, and, therefore, available to the wheat plant, and the available potassium present.

The nitrogen supply in our soils is very materially increased, especially while lying fallow, by fixation, and the nitrates are formed in sufficient amounts to materially modify the wheat produced. As this supply of nitrogen as nitrates is the factor that determines the character, composition, and quality of our wheat, those agents which determine the total supply of nitrogen and convert it into an available form are the factors, in all those cases in which nitrogenous fertilizers are not applied, which determine the character of our wheat. In the case of the application of fertilizers containing organic nitrogen, the character of the wheat will be determined by the power of the soil to convert this nitrogen into the form of nitrates. In both instances the biological conditions of the soil constitute the factor which under our conditions determines the quality of the wheat. We conceive our conditions to be such that the ratio between the available nitrogen and potassium is sufficient to produce, under favorable conditions, an

excellent, if not a maximum, crop. In many instances the potassium is in slight excess of that which is the optimum ratio for the production of the very best quality of wheat and the result in such cases is the production of wheat spotted and mealy in various degrees. If this occurs in a high degree the quality will be far below normal for the variety of wheat. This difference may be very great, as illustrated by two samples of Defiance wheat grown during the same season, one of which was a very flinty or hard sample, the other a very mealy or soft one. The flinty sample contained 14.44 percent of protein, the mealy one, 8.05 percent. These samples were not grown in the same district but I have seen just as flinty Defiance wheat grown in the district that produced the poor sample as I have seen produced anywhere. This difference of a little more than 6.0 percent in the protein content was due to the supply of nitrogen in the form of nitrates.

The supply of potassium in our soils is so abundant that we consider it the fixed factor in the problem. Besides, it is a fact that the amount of nitrates in our soils is a constantly varying quantity and has been shown to have increased in five months by a greater quantity than that which determined the character and composition of the crop when applied at the time of planting.

The balance in this ratio of the nitrogen to the potassium was so near to adjustment in the soil on which our experiments were made that the addition of 10 parts of nitrogen in the form of sodic nitrate per million parts of soil was sufficient to change the composition of the wheat produced. On the other hand, the addition of 37.5 parts of potassium per million parts of soil sufficed to show very pronouncedly the specific effects of this element. In this connection it is interesting to note the results obtained in an experiment to ascertain the amount of fixation and nitrification that takes place in this soil under field conditions. We found a fixation of over 36 parts per million in 40 days and an increase of 15.79 parts per million in the nitric nitrogen. This is one and a half time as much as we found sufficient to determine the character of our crop. This is the explanation that we offer for the character of wheat grown on fallowed land. As an illustration of this effect I cite two samples of Red Fife grown the same season and on adjacent plots; that grown on the land fallowed the preceding season contained 17.15 percent of protein, while that grown on land that had been cropped to oats the preceding season contained 12.94 percent.

We have shown how the properties of our crops were modified by the application of nitrogen in the form of sodic nitrate and of farmyard manure, of phosphorus, of potassium, and of

water, *and conclude that the determining factor is the ratio of nitric nitrogen to the available potassium in the soil.*

**FLOUR FROM COLORADO WHEAT EQUAL TO THE  
BEST FOR BREAD-MAKING**

We have extended our study to ascertain whether the current estimate of our wheat—i. e., that it is soft and yields a poor flour for bread-making—is a just one. We conclude that it is not, but that while our wheat often shows a large percentage of mealiness it is in the main fairly hard, often very hard, and when skilfully milled yields a flour of excellent quality, comparable to the very best for bread-making.

The general statements that have been common in the past regarding the quality of our wheat were in the beginning probably based on the characteristics of the variety grown, a soft, spring wheat, which at the time was popular with the ranchmen. We cannot change a characteristically soft variety into a hard one, but we can grow hard and soft crops of this variety and the hard crops will be much better in quality than the soft ones. The same is true of the hard varieties.