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THE PROPERTIES OF COLORADO WHEAT

By W. P. HEADDEN

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THE PROPERTIES OF COLORADO WHEAT

By
W. P. HEADDEN

This station has published four bulletins* as the result of its study of Colorado wheat. These bulletins have been written for the student of this subject rather than for the farmer of Colorado. In presenting this subject to students it was necessary to give a mass of details of so good as no interest to others than such as are not satisfied with the statement of general results. This bulletin is not written for that class of readers. All such readers are referred to the previous bulletins wherein they will find a great many details of the investigation.

GENERALLY BELIEVED THAT COLORADO WHEAT MAKES INFERIOR FLOUR

It has been a generally accepted statement among us that wheat grown in Colorado is "soft" and does not make as good flour as the wheat grown in many of the Northwestern States. The question why, has usually been answered by the statement that our wheat does not contain as much gluten as the harder wheats. It has been the belief of both bakers and housewives that Colorado flour yields less bread than Kansas or Minnesota flour, because, as has generally been accepted, the flour will not take up as much water in making a dough, which is a result of there being less gluten in it. These are the reasons that I have heard stated for the preference given to Minnesota and Kansas flours over our Colorado flour and for their very general use by bakers and our housewives in bread-making. The Colorado flour is credited with making an attractive, white, well-flavored loaf, but smaller and lacking, in some important respects, those superior qualities for which the Minnesota and Kansas flours are justly prized.

We assumed all of these statements, made concerning our wheat, to be correct; for instance, we assumed that the statement that a hard seed from Kansas or North Dakota produced a soft wheat when planted in Colorado and that this soft wheat produced a less desirable flour than the parent wheat. We proposed to inquire into the facts and, if we should find these statements

*Bulletins Nos.: 205, 208, 217, and 219.

correct, of which we had no doubt at the time, for we have a great deal of confidence in the common judgment of a community, we proposed to try to find out the reasons for them.

The subject itself pertaining to the causes for differences in the properties and composition of wheats is really an old one, and has been studied by so many very able men that our proposal to take up this question as it applies to Colorado wheat provoked a smile, but permission to undertake it was given, and the following pages present our endeavor to make our views and result known to the Colorado wheat grower.

CLIMATE AND SOIL IMPORTANT FACTORS

There are two big groups of factors concerned in the production of a crop of wheat. This much is very evident and agreed to by all parties. The first group comprises the climatic factors; the second the soil factors. In the first group we have all of those factors which we often express as weather, such as temperature, rainfall and winds. In the second group we have the actual content of the soil in plant food and the ratios in which these foods exist in the soil and the forms in which they may be present, i. e., whether the plant can take them up easily enough to produce the best results or not. We also have the mechanical and physical properties of the soil, its deportment toward moisture, whether it is retentive of it, whether it puddles, bakes and cracks or not. These are all things that the farmer knows when he comes to think of them.

OTHER FACTORS

There are still other things that he knows, one of which, for instance, is that a few, only three or four, wet, muggy, warm days, just before the wheat ripens, will practically spoil his crop. Many of us have seen heavy dews, or a few hours of fogginess, produce the same result, and we rightly believe that it was not the wet, nor the heat, nor the cloudiness in themselves that did the damage, but it was because rust developed under these conditions. The farmer knows that when the rust comes on his wheat that the grains of wheat will be shrunken and will not sell so well, in fact, will be inferior. This is an indirect result of unfavorable weather. If there were no rust plants growing in the country, and consequently no rust spores, ready to germinate, the warm muggy weather would probably do very little, or no harm at all. The weather in an indirect way may mean more than it does by its direct action, for the wheat plant itself, as well as the rust plant, will not grow if the weather be unfavorable. A hot, dry wind

may kill the wheat plant as quickly as a warm muggy spell, or the lack of ventilation in lodged grain may start an unwelcomed development of the rust fungus. The rust fungus is not the only hostile form of plant life whose development may depend upon the weather, but whose presence we are unable to observe under ordinary conditions. On the other hand, the soil may also contain beneficial organisms, whose development may be made more easy or more difficult by the weather conditions, and the good or bad influence of these factors upon the crop must be considered as an indirect effect of the climate.

These plants are not so unlike the wheat plants themselves, for they are not wholly independent of either the climate or the soil. The rust fungus happens to be an injurious parasite on the wheat plant, and its development seemingly depends, in an extreme measure, upon the weather and the condition of the wheat plant for its development in an injurious degree. On the other hand, our soil conditions may be unfavorable; for instance, in the case of peas, etc., they may be such that the little wart-like growths which are ordinarily present, on the roots of our peas, red clover and alfalfa may not appear and these plants will not do so well and will not yield satisfactory crops.

ALL FACTORS MUST BE CONSIDERED

So, if we separate soil and climate from one another or leave out these other factors, we make a mistake which will quite surely defeat us in trying to explain the facts with which we meet.

The climatic factors are not, as a rule, under our control. We cannot regulate the temperature nor control the winds, clouds and rains. If there is no rainfall, we can apply water, even in field culture, which of course is the only culture that we have in view. Practically all writers on this subject have attributed the greatest importance in determining the properties of the wheat to the supply of water. One writer on this subject points out that in Hungary they have, in the regions of light rainfall, small-grained, hard wheat which grows softer and larger in the grain as they go up into the hill and mountain countries, where the rainfall is greater, further, that in France, England, Holland, Denmark, and the Scandinavian countries, where they have a coastal climate with a heavy rainfall, the wheat is soft, with large plump grains. English writers in discussing the character of their wheats, attribute deficiencies, in this respect, to an excess of rainfall, rather than to a deficiency in the mean temperature of their country. These writers point out that the supply of plant food is usually sufficient. Our own writers almost without excep-

tion have attributed the greatest influence in determining the character of a wheat crop to the climate.

The two features of climate referred to mostly in this connection, are the temperature and moisture supply. The English writers referred to above express it in terms of rainfall and mean temperature. A German writer referring specifically to Colorado says:

"We shall have to remind the reader that the climate of the Colorado section is characterized by an extraordinary degree of dryness of the atmosphere and great daily variations of temperature. The advantages of the Colorado climate consist in the clearness of the sky, infense sunshine, and a light atmosphere favorable to evaporation."

The same author again says:

" I have referred previously to the fact that the cultivation of wheat in this zone is only possible under irrigation, but which, under the other favorable climatic conditions, yields extraordinary results, as it can be applied at exactly the opportune time. The high yield and weight per kernel is explicable only by this."

An American writer expresses himself in almost identical words, to-wit:

"Where irrigation is practiced in Colorado * * * ideal conditions for plant growth prevail, for there the sky is clear, the sunshine intense, the air dry. Therefore, if water can be supplied when the crops are in need of it, assimilation will go on at its best, and the production of organic substance will be all the more favored. The result will be a large crop of large-sized grain."

These statements represent very fairly the general views held in regard to the part played by the climate, more particularly, by water. If there be any doubt that this is the principal feature had in mind, the following sentences from the English authors remove it.

"Thus, the plant, which luxuriates in a comparatively dry soil and climate passed its whole existence under exactly opposite conditions; and the result was only what was to be expected."

In another place they say:

"It has, of course, long been known that an excess of wet is injurious to the wheat crop."

In passing we may add, that yellow-berry, a condition very frequently observed in Colorado wheat, has been held to be a result of our practice of irrigation, or is also an effect of water. The European writers also virtually maintain this; for instance, they attribute the character of the French, English, and Danish wheats to their moist climate, and the characteristics of these wheats are that the grains of the wheat are big, plump and mealy and are not small, hard, flinty and dark-colored.

RELATION OF WATER SUPPLY TO YIELD

This brings up possibly the most important practical question that we have to deal with in wheat growing, namely: What is the relation of the water supply to the yield and character of our wheat? The answer to this question is somewhat difficult to present, but for the sake of having a definite presentation of our answer we will assume that water has two sharply distinguishable effects, direct and indirect, and that these may vary with the manner of application. If we should have a long continued rainfall which actually changed the chemical composition of the whole plant and its product, the seed, we would consider it a direct effect. Such an effect is possible, but if the rain or moist spell chanced to come during a period of hot weather, with little wind, and the rust developed, as we know it will in Colorado, we would consider this an indirect effect of the wet and warm weather.

IRRIGATION AFTER WHEAT IS IN HEAD DOES NO GOOD

These different effects are actually produced and we cannot control these conditions. So far as the growers of wheat in Colorado are concerned, it would be a good thing if we had no rain at all from the time the wheat comes into head till after it is threshed, for water, applied after the wheat comes into full head, does no good and may be very dangerous, especially in the form of frequent light rains accompanied by warm, cloudy weather.

It is perfectly well understood that plants must have water in order to grow, and while some plants may thrive in a comparatively dry soil and climate, as the wheat plant is said to do, there is a period during which an amply sufficient supply is necessary for its best development and no abundance of supply, at some other time, will make up for a lack during this period; for this reason this is often spoken of as the critical period.

We did not attempt in our work to establish the limits of this period. Every man who has cultivated plants has learned that it is a general rule that plants which have been stunted, whatever the cause, will not produce as good plants as those that have been kept continuously in good growing condition, even though the cause of stunting may be wholly removed, as in the breaking of droughty conditions; a few varieties of plants may recover from such stunting, but most plants will not. The wheat plant needs an abundant, i.e., an amply sufficient, supply of moisture to keep it growing vigorously till it is well advanced in boot. If there should be any signs of a want of moisture previous to this time, it should be irrigated. If, however, there is no lack of moisture

up to this time, and the wheat is coming into head, some of it, perhaps, already in head, it should then receive a liberal irrigation, enough water to wet the land thoroughly. The quantity of water and the time necessary to get over the land will depend upon the moisture in the soil and its texture. But whether it takes little or much, the crop should be irrigated thoroughly at this time. The application of water much later than this is worse than labor lost, for it involves the risk of lodging and the accompanying dangers without compensating advantages.

We have the results of four series of experiments on this point in which 1, 2 and 3 feet of water were applied. The application of 1 foot of water in our series when the wheat was well up in the boot, produced as much wheat and straw as the application of 1 foot at this time and a second foot four weeks later. The second application produced no effect whatever upon the quantity or quality of the crop. This was true of the growing plants as well as of the matured crop. In the two other series the water applied, was 1, 2 and 3 feet, applications being made through the season at intervals of from 12 to 26 days. In this case there were slight differences in the crop in favor of the larger applications of water, but no differences in the character and composition of the wheat. So far as the application of irrigating water to wheat is concerned, no commensurate good is done if it is made materially later than the period of heading, at which time it must have an ample supply. It should have water previous to this if it shows distress. On the other hand, the application of water to the land up to within 15 days of ripening, exercises no influence upon the character and composition of the wheat.

IRRIGATION AND RAINFALL HAVE DIFFERENT EFFECTS

This appears to be in direct opposition to the view held, almost without exception, by writers on this subject previously referred to. Their statements, at least the most of them, are based upon the observed effects of a wet climate, a continued excessive supply in the form of rain, in which case the plants are kept wet nearly all of the time, either by the rain or the dews which accompany these conditions. Our statements pertain to the application of the water to the land while the plants themselves are dry, and the weather usually clear, with a strong, bright sunlight. This makes a big difference. We have never collected the dew from our wheat plants to see how much such water had dissolved out of the plant, but we have analyzed plants grown in a season of almost no rainfall and in one of very frequent rainfall and

very heavy dews. The plants during these two seasons received in the aggregate, the same amount of water, so that any differences in the effects can be attributed only to the differences in the manner of application. One might think that the condition of the plant at the time the water was applied had determined the effects observed. This does not seem to be the case, for the application of 5 inches of irrigating water every 8 or 10 days had no effect upon the composition of the wheat grown. While very much less water in the form of rainfall caused the production of plants with less nitrogen and less ash constituents and the wheat produced was of inferior quality which may have been mostly due to rust which developed very strongly under the conditions of that year. The rain water, without doubt, simply washes the substance out of the plants. We made an experiment to see whether water would actually wash out nitrogenous substances from the plants by simply putting cut-up plants in water, and it did. We already knew that water will wash out the ash constituents of both the plants and the ripe wheat grains. So, after all, it is no great wonder that a season of well distributed and high rainfall should produce results different from those produced by the same, or even a much larger amount of irrigating water applied to the soil.

These statements are true of all the varieties with which we have experimented. These include Dicklow Spring, Marquis, Defiance, Red Fife, Kubanka and Turkey Red. The number of experiments made to show the effect of the amount of irrigating water applied was 32.

These are the principal facts that our observations on the effect of the amount of irrigating water and the time of its application have shown, namely, that the last application of irrigating water should be made when the wheat is well in boot or early head. Whether an earlier application should be made will depend upon the season and can be judged by the condition of the plants. Water applied much later than this will do no good and may do harm.

The land may be kept wet up to within 15 days of ripening without affecting the composition of the wheat, but if the plant is kept wet by frequent rains, the composition of the grain will be affected, and if rust is induced, which will be while the plant is somewhat green, both the yield and the quality will be affected.

OBJECT OF INVESTIGATION TO DETERMINE WHY WHEAT IS SOFT

The object of our investigation has already been stated, namely, to discover, if possible, why our wheat is soft. The writers who have discussed the causes for the differences in the quality of wheats have agreed that the weather prevailing during the season, is the big factor in the problem, wet weather producing inferior wheat. We have just seen that there are reasons for this conclusion, but they do not hold good in our case, for our wheat has been considered as soft wheat though the seasons are dry. We have sections in which the farmers grow soft wheat where the average annual rainfall is less than 12 inches, and the amount that falls during the life of a crop of spring wheat, say from 108 to 130 days, is insufficient to grow the crop, even if it should fall at the very best time in the case of each individual field, which is, of course, not possible.

Some have claimed that irrigation produces soft wheat. If this were true, it would explain why our wheat has gotten the reputation of being soft, and would take the place of climate. We did not quite believe this in the beginning and have told in the preceding pages some of the facts that we have found in studying the effects of irrigation on the composition of the wheat plant and the grain produced.

METHODS OF DETERMINING WHETHER WHEAT IS HARD OR SOFT

We have repeated the assertion that our wheat is soft and that the flour made from it is not so good as flour made from harder wheat. It is a difficult matter to tell just what is meant by hard wheat and soft wheat. The people of the Kansas Experiment Station have suggested that we determine, by means of a proper machine, what weight it will take to crush an average grain of the wheat. If it takes less than a certain weight, they suggested that it be classed as soft; if it requires a greater weight than this, but less than another certain weight, they suggested that it be classed as medium; and the wheat requiring a still greater weight to crush it, should be classed as hard. This gives us a definite standard by which to judge, but it is a difficult matter to get the average grain of wheat. As a matter of fact we all apply this principle in a rough way when we crack grains of wheat between our teeth; if they crush with difficulty we say that the wheat is hard, if not, that it is soft and the judgment formed is about right.

There is another way that we judge whether a wheat is soft or hard. If the wheat is dark-colored, glassy, and more or less translucent, we say that it is hard; it looks flinty. If, on the other hand, it has a yellowish white, chalky or mealy appearance, we say that it is soft. Of the former, we say that it is rich in gluten, of the latter that it is poor in gluten; it is starchy. This is about as near as one can arrive at a definition of hard and soft wheat, but the distinction is really of a great deal of importance, for the flour yielded by hard wheat is more desirable for bread-making than that made from soft wheat.

There are differences in varieties in this respect; for instance, our Colorado Defiance is, at the very best, a soft wheat compared with Kubanka, a durum wheat, or with Turkey Red. This, however, is not the softness of which we set out to find the cause. It must be remembered that some grains of Defiance wheat are harder than other grains and the same is true of other varieties. Some grains of Kubanka are flinty and very hard, while others are mealy and much softer. Now it sometimes happens that all the grains are mealy and soft when they ought to be flinty and hard, and it is the cause of this that we have been trying to find out, and not why one variety is harder than another.

A few years ago spring wheat was grown almost exclusively and Defiance, a soft wheat, was our popular variety. Of late years we have been growing other varieties and more winter wheat, so that the wheat milled now may be harder than that previously milled, and the flour produced better. I make this statement in this connection, for I think that the reader should bear in mind the fact that the practices of the country have changed in regard to wheat growing of late years, whereas, the reputation of our wheat has not changed and what may have been true of our flour some years ago, may not be true now. The low estimate so generally put upon our flour some years ago may have been just, but may not be just at this time, and still that reputation will be passed along and be kept alive for a long time to come.

AMOUNT OF IRRIGATING WATER DID NOT AFFECT QUALITY

Let us return to the question why some grains of wheat, or a whole crop, may be yellow and soft and others amber-colored, flinty and hard. The amount of irrigating water applied not only did not produce such results, but did not seem to influence them either one way or the other in the experiments that we made, and the effect of rain was not to produce this peculiar condition. The reader will observe that this is stated as a matter of fact, that the

application of 3 acre-feet of water in the experiments given did not appear to have any influence upon this condition that 1 acre-foot did not have. I have seen this condition present to just as great an extent in the so-called dry-land wheat as in irrigated wheat.

THE EFFECTS OF PLANT FOOD

We endeavored to find out what the effects of the individual plant foods, usually considered necessary for the growth of crops, are. It is well established that the plant foods of first importance are only three in number and if these be present in the soil in sufficient quantities, the other necessary elements of plant food can be considered as also present in sufficient quantities. We know that this is true of practically all of our Colorado soils. The three important elements are potassium, phosphorus and nitrogen. Our soils are not excessively rich in phosphorus and total nitrogen. I say total nitrogen because there are two kinds of nitrogen, organic and inorganic, and we get these together in our ordinary analysis. So far as our present problem is concerned, we can consider the organic nitrogen as of no use to the wheat plant. The total nitrogen present in our soils is usually very moderate. Still our crops do not show by their color or the manner of their growth that there is any shortage of nitrogen. As our soil already contains enough plant food to grow good crops, the only way that we could study the effect of these foods on the plants and their seed, on the field scale, was to apply enough to exaggerate the effects of each one, and compare the results with a check plot, which received no fertilizer. In this manner we obtained a most definite answer to the question which we have stated, i. e., why some of our wheat is yellow and soft. This condition is quite frequently designated by the specific name yellow-berry.

INCREASE IN NITROGEN PRODUCES HARD WHEAT

We applied the nitrogen in the form of sodic nitrate, chile-saltpetre, and found that with the application of 250 pounds of this salt to the acre, put on at the time of planting, we changed the character of the wheat produced to a small-grained, flinty, hard wheat, with a decided increase in the amount of gluten over that grown without it. This was the answer to one side of our question, namely, how to produce hard wheat. The answer to the other part of the question, What makes the wheat yellow, mealy and soft? was just as plain, for the potash increased the yellow-berry very greatly in each of 45 different experiments.

EXCESS OF POTASH CAUSES YELLOW-BERRY

So here was the whole problem worked out in land sufficiently well supplied with inorganic nitrates, which furnish the nitrogen to the wheat plant, to grow big crops of mixed hard and soft wheat. If the potash be in excess, then we have yellow-berry. By this we mean that some grains of the wheat will be yellow, others will be partly yellow, while some may be wholly flinty and hard. This is the case with a great deal of the wheat grown in different parts of the State.

We increased the nitrates and obtained hard wheat. We applied more saltpetre than was necessary to produce a satisfactory result on our ground, but how much more than was needed to correct the excess of potash we have not determined, and it would do no one any good if we had determined this point, because the reader's land might need more or less than ours. The big thing for us was to find out the facts as to what makes the wheat yellow and soft, and what to put on the land to make it hard.

FALLOW CULTIVATION INCREASES NITROGEN

There are other ways to increase the inorganic nitrogen in the soil besides buying Chile-saltpetre at a high price. The best way in Colorado is to cultivate the land fallow. This both improves the condition of the soil and adds nitrogen to it, which is finally changed into the form in which the wheat plant can use it.

MANURE DOES NOT AFFECT COMPOSITION

In one series of experiments which we have recorded 16 loads of well rotted manure was applied to the acre but it had no perceptible effect upon the number of yellow grains in the wheat. The reason for this was that the nitrogen in the manure was present as organic nitrogen and the soil agencies were not able to convert this organic nitrogen into a usable form fast enough to affect the character of the wheat produced. The effect of this manure, 16 loads, upon the size of the crop, was to increase it by about 7 bushels of wheat and 600 pounds of straw to the acre; it did not affect the composition of the wheat at all. The biggest increase that we obtained from the application of Chile-saltpetre was about 4 bushels of wheat, but the composition of the wheat was changed, that is, the gluten was increased. Evidently our soil contained enough nitrates to produce about its maximum crop, so there was no great increase in crop, as is often observed as a result of the application of saltpetre.

The recorded observations of different experiments on the effects of farmyard manure are contradictory, some saying that it does and others saying that it does not affect the composition

of the wheat. Our record is that it does not change the composition of the wheat produced, and further, that the increase in the crop was very moderate indeed. The crops ranged from 17 to 30 bushels to the acre, so this was not due to the production of a great big crop on the unmanured plots that was hard to make any bigger.

The fact is that two experiments made in exactly the same manner on two different, perhaps very different pieces of land, may give very different results, and this is the explanation for the contradictory results in this case; besides, farmyard manure may be young or old, of one kind or another. We believe that the wheat plant can use practically only one form of nitrogen in building its tissues and this form is nitric acid which is present in the soil as nitrates. If this be true, then all of the organic nitrogen present in the manure must be changed into this form before it is of any use to the wheat plant. This change is called nitrification, and the ability of soils to bring this about varies greatly, and the effects of nitrogen applied to wheat land in the form of farmyard manure will vary just as this power of the land varies. This is why experiments with farmyard manure on wheat on different lands have given such different results.

With us the practice of cultivating fallow gives excellent results for two reasons: First, because the amount of nitrogen in the soil actualy increases by amounts as great as are involved in the different characters of the crops, and second, by the change of this organic nitrogen into a usable form for the wheat.

EXAMPLES OF RESULTS OF FALLOWING

When we have no bad weather or other accidents to interfer with the development of the wheat, it is perfectly proper to compare the gluten in two wheats as the measure of their quality, and likewise, as a measure of the nitrogen used by the plant, so if we compare the amount of the gluten in two samples of the same variety of wheat grown under equally favorable conditions of soil and climate, the one having the more liberal supply of usable nitrogen will contain the larger amount of gluten. The best illustration that I have of this is presented by two samples of Red Fife wheat grown on pieces of land separated by a roadway 16 feet wide. The land on the west side had been cultivated fallow, that on the east side had been cropped to oats the preceding year. These plots were planted to Red Fife wheat. That grown on the fallowed land was flinty and contained 17.14 percent of protein, while that grown on the cropped land was affected by yellow-berry and carried 12.93 percent protein. I also have a pair of samples of Marquis wheat, but they are not so thoroughly

comparable as the preceding pair given, still the samples grown on fallowed land contained 14.09 and that grown on cropped land 10.42 percent of protein, or, in general terms, gluten. With us, then, to cultivate the land fallow the year before it is planted to wheat helps wonderfully in increasing the hardness of our wheats. I have given the reason as being due to the accumulation of nitrogen, and its conversion into the form best suited for use by the wheat plant. If we had from 40 to 60 inches of rainfall, as they have in some states, the nitrogen might be washed out if no precautions were taken to prevent it, but with a rainfall of less than 15 inches per year, this does not make much difference.

When the potash does not produce yellow, spotted and mealy berries, it produces a distinctly lighter color in the wheat grains, which is easily recognized, also a marked plumpness, and the grains really crush easier than the flinty or dark colored grains grown in the same field. The yellow-berry grains crush more easily than the flinty grains picked out of the same sample. In the case of the Defiance, we found that it took 8 pounds more to crush the flinty grains than it took to crush the yellow-berry grains; in the case of the Kubanka it took 10 pounds more to crush the flinty than the yellow-berry grains. As the potash produces the yellow-berry and the light-colored wheat which is soft, we conclude that the presence of too large a proportion of this element is present in the soil. Of course, we may state it the other way, that as the addition of nitric acid or nitrates makes the grains flinty, there is too small a proportion of this element present in the soil to produce hard wheat. It makes no difference how we state it, the fact remains the same, i. e., to increase the nitric nitrogen in our soil tends to harden our wheat, without materially increasing the crop, and to increase the potash tends to soften it.

NITROGEN MAY BE WASHED FROM LAND BY EXCESSIVE RAINFALL OR IRRIGATION

The statement made about the possibility of the nitrates being washed out of the land by excessive rainfall was emphasized by English writers more than 30 years ago as the following sentences makes very plain:

"It has, of course, long been known that an excess of wet is injurious to the wheat crop, but it is only comparatively recently, that one, at least, of the material causes of the adverse influence has been made out; namely, the great loss of nitrogen carried off by drainage in the form of nitrates."

This is another manner, in addition to that already mentioned, in which rain may be bad for a wheat crop. Too heavy and too frequent irrigations might produce the same effect.

The application of 1 acre-foot of water on 12 June was not

sufficient to perceptibly modify the effects of 40 pounds of nitrogen applied in the form of Chile-saltpetre at the time of planting, and, as this amount of water is, under our usual conditions, sufficient to mature our wheat in the very best manner, there is no reason at all why such a thing as the washing out of the nitrates, due to water applied, should happen. I think that usually 1 acre-foot applied when the wheat is in boot or early head is about the maximum that will be found necessary.

Some writers have stated that wheat is softened by irrigating it. The statements just made show how this might be the case, but I think that it seldom happens in our practice that wheat is softened by over irrigation. It is, however, worth bearing in mind, that while water is indispensable, we can do harm by using too much of it.

CHIEF CAUSE OF SOFTENING IS EXCESS OF POTASH OVER NITROGEN

The only cause for the softening of our wheat, unless it be where subirrigation is practiced, is, I think, due to the large excess of potash over the nitric nitrogen present in our soil. This nitric nitrogen, then, is something that we should cultivate and preserve in our soils if we wish to grow good wheat. I have said "cultivate" for this is one of the things that we do when we cultivate our land fallow.

COLORADO WHEAT VARIES GREATLY IN COMPOSITION

Our wheat varies greatly in respect to its hardness. I have samples from some sections of the State that are as good wheat as we could possibly desire, and I have others that are as soft as wheat can be. The Defiance is a very popular spring wheat, but it is often an extremely soft wheat, though the grains are large and the yield is satisfactory. This latter statement has not been exemplified in my own experience. Red Fife and Kubanka have each yielded better than it for the 5 years that I have grown them side by side. Defiance wheat has not only failed to give me the yield, it has not had the quality of these others. The Kubanka is a durum wheat and it may be that I should not compare the Defiance with it, but this is not the case with the Red Fife. I have seen some samples of winter wheat which were very soft but the most of it is very good, hard wheat, and, as I believe, worth just as much as wheat grown anywhere. This lack of uniformity in the quality of our wheat is unfortunate, for it seems to be true that the soft wheat is not so desirable as the hard wheat,

but it is all Colorado wheat and the flour made is all Colorado flour, but it is not all equally good, very far from it.

I call to mind two samples of Turkey Red wheat grown on neighboring farms, in one all of the grains were narrow, glassy, and hard, in the other they were mostly yellow or partly yellow. The manager of the local mill went with me to see these wheats in the hope that I could tell him what made the difference in them. He said that he would willingly buy the hard wheat for he knew that he could make good flour out of it, but that he did not want to buy the yellow wheat because, if he mixed it with good wheat, he could not be sure that the flour would be up to the best standard. Now this wheat was grown from the same lot of seed and on two neighboring farms, and yet the crops produced were, in the judgment of this mill-manager, of very different quality, and he was entirely right in putting different values upon them.

ALL COLORADO FARMERS SHOULD BE GROWING BETTER WHEAT

While some of our wheat is very good it is not all good; on the other hand, while some of our wheat is very soft, a very great deal of it is hard. The hard wheat is richer in nitrogen, which is practically the same as saying richer in gluten, than the soft wheat and yields a better bread-making flour. In the first place it takes more water to make a bread-dough and consequently makes more pounds of dough. It may take 20 or 25 pounds more water to 100 pounds of flour. If we were making bread, even for a big family, we would appreciate this and we can not blame the baker for wanting this kind of flour. Many of our farmers are growing wheat that produces this kind of flour, and everybody ought to try to grow it and then they ought to get pay for this quality of wheat, but they are not all growing it. I understand that a difference of about 5 cents a hundred is sometimes made in favor of the hard wheat, and this is just.

Very many of the bakers, if not nearly all of them, in the larger towns of Colorado, claim to use, and I believe actually do use, Kansas flour for bread-making; at least they mix it with the better grades of Colorado flour. Some families that do their own baking use Kansas flour and think that they save money by doing it, because it makes more bread. I have heard this story now for thirty odd years and it must be true, at least they believe that it is true. I went to the largest bread-making establishment in Colorado and asked them what flour they used in bread-making. They said "Kansas flour"; but for other purposes they used Colorado

flour. I asked them why they did not use Colorado flour for bread-making. The reason given was definite, i. e., because it made less bread to the barrel of flour by from 30 to 40 loaves. Now these people were using a great many carloads of flour every month for making bread and this was a commercial fact, concerning which they were certainly not deceiving themselves. The difference in these flours corresponds to the wheats from which they were made. The hard wheats of Kansas produce good bread-making flours while the softer wheats of Colorado yield less desirable ones. This is not only true in respect to the amount of bread made, it is also true in regard to the quality of the bread itself.

COLORADO CAN PRODUCE FIRST-CLASS WHEAT

These statements may be, and I believe are, true of some Colorado flours but they certainly are not true of all Colorado flours. The best of our flours may not be as good as the very best Minnesota or Kansas flours, but of some of them it is true that they rank in real merit just as close to these very best samples as the other Minnesota or Kansas flours do. By the choosing of good varieties and proper care in the cultivation and care of the grain, Colorado can produce first-class wheat and flour so that the baker will have no excuse for using Kansas flour nor the miller for claiming that the wheat is low in gluten.

QUALITY OF COLORADO WHEAT SHOWN BY PROTEIN CONTENT

The relation between the composition of the wheat and the flour produced is quite intimate, so intimate that it is quite permissible in this presentation to speak of the wheat only, and assume that the statements made apply to the flour. This is true to such an extent that the amount of crude protein is justly taken as the measure of the quality of the wheat. The crude protein is estimated by multiplying the nitrogen found in the wheat by the factor 5.7. The factor 6.25 has been used in estimating the amount of crude protein in many of the older analyses of wheat. It is necessary to remember these factors in comparing the statements of the protein content of wheat. We could avoid this confusion by giving the total nitrogen instead of crude protein, but we wish to give the amount of protein as nearly as possible, for this is the substance in the wheat that contains the nitrogen, and corresponds nearly to the gluten present, which everyone associated with the quality of the flour.

Someone may wonder why we have two different factors for the same thing and if they can both be right. They are probably neither exactly right, but one is more nearly so than the other.

The explanation for the use of two factors in this case is simple. The average nitrogen content of proteid substances is 16.00 percent, so if we find the nitrogen in a substance that contains no other than proteid nitrogen, this is equal to 16/100 of this substance present, so we multiply the nitrogen found by 6.25. It has been found, however, by extended investigations that the proteids of wheat are richer in nitrogen than the average proteid; they contain about 17.5 percent instead of 16.0 per cent; so the factor is 5.7 instead of 6.25. This factor of course gives a lower figure for the proteids in wheat; for instance, the protein content of the average American wheat is given as 12.23 percent. This statement was made, using the old factor 6.25, and becomes 11.16 percent, using the smaller and more recent factor. These two statements are for the same wheat. The importance of this point is this; if the reader should chance to compare the proteid content of Minnesota, Kansas or Hungarian wheat with that of a Colorado wheat given in this bulletin and find 18.75 given for the percentage of protein in the Hungarian wheat and 17.10 for that in the Colorado wheat, he would feel satisfied that the foreign wheat, be it Minnesota, or Hungarian, was more than 1.5 percent richer in protein than the Colorado wheat, whereas they are supposed to have exactly the same amount of nitrigen, 3.0 per cent, and to be wheats of the same quality.

The average composition of whole wheat is given as follows:

	Domestic Wheat Percent	Foreign Wheat Percent
Moisture	10.62	11.47
Protein	11.16	11.02
Fat	1.77	1.78
Fibre	2.36	2.28
Ash	1.82	1.73
Carbohydrates (Diff)	72.27	71.72
Wet Gluten	26.46	25.36
Dry Gluten	10.31	9.82
Weight of 100 grains	3.866 grams	4.076 grams

The one substance in this analysis that is of the greatest interest to the general reader is the protein, for this is the substance that yields the gluten which shows the bread-making qualities of the wheat. The wet gluten and dry gluten simply show the following; the former how much this wheat-proteid weighs when it is combined with water, and the latter how much of the crude protein is recovered in this form. In the two analyses just given, 10/11 of all the protein in the wheat was recovered from the wheat by washing out the starch and other constituents. The two analyses given are average analyses, one of domestic and the other of foreign wheat. Of course many wheats contain more protein than is given in these analyses and all of those that contain

more than 11 percent belong to the higher grades of wheat. This is the principal thing that an analysis of wheat shows, so far as the farmer is concerned. This, however, is just what, in the next place, we want to show the Colorado farmer about our wheats, and to show him further how he can grow better wheat, and wheat which is more uniform in quality than we are growing.

First, however, we shall give him some idea of how our wheats vary in quality, and, as we have shown why we use the amount of crude protein in wheat as the measure of its quality and that the other details of the composition of wheat are not material for the farmer's understanding of the question with which he has to deal, we shall give only the crude protein, wet and dry gluten. While the ash and other constituents may be important from certain points of consideration, they do not play any big part in the questions interesting the wheat grower, and, besides, they will largely take care of themselves under our Colorado conditions. The only object in giving wet gluten and dry gluten is to show how much water the wheat proteids take up. Gluten washed out, as these glutens were, always contains some starch and other things, but we will not go further into these details.

GENERAL SAMPLES OF COLORADO WHEATS, TAKEN IN 1913-1914

SPRING WHEATS

Variety	Locality	Crude Protein Percent	Wet Gluten Percent	Dry Gluten Percent
Defiance	Ft. Collins	13.46	30.66	11.74
Defiance	LaJara	8.29	14.33	6.10
Defiance	Del Norte	8.05	13.73	5.44
Defiance	Ft. Collins	13.93	35.33	13.41
Defiance	Grand Junction	13.92	29.73	10.90
Defiance	Clifton	14.44	28.74	11.68
Defiance	Eckert	11.25	28.37	12.49
Defiance	Ft. Collins	14.92	23.30	12.89
Defiance	Ft. Collins	12.04	32.00	12.99
Marquis	Ft. Collins	16.00	38.63	15.06
Marquis	Ft. Collins	14.06	40.40	16.40
Red Fife	Ft. Collins	15.20	38.00	14.83
Red Fife	Ft. Collins	17.14	40.67	15.58
Red Fife	Ft. Collins	14.79	43.20	16.90
Kubanka	Limon	12.99	30.00	12.49
Kubanka	Ft. Collins	12.77	25.40	10.79

WINTER WHEAT

Variety	Locality	Crude Protein Percent	Wet Gluten Percent	Dry Gluten Percent
Turkey Red	Wellington	10.99	28.50	10.34
Turkey Red	Wray	10.14	20.53	7.87
Turkey Red	LaJara	8.22	16.07	6.42
Turkey Red	Las Animas	11.44	24.63	9.85
Turkey Red	Fruita	13.31	28.00	10.98
Turkey Red	Clifton	13.03	32.67	12.52
Turkey Red	Fruita	9.65	24.37	10.06
Turkey Red	Fruita	10.05	26.66	10.67

Variety	Locality	Crude Protein Percent	Wet Gluten Percent	Dry Gluten Percent
Turkey Red	Fruita	13.21	37.60	15.49
Kharkov	Ft. Collins	11.98	25.40	9.72
Kharkov	Ft. Collins	15.30	38.67	14.00
Jaroslov	Ft. Collins	15.97	40.73	15.04
Jaroslov	Ft. Collins	14.99	48.83	18.15
Red Cross	Fruita	14.15	28.30	11.13
Red Chaff	Eckert	10.05	21.53	8.57
Red Chaff	Eckert	8.04	17.63	7.20
Fultz Mediterranean	Ft. Collins	14.00	42.00	16.00
Fultz	Ft. Collins	16.33	42.23	14.96
Big Frame	Ft. Collins	16.25	42.50	14.63

These samples show that our wheat, whether spring or winter, varies in quality very greatly indeed even for the same variety. In collecting these samples we were surprised and disappointed in finding that the average miller, and the farmer too, took no interest in this matter and occasionally we found a man who demanded pay for the few pounds of wheat making a sample. A greater difficulty was to obtain reliable information concerning the conditions under which the samples were grown. The reasons for this were many; it was seldom possible for the millers to give them and the farmers were but little better able to do so, because they do not understand the things that we want to know about the soil, the weather, the irrigation, the crop grown on the land the previous year, and the treatment that they had given the land and crop. The great importance attaching to these data, made it evident that, so far as the problems that we were studying were concerned, general samples would not serve any good purpose, so we made no attempt to collect such after the first year.

The samples given, however, serve to show that the same variety of wheat grown on different land in the same general section of the State, Turkey Red for instance grown near Fruita, varied from 9.65 to 13.21 percent of crude protein. These samples were grown the same season and it is only from my personal knowledge of certain conditions which existed in these cases that it is possible to account for the difference in the amount of protein in the wheat. The difference was that there was more nitric nitrogen in one piece of land than in the other. These wheats were irrigated, probably once each. When we consider the Defiance we see that this may be a very good wheat or a very poor one when grown in different sections of the State; for instance, the Del Norte sample contained only 8.05 percent crude protein while a sample grown the same year at Fort Collins contained 14.92 percent, or almost twice as much; the dry gluten is twice as much and a little more. The season of 1913 was a good one for wheat in all sections of the State and yet we have these great differences

which are mostly due to the land on which the wheat was grown.

They further show that there are still greater differences between varieties. The highest protein percentage for the Defiance is 14.92, for Marquis 16.00 and for Red Fife 17.14. Of course these are all excellent samples, but the Red Fife is much better than the Defiance. The Kubanka, which is a maccaroni wheat, is not so rich in crude protein as one would expect; with us it is not an especially high protein wheat though it is a hard wheat.

We see the same variations in the amounts of protein in the winter wheats and these variations are largely due to the same causes, the principal one of which is the variation in the amount of nitric nitrogen in the soil.

SPRING WHEATS USED IN EXPERIMENT

It is the province of the agronomist to point out whether it is better to grow spring or winter wheat, and to determine the best varieties of these to be grown, but we chose spring wheats with which to experiment. We made this choice for the following reasons: First, The time from planting till harvest is short; second, The growing period is continuous; third, The spring wheats are known to be of excellent quality; fourth, Because, up to within a very few years, spring wheat was the principal wheat grown in the State.

The first fact enabled us to follow the effects of our fertilizers quite easily, the second removed the uncertainty of changes in both the soil and plants during the winter or resting months and the third feature promised us a bigger range of effects of fertilizers, or weather, on the amount of protein present in the grain. We chose three varieties, our Colorado Defiance because it has been our most popular wheat and I do not know but that it still is, the Red Fife because it is a dark-colored wheat of the very best repute in the northwest, and the Kubanka because it is probably the best of the durum wheats.

The reader already knows that the object of the investigation was to find out the reason for the softening of wheats in Colorado. We assumed that the general opinion held on this subject and in regard to the quality of our flour was correct on the principle that what is generally believed has its foundation in facts and is not prejudice created by a continued effort to depress the selling price of the grain. The general samples given, both those of spring and winter wheats, show that there are enough samples of poor wheat to give color to very bad stories about our wheat. There must be some cause for these poor wheats which probably have given rise

to this generally prevailing bad impression of our wheats and flours. The three varieties of spring wheat chosen for our experiments represent two of the hardest and our own Defiance, not only a soft wheat, but one which was originated here and has been grown in this section for 30 or more years and represents perfectly a Colorado product which from the beginning was adapted to Colorado conditions.

We were very fortunate the first year of our experiments, 1913, in having an ideal season, so that no unfavorable seasonal influence interfered with the quality of the crop. This was not the case in the succeeding three seasons, 1914, 1915 and 1916. So far as our 1916 experiments are concerned, we simply abandoned the large plots. The seasons of 1914 and 1915 favored a strong development of rust which made a big difference in the quality of the grain.

In 1913, as I have just said, the season was as nearly ideal for our experiments as we can ever expect a season to be. We had two hard wheats and one soft wheat. Our experiment could work both ways, to soften the two hard wheats or to harden the soft wheat.

The softening of wheat under Colorado conditions seemed to me to show that the usual explanations for this condition could not be true. I believed that it must be due to something in the soil or possibly to irrigation as some claimed, though I did not belive this latter, for I knew that our dry-land wheat, and dry land here means really dry land, not a country of 19 or more inches of rainfall, fairly well distributed, is often quite soft, or shows yellow-berry badly. For reasons which it will be well to leave out in this place, I thought that the key to the matter lay in the food supply furnished the plant. I could, in a measure, control this and the amount of water, but in regard to the weather, I had to take my chances. Concerning the irrigating water and its effects, I have already said that it may determine the size of the crop but not its quality, as our problem has to do with the quality alone, the question of water is wholly set aside.

There are only three plant foods, aside from water, which it is deemed in any case necessary to add to the soil. These are potash, phosphorus and nitrogen. I have stated on previous pages that nitrogen must be present as nitric nitrogen, i. e., in the form of some nitrate, in order to be taken up by the wheat plant. The land that was placed at my disposal, fortunately, did not need the addition of anything to produce the biggest crop for the season. So the addition of these plant foods would simply show the effects of the food or fertilizer applied upon the quality of the grain

by exaggerating the particular quality affected by it, and, as we planted both hard and soft wheat, we had two ways to observe these effects, namely, by the hardening of the soft wheat and the softening of the hard wheat. The results were all that we could have expected and as we repeated each experiment nine times that year, we might have taken the results as conclusive, but we did not. We have repeated them now for five years with the same results each year. In the bad years these effects were less satisfactory because so many things had a part in fixing the quality of the wheat. So we shall say nothing about any other than the 1913 crop. While I shall give the general composition of the three varieties, I shall not discuss them separately.

PRODUCED HARD AND SOFT WHEAT UNDER SAME SOIL AND MOISTURE CONDITIONS

In order to save labor and avoid confusion, I shall speak of "nitrogen," "phosphorus," and "potash" wheats to show which plant food was applied, and "check" wheat to show that nothing was added. When we threshed these different parcels, we could easily see that there were very great differences in the color of the wheats, also in the size of the grains, but we obtained no differences in the yields which were worth mentioning. I think that any farmer will agree with me that almost any two acres in a 20-acre field of wheat may differ in yield by 3 or 4 bushels, and unless the yields on 1/10-acre plots showed more of a difference than this, they would not be sure that it was the fertilizer applied that made the difference, unless this difference was made in the yield of every plot to which the fertilizer or plant food was applied. This was not true in our case, and even if the favorable differences found had been produced by the fertilizer, it cost so much to produce it that a man would be much better off without it. As I have said, the color of the wheat from the different plots varied just as the grains in some lots of wheat vary, some were darker, more glassy and harder than others. Here was the very thing that we were looking for; here was hard wheat and soft wheat grown during the same season on the same piece of land, which we had divided into 1/10 acre plots, and to which we had applied the same amounts of irrigating water. Our nitrate wheats were all harder, and potash wheats were all softer than the check wheats, while the phosphorus wheats were just like the check wheats.

There were no regular differences in the yields in favor of one or the other of the fertilizers and the yield from the check plots often had the advantage. All of our results showed in the quality of the wheat. The nitrogen had hardened the wheat; the

potash had softened it. We have found this to be the case every time in upwards of 90 experiments, which proves that the cause of our yellow-berry, which is an extreme case of softening, is due to the presence of potash in excess of nitric nitrogen in our soil.

The following analyses represent our own wheats grown in these experiments and show, I think, the real quality of Colorado spring wheats grown under favorable weather conditions. Each analysis given is the average of nine analyses made of different samples of the particular kind of wheat.

WHEATS GROWN WITHOUT THE APPLICATION OF NITRATES

Variety	Crude protein Percent	Wet gluten Percent	Dry gluten Percent
Defiance	11.66	23.79	9.77
Red Fife	12.63	27.78	11.25
Kubanka	12.53	25.91	10.68

WHEATS GROWN WITH THE APPLICATION OF NITRATES

Variety	Crude protein Percent	Wet gluten Percent	Dry gluten Percent
Defiance	13.94	30.43	12.15
Red Fife	14.86	32.78	12.98
Kubanka	14.18	31.24	12.56

These analyses present the clearest and best statement that I know of in regard to the quality of our spring wheats. All of the wheats produced without the application of the nitrates were soft to a greater or less degree and those produced with the application of the potash were affected to the greatest extent by yellow-berry, and in the cases of the Red Fife and Kubanka, showed lower crushing strengths. On the other hand, all of the wheats grown with the application of nitrates were free from yellow-berry. The grains were smaller, glassy, semi-translucent and sometimes more or less shrunken. They would be graded as hard wheats.

These analyses show that wheats grown with the application of nitric nitrogen are richer in crude protein, by about 2.0 percent, than the same variety grown under the same conditions of season and soil but without the application of nitrates. Further they show that both the wet and dry gluten are very materially higher than in the same varieties grown without the application of nitrates.

If these analyses be compared with the average given for the composition of whole wheat, it will be seen that our Defiance grown without the application of nitrates is just about an average wheat so far as the crude protein contained is concerned, but a trifle below the average in both the wet and dry gluten. The Red Fife and the Kubanka grown without the application of nitrates are fully up to the average for domestic wheat, which is higher than

the average for foreign wheat. All three of the varieties grown with the application of nitrates are well above the average, in fact, are very good indeed. If the reader will turn back to the table of general samples of winter wheat he will observe that only three of the 19 samples are much below the average for domestic wheats, while nine are much above it.

COMPARISON OF COLORADO AND MINNESOTA WHEATS

Of course the question which has been at the basis of all of this work is simply, What makes this difference? The general impression is that all of our wheat, when compared with Minnesota wheat for instance, is inferior in composition, that is, contains less gluten. This is not true, a great deal of our wheat is just as good and even better than Minnesota wheat. In 16 analyses of Minnesota wheats which I find in one of their bulletins the crude protein varies from 11.63 to 16.02 percent, and in 28 analyses that I find in another bulletin the crude protein in the wheat, which is about 1 percent more than is found in the flour, ranges from 11.17 to 15.75 percent. In some samples that I obtained from Minneapolis as samples of wheat which was on that market, marked Minnesota Spring No. 1, 2 and 3, I found:

	Crude protein	Wet gluten	Dry gluten
No. 1	12.81	24.67	9.88
No. 2	12.61	26.27	10.29
No. 3	12.20	24.73	9.62

Hard Winter Wheat from the same market gave,

	Crude protein	Wet gluten	Dry gluten
No. 2	11.22	21.73	8.64
No. 3	10.76	21.87	8.99

These samples were not as fine looking wheats as our own products and the analyses are just about average.

One thing to notice in these results is that they are more uniform than ours but the number of samples is smaller. We have some very low ones, our Red Chaff from Eckert carried only 8.04 percent crude protein and the Defiance sample from Del Norte 8.05 percent, whereas the Fultz from Fort Collins carried 16.33, and another sample of Red Fife 17.14 percent crude protein. These differences are very big though these samples were grown in good seasons, so that we cannot blame the weather, nor can we blame much of the difference to the variety, for while the Defiance is a soft wheat it is not always a poor wheat. This difference in the value of samples cannot but hurt the reputation and perhaps the market price of our whole crop. We can obviate this in so far as it is due to the land. We can, in the first place, plant varieties with a high protein content. The Marquis, for instance is, with

us, richer in protein than the Defiance. So is the Red Fife, and the latter, though it is a bearded wheat with an apparently much smaller head than the Defiance, is a much surer cropper, because, it is earlier, stiffer in the straw and withstands rust better. I have not grown the Marquis and this is the reason that I say nothing about it. With us the thing that we have to dread most of all in connection with the quality of our wheat is rust. Continued wet weather, which would keep all parts of the plant wet most of the time would without doubt give us poorer wheat than clear weather. It is not the amount of water that does the damage but the fact that the plants are wet almost all of the time, which either washes out material that should be stored in the plant and later in the grain, or prevents the plant from taking this material up from the soil. The fact is that plants kept wet most of the time while they are growing are poorer in those substances that make good grain than plants not kept wet. We may keep the ground wet and not make the grain poor, but if we keep the plants wet, that is another thing. The difference made by the water alone is not so very big though it is big enough to be a matter of regret. The biggest danger to which our crops are exposed is an attack of rust. When this is prevalent, the crop is very poor in quality, even if it is not badly shrunken. When the rust develops abundantly on our wheat, the nitrogen which makes the protein in the wheat, and with it the other constituents also, seems to be very largely stopped from going into the grain. When this happens just when the grains ought to fill out, they don't fill and we have shrunken wheat. The Defiance is late in ripening and is susceptible to rust. My own experience with it has been very unsatisfactory on this account. The season of 1913 was a very favorable one. That of 1915 was wetter, but the promise of a crop was good till within 15 days or so of harvest, when, due to rain, lodging of the wheat and high temperature, rust developed very abundantly.

The yield and the analyses of the wheat from the same plots treated in the same manner in the two years follow. The only difference in the two seasons was the development of the rust. The promise in 1915 up to this point was good.

The statement of the results shows for itself the differences.

DEFIANCE SECTION 1800, SEASON OF 1913

Fertilizer	Bushels per acre	Crude protein percent	Wet gluten percent	Dry gluten percent
Nitrogen	38.83	13.79	31.33	12.32
Phosphorus	39.50	12.01	24.50	9.85
Potassium	41.66	12.33	24.50	10.08
None	40.58	12.14	25.07	10.22

DEFIANCE SECTION 1800, SEASON OF 1915

Fertilizer	Bushels per acre	Crude protein percent	Wet gluten percent	Dry gluten percent
Nitrogen	10.83	10.72	27.17	10.71
Phosphorus	22.50	8.76	18.50	7.47
Potassium	25.33	8.44	20.00	7.99
None	19.50	9.00	18.70	7.37

These two crops were grown with the same amount of water. In 1913 we had 7 inches of rainfall during the life of the wheat and we applied 12 inches of water; in 1915 we applied 6 inches of water and had 13 inches of rainfall. In 1913 we had very little, we may say no rust; in 1915 our wheat was very badly rusted. The yield for the Defiance in 1915 was not quite one-half of that of 1913 and the quality was no good at all.

I have stated one of the objections to the Defiance to be its late ripening. A comparison of the above data with similar ones for the Red Fife may be instructive.

RED FIFE, SECTION 1800, SEASON OF 1913

Fertilizer	Bushels per acre	Crude protein percent	Wet gluten percent	Dry gluten percent
Nitrogen	39.91	14.91	32.20	12.84
Phosphorus	34.90	13.24	27.00	11.04
Potassium	33.90	13.81	27.20	11.07
None	33.16	14.43	28.83	11.55

RED FIFE, SECTION 1800, SEASON OF 1915

Fertilizer	Bushels per acre	Crude protein percent	Wet gluten percent	Dry gluten percent
Nitrogen	23.66	10.07	24.70	9.28
Phosphorus	33.00	8.01	18.00	7.27
Potassium	33.16	8.82	22.17	8.99
None	33.66	8.38	19.40	7.73

This variety matures about 10 days earlier than the Defiance. We find that the 1915 crop is only a little less in volume than that of 1913 but the quality is extremely poor, just about the same as that of the Defiance. The Kubanka showed the same effects as the Red Fife, but in a much less degree in regard to the wet and dry gluten. We had two bad conditions in the season of 1915. The plants were kept wet most of the time by a succession of light rains and by heavy dews, and rust developed very badly. Of course the rust would not have developed except for the moisture, but how bad things would have been had the rust not developed we cannot say. Judging, however, from results obtained through our observation of the movement of nitrogen in the plant, the more injurious condition was the rust.

The differences in the composition of the crops of 1913 and 1915 are no greater than the differences in the milling results. The crop of 1913 yielded much more flour and less bran. The Defiance yielded about 72.0 percent flour and 21 to 27 percent

bran in 1913, and from 64.0 to 66.0 per cent of flour and from 34.0 to 36.0 percent bran in 1915. The quality of the flour yielded by the 1913 crop was better than that of the 1915 crop.

COLORADO FLOUR COMPARED WITH OTHER FLOUR

Tests made on our flours in comparison with other flours bought in our market show our local flours to require from 57.06 to 68.0 percent of water to make a good bread-dough, Kansas flours 59. to 63., Minnesota flour 56. The size of the loaf produced compared favorably with the other flours, though it was a little smaller than the best Kansas that we tried. The flavor of the bread made from local flour is good and the color depends upon whether the flour is bleached or not.

To repeat some of the points of most interest.

BETTER COLORADO WHEATS ABOVE AVERAGE

The better wheats grown in Colorado, whether spring or winter, are very good wheats, far above the average in composition.

Some of our wheats grown in seasons producing in general a high quality of grain are poor in quality, due to lack of nitric nitrogen in the soil, which can be avoided. Other years we may have lower quality in our grain due to unfavorable weather and the prevalence of rust. The variety planted may be of much importance in this respect as a long-growing variety susceptible to the attack of this fungus, makes the loss more certain and serious.

BEST QUALITY OF WHEAT CAN BE PRODUCED IN COLORADO

There seems to be no reason why we should not produce more uniform wheat and of the very best quality. The flour made from our best wheats is as good as any flour and will make just as many and as big loaves of good bread as most other flours. The general impression seems to hold among us that wheat is wheat and it is all good so long as the miller buys it. If the flour is not good it is the miller's fault. This is not altogether true; the miller might spoil good wheat by his treatment of it, but when wheat is of poor quality when it goes into his bins he can not make it good. The grower should see to it that he grows good varieties on properly-cared-for land and that his good wheat is not injured by the weather in so far as he can avoid it.

Some of us think that it does not hurt wheat to lie on the ground in sheaf or to be wet in the shock; this is not true.

POOR REPUTATION OF COLORADO WHEAT UNDESERVED

Colorado wheat has among our bakers and people a rather indifferent reputation. This is wrong, for much of our wheat is A1 in every respect. Great improvement could be made by the exercise of a little more intelligent attention to these points: The variety planted, the condition of the land and the care of the crop after harvesting. These points are in the control of the farmer. The miller too, has his share in producing good flour but the Colorado farmer can produce a very good wheat if he has the will to do it.

RECAPITULATION

Some of the most important conclusions are as follows:

The better grades of Colorado wheat rank well with the wheats grown in Kansas and the Northwest.

When Colorado wheat is low in gluten, soft, it is due to its growing in a soil relatively low in available nitrogen—a condition that the farmer can remedy if he will.

A poor quality of grain sometimes results from an attack of rust, but not more frequently than in other states.

The Defiance is very susceptible to this disease and is late in maturing, increasing the chance of an attack. The growing period of the Red Fife is from 8 to 10 days shorter than that of the Defiance, has a stiffer straw and has proven less susceptible.

Flour made from the better grades of Colorado wheat, grown on ground rich in available nitrogen is as good as Minnesota or Kansas flour for bread-making. It produces as many loaves and the quality is as good.

The quality of the wheat varies a good deal with the variety. We find the Defiance the poorest of the varieties used in our experiments.

We have found that the available nitrogen can be greatly increased in our soil by cultivating it fallow the preceding season. This is brought about by the activity of micro-organisms. Early fall plowing is also very helpful.

The available nitrogen necessary to produce hard wheat may be added to the soil by growing alfalfa or clover and turning under the stubble.

The effects of subirrigation on the quality of wheat are small.

Wheat should be well supplied with moisture till in early head, when it should have its last irrigation.

Water applied later than this does but little or no good and may do harm.

If the plants are kept wet by frequent rains and heavy dews the quality of the wheat is lowered.

Rust is the most dangerous enemy of high quality in wheat that we have.

Wheat should not be exposed to the weather after harvesting; the sheaves should not be left lying on the ground till threshed.