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A STUDY OF COLORADO WHEAT

By W. P. HEADDEN

PART III

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A STUDY OF COLORADO WHEAT

By W. P. HEADDEN

PART III

In the preceding portions of this work I have shown that the moisture which we determined at short intervals throughout the two seasons varied but little. These intervals were not all equal, but varied according to the weather or the application of water, irrigation. For the actual variation of this factor reference may be had to Bulletins 208 and 217. The moisture in the soil during the two seasons was not far from 15 percent. The plants did not, at any time, show the need of more water than was at their disposal.

The total nitrogen in the soil is given for a rather large number of samples of the surface soil, for the top four feet, and also for the top eleven feet. The surface portion varies considerably in the amount of total nitrogen present in it. The total nitrogen in 150 samples, taken at the same time and from a space 5 by 30 feet, varied from 0.11016 to 0.14552 percent. We have here a difference of 0.0354 percent of nitrogen. This variation involves an amount of nitrogen many times greater than that which, in the form of sodic nitrate, is necessary to produce most positive effects upon the growth and composition of the plant. The application of nitric nitrogen equivalent to 0.001 percent, or 10 parts per million is, in our case, sufficient to cause the grain to lodge, to change the physical properties of the kernels, also to increase the nitrogen in both the plant and kernel, and to affect the amounts of the various ash constituents appropriated.

THE FIXATION OF NITROGEN IN SOILS USED

In regard to the fixation of nitrogen by this soil, I have so far relied upon laboratory experiments, because the variation in the nitrogen content of field samples on a given date is greater than the amounts involved in the question of fixation itself. In the case just mentioned, we had a difference of 354 parts per million, and this difference was found on contiguous areas of 1 square foot each. The largest actual increase in the total nitrogen observed in this soil to which nothing but boiled distilled water had been added, was 105 parts per million; stated otherwise, samples gathered from the field on different dates cannot be relied on to either prove or disprove the fact of fixation, for if the samples taken for this purpose at different dates had been taken on the same date, they would probably have varied in the same direction to such an extent as to render any conclusions based on them unsatisfactory, if not useless. It is not feasible to increase the number of subsamples sufficiently, in cases where one samples the land every fortnight, to eliminate this uncertainty.

If it be objected that the fixation found in a laboratory experiment lasting from 25 to 30 days is not a safe basis for estimating the extent to which this process may take place in the soil, the answer is evident. The results of the laboratory experiments prove conclusively, especially where the experiment is made with the soil without addition of anything except water enough to produce a favorable degree of moisture, 18 to 20 percent, that the soil is populated by an efficient nitrogen-fixing flora. While a laboratory experiment extending over 25 or 30 days does not prove that the fixation will proceed at the same rate for every other period of 25 or 30 days throughout the year, it does show that fixation is going on and may reach 105 parts per million, or 420 pounds of nitrogen for the surface acre foot, in one or more 30-day periods during the year. If we assume that the fixation is constant at one-half this rate, 50 parts per million, it would account for a large amount of nitrogen, the quivalent of a little more than 7 tons of proteid substance *per annum*.

For the benefit of some reader not accustomed to think in these terms, it may be stated that a fifty-bushel crop of wheat will correspond to about 4,500 pounds of straw. If the wheat weighs 62 pounds per bushel and carries 2.0 per cent nitrogen while the straw carries 0.3 percent nitrogen (this is a higher percentage than we have found in the stems and leaves taken together), the total nitrogen removed by the crop will amount to 74.0 pounds for each acre. If we assume the whole of this nitrogen to have been removed from the surface foot of soil, it is only three-fourths of the maximum fixation and one and one-half times the minimum obtained for a period of 30 days. The laboratory experiments have shown that it is possible for this soil to obtain from the atmosphere as much nitrogen in 45 or 50 days as the assumed crop of 50 bushels per acre would remove. This process tends to keep up the supply of nitrogen, but it is almost certainly not uniform throughout the year. We cannot judge of the amount of fixation by the variation in the amount of nitrogen present, for there is a considerable wastage of nitrogen from our soils. That such wastage takes place is common knowledge, still we may illustrate it by the results of a single irrigation made in 1913 by which we moved about 300 pounds of nitrogen per acre beyond the reach of any ordinary, cultivated plant. This is only one cause of wastage. The writer does not know the results obtained by other observers, but his own results indicate a discrepancy of upwards of 300 pounds per acre for which he can give no satisfactory accounting.

Realizing the weight of the misgivings that may be entertained regarding the applicability of laboratory results to this process of fixation, as it actually takes place in the field, which we have assumed in the preceding paragraphs, we have endeavored to meet them by taking 3,000 pounds of soil from the field, and determining the fixing power of this soil. The details of this experiment do not belong in this place but the general results are apropos to the question just raised.

The experiment was continued for 40 days under field conditions; the only departure from these that could possibly be urged against the experiment was that we endeavored to keep the moisture at uniformly 15.0 percent, it actually varied from this to 18.0 percent.

We found the maximum gain in total nitrogen during the fourth week of the experiment, when the average for the surface foot showed a gain of 45.5 p. p. m.

This period was followed by a rapid increase in the rate of nitrification. We have no check on the loss of nitric-nitrogen by its moving down to the bottom of our container and perhaps into the underlying soil. The important fact in this connection is that at the end of 40 days, this soil, to which nothing except ammonia-free distilled water had been added, showed a fixation of 36.0 p. p. m., calculated on the dry soil.

This experiment was performed under field conditions, not in an incubator nor in a laboratory, but with the soil taken from the wheat field and kept out of doors. It was protected so that animals could not have access to it, and so that no washings from neighboring soil in event of rain, could be carried down on it, and the immediately adjacent soil was wet down constantly to prevent blowing of foreign soil onto it.

We consider this conclusive proof that the laboratory results are applicable, and also that this soil fixes and nitrifies rapidly enough—we had an actual gain of 15.79 p. p. m. of nitric-nitrogen—to justify every claim made in this connection.

While I am persuaded that field samples can not be depended upon in the study of fixation, this is not the case with nitrification, for this nitrogen exists in a definite form which can be determined in its totality at any time with a very high degree of accuracy. That there is difficulty in obtaining representative samples does not need to be stated.

EFFECT OF WHEAT CROP ON FIXATION OF NITROGEN

We have followed the amounts of nitrates present in our soils for two years, and have shown that the amounts of nitrogen present in our soils in this form at different times vary greatly. After a thorough soaking of the land, or if the land is occupied by a good stand of plants, the nitric-nitrogen present is naturally small in quantity, but under other conditions, it is always higher, and often quite high, though we are not now speaking of exceptional cases. On 4 August, 1915, we found, in the top four feet of a fallow plot, 47.4 pounds of nitrogen in the form of nitrates and 7.2 pounds in a like depth of soil planted to wheat. These quantities of nitric-nitrogen are equivalent to 284.4 and 43.2 pounds of sodic nitrate respectively. If this were a single or an exceptional instance, it would show only that this difference might exist in the amounts of nitric-nitrogen present in cropped and fallow land. This, however, is not an exceptional instance, every series of samples taken, 66 in all, shows the same fact. It is not held that the crop has used up this amount of nitrogen, but it is held that the crop either hindered the formation of nitrates or did exhaust them to this extent. The crop certainly did use up nitrates present in the soil, and also possibly hindered the formation of them. If the latter be true it was only a hindrance and not a destruction of the power of the soil to nitrify, for we have shown that the nitrates are rapidly replaced in this soil as soon as the crop is removed. The same plot that on 4 August, 1915, showed the presence of nitric nitrogen, equivalent to 43.2 pounds of sodic nitrate, showed, on 13 December, 1915, taken to the same depth, the equivalent of 232.7 pounds, or five times as much as on 4 August. Nothing had been added to this soil except the wheat stubble which had been disced into the surface soil. Irrigation was not necessary, as enough rain had fallen to keep the soil fairly moist. It is not probable that the wheat stubble disced in modified, in any essential way, the process of nitrification, for the increase of nitrates in the soil began immediately after the removal of the crop and before the stubble was disced in. There is no question about the action of more considerable quantities of decaying organic matter upon the processes of fixation and nitrification but in this case the quantity did not seem to be sufficient to produce observable results, or obscure in any way the process of nitrification, for our samples were not taken close enough together to establish the rate of nitrification from one week to another or to detect variations in this rate.

The quantities of nitrogen thus transformed into nitrates during a single season are more than sufficient to justify their consideration in connection with our problem. We found in the 2nd, 3rd and 4th foot of a sample of this soil taken 29 April, 1913, 23.8, 33.8 and 12.9 parts nitric-nitrogen per million, respectively. These quantities seem high, but we have found in fallow spots in this same land, cultivated to beets, 22, 28, and 35 parts nitric-nitrogen per million in the surface portions of the soil. When one bears in mind that the ratio of available potassium in the land is so high that its specific action on the character of the wheat produced is easily recognized in the plumpness and color of the kernels, and that the supply of available phosphorus is such that the addition of considerable quantities of this element, up to 60 pounds of soluble phosphorus per acre, produces no perceptible effect upon the crop, it will be appreciated, that the formation of quantities of nitrates corresponding to the amounts of nitric-nitrogen given above, or even the less amounts indicated by our general samples, may produce a very pronounced influence upon the character and properties of the wheat produced.

In order to find out what effects we were to expect from the predominance of one or other of the three elements usually considered in this connection, nitrogen, phosphorus and potassium, but particularly of nitrogen, we applied these singly in different quantities, aiming to have a very excessive quantity in at least one case in each series of experiments. To these three elements of plant food we added water, because the supply of this is usually under our control in Colorado and our opportunity for studying its effects is better than that enjoyed by many other experimenters.

APPLICATION OF WATER A PHYSIOLOGICAL PROBLEM

I will digress to state what seems self evident, i.e., that the question of an advantageous or indispensable water supply to the wheat plant, for instance, is rather a physiological than an engineering question, though it is generally considered from the latter standpoint. It is not only a question of how much or little water is actually needed, but also a question of the time and manner of application. To be more specific, I believe that the application of one acre-foot of water at the proper time may produce just as favorable results as the same amount differently distributed in regard to time. Further, 1 foot, or even less, of water, applied at the proper time may produce just as good results as 2 or even 3 feet, provided that the supply at the proper time in the development of the plant be adequate to its needs; after this the water supplied is of little or no benefit, and produces but little or no effect upon the composition of the plant or grain. Two feet of water applied to the soil as irrigating water, even if it be distributed at intervals of a few days, eight to ten days, may do neither the plants nor the grain any harm, and produce no perceptible difference in the composition of either. Whereas, the same amount of water falling in a series of light rains would certainly prove detrimental, perhaps disastrous, even though the last ten, or possibly even fifteen days before harvest were fair and dry. A comparison of the composition of the plant, as indicated by the various forms of nitrogen and the ash constituents given for the crop of 1913, in Bulletin 208, with that for 1915 in Bulletin 217, in which years the plants received essentially the same amounts of water, will show how great a difference the manner of application may make. In 1913, the crop received 12 inches as irrigating water and 6.77 inches rainfall; in 1915, it received 13 inches of rainfall and 6 inches of irrigating water. The plants in 1915 contained less nitrogen and smaller amounts of ash-constituents. The variety of wheat referred to was the same and grown on the same land with the same fertilization. Further, it is a matter of common knowledge that a very light rainfall or heavy fog, just before the ripening period, may cause injury both to the quantity and quality of the crop. If this were not already so well known, we would appeal to our experience in 1914, when a comparatively small amount of rainfall injured our Defiance plots to an extreme extent and all of the plots seriously. In this case rust produced severe injury to the crop, but especially to the Defiance. There were some effects which could not be attributed directly to this parasite, especially in the light of other experiences, but probably should be attributed directly to the wetting of the plants.

EFFECTS OF NITROGEN, PHOSPHORUS AND POTASSIUM

To return to our subject, we found that under our conditions nitrogen produces the most marked effects upon the growth and composition of the plants; that phosphorus and potassium produced less effect than other observers have recorded. For instance, phosphorus did not hasten, nor the nitrate delay, maturation as observed by others. This statement holds irrespective of the amounts applied. It is true that rust interfered two years out of three, particularly in the case of the Defiance.

In the case of the Defiance, all amounts of nitrates applied caused lodging, and that badly. It produced the same tendency in the Red Fife and Kubanka, but these varieties did not suffer much on this account; they did, however, show other effects of the nitrates, such as heavier, darker leaves, slightly taller plants and longer heads, but the average number of kernels to the spikelet was found to be slightly lower. The kernels were smaller, darker in color, flinty, and sometimes shrunken.

Phosphorus, on our plots, produced no perceptible effect upon the growth of the plant, the time of ripening, or the physical properties of the kernels.

The plants on the plots which had received dressings of nitrate and were planted to Red Fife or Kubanka differed so little from the others, that it was only by the darker green color of the plants that one could readily distinguish them. This was not the case with the Defiance, for in these plots the wheat which had been dressed with nitrate went down flat, showing sharply the last drill row to which the nitrate was applied.

Potassium showed at one period a slight hastening in the development of the plant, but this advantage was soon lost and plants grown on the check plots and on those that had received an application of phosphorus, attained the same height and the same perfection of development, so that no difference in the plants grown on these plots could be perceived.

While there were but few, or almost no recognizable differences in the growth and ripening of the plants in comparison with the check plots, there were differences in the physical properties of the kernels. The kernels grown with the application of phosphorus, of potassium, and those on the check plots, were plump and of good size, while those grown with the application of nitrate, were smaller and somewhat shrunken. The chief physical characteristics were shown by the wheats grown with the addition of potassium and these were most pronounced in the Kubanka. These wheats show a difference in their general appearance, in the brightness of the kernel, and especially in the presence of mealy or half-mealy kernels. Yellow-berry was more prevalent than in wheats from the other plots, i.e., than in either those from the check plots or such as had been grown with the application of phosphorus. There are no decided differences between the physical appearances of wheats grown on check plots and those grown with the application of phosphorus. This is not the case with wheat grown with the addition of nitrogen; such wheats are, as has already been stated, small grained or even shrunken, dark colored, and flinty. The starchy or mealy berries are either greatly lessened in number or are absent.

So far, we have stated the physical differences shown by the plants and also the kernels. Bulletin 205 deals with the physical properties of the kernels, while Bulletins 208 and 217 deal with the soil, the chemical composition of the plants, and some other factors. There we find that these fertilizers exert specific influences which are not apparent in the physical appearance of the plants. The greatest correspondence between the physical appearance and chemical effects is found in the case of nitrogen, which produces in the plant an appearance of luxuriance. We find that it increases the nitrogen content of the plant, and modifies the amount and percentage composition of the ash. Further, these elements, nitrogen, phosphorus, and potassium, mutually influence the intake of one another; for instance, nitrogen, applied in liberal quantities, increases the amount of potassium appropriated by the plant. As I have applied only sodic nitrate as a source of nitrogen, it is possible that this effect may be attributed to the action of the sodium upon the soil. Be this as it may, the amount of potassium appropriated was increased, also the amounts of lime and magnesium, while the amount of phosphorus appropriated by the plant or found in its ash was not influenced. The succulency of the plant was increased, or, put the other way, the amount of dry matter in the plant was decreased. Phosphorus did not appear to exercise any marked influence upon the nitrogen content of the plant; potassium lowered it. Bulletins 208 and 217 treat of these features more fully.

PURPOSE OF THIS PART OF OUR STUDY

In this part of our study we propose to present the composition of Colorado wheats in general, in so far as it seems to have any purpose, and then to present the results of our study of the effects of these fertilizers, of water, and in some measure, of the weather, upon the composition of wheat. We will leave the question of the milling and baking qualities for future consideration.

The only person, who, to my knowledge, has treated in any way of the composition of Colorado wheats, is Mr. Clifford Richardson, who apparently analyzed samples of wheat grown at this station by Prof. Blount. Mr. Richardson's conclusions are favorable to Colorado as a producer of wheat of high quality. A few quotations from his report are interesting, even if subsequent developments make us wish that the properties of our wheats might measure up more fully to his estimates of them. He says: "Among the individual states, Colorado sustains the reputation gained in last year's report of producing the finest wheat. . . . . . Minnesota, all things considered, probably ranks next to Colorado."* "As has been seen, the Colorado wheats are certainly the best which have been produced in this country. For two years they have sustained a high average composition and a large weight per 100 grains. Why do they excel in this manner? It is due somewhat to careful cultivation and selection of seed, but more largely to soil and climate as is proved by the experiments of last year."

Of thirteen varieties grown by the department and at the Colorado Experiment Station from the same lots of seed Mr. Richardson says: "In every case the size and general appearance was much improved and, as a consequence, the weight of 100 grains of the crop was much heavier than the seed; in fact, averaged over 26 percent heavier."

"Of 44 wheats from Colorado, grown during two years, only one fell below 11.5 percent of alubumin and only six below 12 percent."

"Too much confidence, it is seen, cannot be placed on the size and appearance of a wheat or conversely on the chemical analysis alone. When both these elements in its constitution are favorable, then alone can it be pronounced a good wheat."

"The effects upon the composition of grain which we have studied seems to be largely dependent upon the soil, seed and cultivation being the same."†

Dr. H. W. Wiley, in discussing Mr. Richardson's conclusion, says: "Mr. Richardson was of the opinion, as a result of these studies, that the soil was the most important factor in producing these varieties. A subsequent study of the department, which will be referred to later on

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* Report U. S. Dept. of Agri., 1883, p. 210.

† Report of U. S. Department of Agri., 1883, p. 211

seems to show that, in this respect, he was mistaken, and that the soil, as a rule, has the least effect of all the important factors of environment upon chemical composition, provided, of course, that it contains the essential elements of plant food necessary to produce an average crop. The soil, it is true, is one of the most potent factors in determining the size of the crop and the amount of material which is harvested, but it does not have a very marked influence on the chemical composition of the crop produced."*

Dr. Wiley does not call Mr. Richardson's facts into question, only his explanation of them. Mr. Richardson attributes the characters of the wheat to the properties of the soil. Dr. Wiley says that the soil has the least effect of all the important factors of environment upon chemical composition, provided it contains the essential elements of plant food, necessary to produce an average crop.

I know nothing about the views that Mr. Richardson may have adopted subsequently, but these quotations present the question in regard to the part played by the soil and the other environmental conditions as succinctly as any others that I might quote. I think that the greater number of writers on this subject agree in their general attitude with the position indicated by the quotation from Dr. Wiley, which, perhaps, is not so decided as the statements of some others. Dr. J. A. Le Clerc says: "The results so far obtained would seem to indicate that the soil and seed play a relatively small part in influencing the composition of crops."† This is one of the conclusions from their tri-local experiments with wheats.

Schindler, in discussing a wheat climate, says: "We shall have to remind the reader that the climate of the Colorado section is characterized by an extraordinary dryness of the atmosphere and great daily variations of temperature. The relative humidity falls as low as 10 per cent." Then he quotes Hann, Climatology, p. 662: "The advantages of the Colorado climate consist in the clearness of the sky, intense sunshine, and a light atmosphere favorable to evaporation."§

Dr. Le Clerc says, in writing of irrigation: "Where irrigation is practiced, in Colorado for example, 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."‡

No author, whose writings I have read, is more insistent upon the very great influence of "climatic conditions" than Schindler, who sets forth strong reasons for his views. Still he acknowledges that soil conditions may produce similar effects. In discussing correlative

* Year Book of the Dept. of Agri., 1901, p. 303.
† Bureau of Chemistry, U. S. Dept. of Agri., Bul. 128, p. 18.
§ Translations by the author.
‡ Year Book U. S. Department of Agriculture, 1906, p. 204.

variability he says: "The study of the wheat plant in regard to its correlative variability has lead to the conclusion that this can be called into activity, not only by transference to another climate, but also by other extraneous conditions, though climate exercises the greatest influence upon its persistency (Dauer). A change in the character of the soil, be it by change of locality, by manuring, or by cultivation, has a similar action in that the conditions of nutrition are changed and with these the organic efficiency" (of the plant) . . . . . "*

Though Schindler in this way recognized the influence of the soil, still, he scarcely mentions it in the first half of his work, but attributes the greatest influence in determining the character of wheat to the climate. This is, in fact, his thesis.

A paragraph of his relative to Colorado is of sufficient interest to justify its reproduction. After quoting some analyses of Colorado wheats he continues: "I have referred previously to the fact that the cultivation of wheat in this zone (the western plateau and mountain region of the United States) 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. The relatively high protein content is noteworthy, and is probably dependent upon the characteristics of the soil, which is reputed to be very fertile. The Blount samples excel in this point and suggest that their richness in protein has been forced up by a corresponding application of manure, which is, as is known, easily done. Blount rightly praises the action of sheep manure upon his crops. This was, without doubt, the lever to which he owed his striking results and not his crosses whose influences are difficult to control."†

If the soil has so little to do with the composition and quality of the crops, our wheat ought to be both uniform and good, for our climate is favorable and we have the water supply largely in our control. I think that this statement is true, though the State is large, varies in altitude from 3,000 to 7,500 or even 7,700 feet in the districts where wheat is successfully cultivated, and also in climate. I know of no section, however, of high rainfall. The average annual rainfall at Fort Collins is 14.0 inches and at Grand Junction it is about one-half as much.

I have already stated in Part I of this study that, according to the best information that I can obtain, flour made from Colorado wheat

* Schindler, Der Weizen in seiner Beziehung zum Klima und das Gesetr der Correlation, 1883, p. 138. Translation by the author.

† Schindler, Der Weizen, p. 72. Translation by the author.

falls from 30 to 40 loaves per barrel behind Kansas and the best Minnesota flours.

This seems to be contradictory to what we should expect, as our summers are usually dry and the days hot. Our spring wheat matures in from 100 to 128 days from planting.

We shall present in the following pages the analytical results obtained in the study of the wheats grown in the seasons of 1913, 1914, and 1915.

The varieties grown were Defiance—a wheat originated at this station by the late Prof. A. E. Blount—Red Fife, and Kubanka. The seed of the last two varieties was obtained from the South Dakota Experiment Station.

The three seasons were very different, and the data pertaining to temperature and rainfall do not convey a very definite idea of the weather conditions that prevailed; nevertheless, I shall give them as furnished to me by Mr. R. E. Trimble, who is in charge of such observations

1913	April	May	June	July	August
Mean Air Temperature	46.1	54.8	63.2	66.8	69.8
Mean Soil Tem. 3″	46.2	58.7	67.9	71.7	74.4
Mean Soil Tem. 6″	46.3	58.8	67.9	72.6	75.2
Rainfall (inches)	1.49	2.09	0.15	2.63	0.41
Cloudy or partly cloudy days	17	21	19	18	11
1914	**April**	**May**	**June**	**July**	**August**
Mean Temperature of Air	44.75	54.56	63.58	68.30	66.95
Rainfall inches	3.23	2.73	2.01	1.68	1.28
1915	**April**	**May**	**June**	**July**	**August**
Mean Temperature of Air	50.04	50.35	59.62	64.74	62.77
Temperature of soil 3 inches A. M.	45.25	48.96	58.03	63.30	61.00
P. M.	54.62	59.66	69.58	75.10	72.00
Rainfall (inches)	4.01	3.78	1.90	2.12	1.56
Cloudy or partly cloudy days	19	21	15	19	21

This tabulation gives a record of the rainfall, for instance, as accurately as we can read the pluviometers, or the temperature, as accurately as we can read the thermometers, but it does not give us the deciding factors in the development of the wheat. The rainfall up to 12 June in any of the three years was probably without influence upon our crop, as there was at no time a lack of moisture up to this date. On 12 and 13 June, we applied 1 acre-foot of water. This much was necessary, especially in 1913, for with less water we could not get over the ground. A few spots which were not covered, owing to the imperfect leveling, produced only a very light crop of grain. The rainfall in July, 1914, was only 1.68 inches, but 1.45 inches of it fell during a very few days late in the month and a very good portion of this came in one violent shower, about fourteen days before harvest. This rain did apparently but little injury to two of the varieties, but injured the third, especially those plots which had been treated with sodic nitrate, very badly. This rainy period was, of course, accompanied by more or less cloudiness and dewy nights. I have given the number of cloudy days for the months concerned in 1913 and 1915. This simply gives a general and very indefinite measure of the sunshine. These tables, however, give the best meteorolgical data that I have.

The crops for the three seasons are given in the following tabular statement. The bushels are thresher weights; the weight per bushel is for cleaned wheat; and the ratio of straw to wheat is based upon the weights of straw and grain as threshed.

CROP OF 1913

Section	Variety	Fertilizer Pounds per Acre	Bushels per Acre	Weight per Bushel	Ratio of Straw to Wheat
1700	Defiance	Nitrogen 120	34.83	61.00	1.34
1800	Defiance	Nitrogen 80	38.83	60.00	1.17
1900	Defiance	Nitrogen 40	29.00	61.50	1.33
1700	Defiance	Phosphorus 60	28.30	62.00	1.14
1800	Defiance	Phosphorus 40	39.50	62.00	1.29
1900	Defiance	Phosphorus 20	33.83	62.50	1.41
1700	Defiance	Potassium 200	38.50	62.00	1.16
1800	Defiance	Potassium 150	41.66	62.00	1.32
1900	Defiance	Potassium 100	33.00	63.00	1.29
1700	Defiance	Check	41.41	62.00	1.45
1800	Defiance	Check	40.58	62.50	1.57
1900	Defiance	Check	41.33	62.50	1.54
1700	Red Fife	Nitrogen 120	37.08	62.75	1.62
1800	Red Fife	Nitrogen 80	39.91	63.00	1.75
1900	Red Fife	Nitrogen 40	33.81	64.00	1.90
1700	Red Fife	Phosphorus 60	27.83	63.25	1.32
1800	Red Fife	Phosphorus 40	34.00	63.50	1.62
1900	Red Fife	Phosphorus 20	31.29	64.25	1.34
1700	Red Fife	Potassium 200	31.27	63.50	1.35
1800	Red Fife	Potassium 150	33.91	63.50	1.53
1900	Red Fife	Potassium 100	32.83	64.25	1.64
1700	Red Fife	Check	33.16		1.79
1800	Red Fife	Check	32.75	63.50	1.55
1900	Red Fife	Check	33.91	64.50	1.54
1700	Kubanka	Nitrogen 120	41.41	62.75	1.49
1800	Kubanka	Nitrogen 80	39.82	63.00	1.68
1900	Kubanka	Nitrogen 40	39.00	64.00	1.57
1700	Kubanka	Phosphorus 60	32.80	64.50	1.28
1800	Kubanka	Phosphorus 42	39.60	64.50	1.40
1900	Kubanka	Phosphorus 20	32.40	64.25	1.57
1700	Kubanka	Potassium 200	33.80	64.25	1.31
1800	Kubanka	Potassium 150	36.08	64.75	1.51
1900	Kubanka	Potassium 100	30.50	64.50	1.35
1700	Kubanka	Check	34.00	62.50	1.35
1800	Kubanka	Check	34.16	63.50	1.39
1900	Kubanka	Check	34.33	63.50	1.67

CROP OF 1914

Section	Variety	Fertilizer Pounds per Acre	Bushels per Acre	Weight per Bushel	Ratio of Straw to Wheat
1700	Defiance	Nitrogen 120	25.70	52.00	2.73
1800	Defiance	Nitrogen 80	26.70	56.00	2.53
1900	Defiance	Nitrogen 40	28.50	54.25	2.48
1700	Defiance	Phosphorus 60	33.33	58.00	1.55
1800	Defiance	Phosphorus 40	34.50	58.50	1.64
1900	Defiance	Phosphorus 20	34.00	56.50	1.62
1700	Defiance	Potassium 200	39.16	60.00	1.48
1800	Defiance	Potassium 150	34.33	59.50	1.52
1900	Defiance	Potassium 100	33.33	59.50	1.77
1700	Defiance	Check	32.83	58.25	1.97
1800	Defiance	Check	30.60	56.00	1.99
1900	Defiance	Check	30.00	56.00	1.92
1700	Red Fife	Nitrogen 120	55.50	64.50	1.48
1800	Red Fife	Nitrogen 80	53.00	64.25	1.64
1900	Red Fife	Nitrogen 40	52.33	64.00	1.66
1700	Red Fife	Phosphorus 60	49.33	63.50	1.33
1800	Red Fife	Phosphorus 40	47.66	63.50	1.78
1900	Red Fife	Phosphorus 20	49.33	64.00	1.54
1700	Red Fife	Potassium 200	44.83	63.00	1.54
1800	Red Fife	Potassium 150	45.33	64.25	1.54
1900	Red Fife	Potassium 100	50.33	63.75	1.60
1700	Red Fife	Check	48.60	63.50	1.64
1800	Red Fife	Check	45.70	63.75	1.54
1900	Red Fife	Check	47.33	63.50	1.57
1700	Kubanka	Nitrogen 120	51.66	65.00	....
1800	Kubanka	Nitrogen 80	52.66	64.50	1.53
1900	Kubanka	Nitrogen 40	51.16	64.50	1.53
1700	Kubanka	Phosphorus 60	54.50	64.50	1.37
1800	Kubanka	Phosphorus 40	51.00	65.00	1.44
1900	Kubanka	Phosphorus 20	48.33	65.50	....
1700	Kubanka	Potassium 200	51.16	65.00	1.33
1800	Kubanka	Potassium 150	49.16	65.00	1.49
1900	Kubanka	Potassium 100	43.00	64.50	1.60
1700	Kubanka	Check	52.83	64.75	1.21
1800	Kubanka	Check	46.66	65.00	1.33
1900	Kubanka	Check	44.00	65.00	1.90

THE
STATE TEACHERS
COLLEGE OF COLORADO
Greeley, Colo.
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CROP OF 1915

Section	Variety	Fertilizer Pounds per Acre	Bushels per Acre	Weight per Bushel	Ratio of Straw to Wheat
1700	Defiance	Nitrogen 120	8.33	47.00	13.40
1800	Defiance	Nitrogen 80	10.83	47.00	7.00
1900	Defiance	Nitrogen 40	13.70	51.00	4.50
1700	Defiance	Phosphorus 60	21.16	51.00	3.19
1800	Defiance	Phosphorus 40	22.50	50.00	3.96
1900	Defiance	Phosphorus 20	30.40	52.75	2.54
1700	Defiance	Potassium 60	26.83	53.00	3.16
1800	Defiance	Potassium 40	25.33	52.50	2.13
1900	Defiance	Potassium 20	23.50	55.25	3.33
1700	Defiance	Check	20.58	49.75	3.05
1800	Defiance	Check	19.50	49.00	4.43
1900	Defiance	Check	18.50	50.00	2.84
1700	Red Fife	Nitrogen 120	23.33	53.50	3.79
1800	Red Fife	Nitrogen 80	23.66	56.50	4.69
1900	Red Fife	Nitrogen 40	24.50	56.25	3.12
1700	Red Fife	Phosphorus 60	31.33	60.00	3.17
1800	Red Fife	Phosphorus 40	33.00	60.00	2.43
1900	Red Fife	Phosphorus 20	29.50	61.00	3.28
1700	Red Fife	Potassium 200	32.50	61.50	2.28
1800	Red Fife	Potassium 150	33.16	60.25	2.84
1900	Red Fife	Potassium 100	30.83	60.00	2.22
1700	Red Fife	Check	32.33	60.75	3.12
1800	Red Fife	Check	33.61	60.50	2.36
1900	Red Fife	Check	31.00	61.00	3.15
1700	Kubanka	Nitrogen 120	35.50	59.00	2.90
1800	Kubanka	Nitrogen 80	40.83	60.00	2.09
1900	Kubanka	Nitrogen 40	21.91	61.00	2.09
1700	Kubanka	Phosphorus 60	36.50	62.50	2.06
1800	Kubanka	Phosphorus 40	39.75	62.25	2.36
1900	Kubanka	Phosphorus 20	23.75	62.00	2.44
1700	Kubanka	Potassium 200	36.16	62.75	2.55
1800	Kubanka	Potassium 150	34.91	63.00	2.70
1900	Kubanka	Potassium 100	25.01	62.50	3.64
1700	Kubanka	Check	36.25	62.00	2.68
1800	Kubanka	Check	35.16	63.00	3.10
1900	Kubanka	Check	27.00	63.00	2.55

It is scarcely proper to give the ratio of straw to wheat for 1915, for the reason that a very liberal seeding of wild oats was applied with the irrigating water in September, 1914, preparatory to cultivation. There was enough of the wild oats to affect the ratio so seriously as to make it of but little value, still it does not lead us astray in concluding that the ratio in 1915 was not far from twice as high as in the preceding years. The promise for a very large yield was good up to the last week in July, except on the nitrated plots, some of which were badly lodged. About the end of July, due to light rains and cloudy weather, rust attacked all of the plants badly, but injured the Defiance worse than the other varieties. It is my judgment that the effects of this parasite, which were marked, upon the composition of the plant, as is shown in Bulletin 217, were greater than those of the weather.

An inspection of these data shows some interesting things, especially when taken in connection with the weather conditions. Our table on a previous page shows that we had a rainfall of 2.63 inches during July of 1913, 0.8 of an inch fell on the 18th, and 1.19 inches on the 23rd, which was cloudy all day, otherwise the sky was practically clear during the month and also during August. The yield of the Defiance was a trifle better than that of the other varieties. Its weight per bushel being between 60 and 63 pounds, and the maximum ratio of straw to grain was 1.57. It was surpassed in weight per bushel, but in no other respect by the other varieties. In 1914 we had an excellent season, with only 1.68 inches of rainfall in July. We had a shower on 30 July, during which, 0.87 of an inch of rain fell. This shower was violent and beat down the grain somewhat, especially the Defiance, which was luxuriant and growing rapidly. Rust developed and the grain ripened prematurely. The minimum yield of Defiance fell almost 30 bushels per acre below the maximum for the Fife. Only one plot in the twelve yielded grain weighing 60 pounds per bushel and one plot yielded grain weighing only 52 pounds, while the minimum for the other two varieties was 63 and the maximum 65.5 pounds per bushel. The maximum yield of Defiance was 39.16 and the minimum 25.70 bushels. The maximum yield of the other two varieties was 55.5 and the minimum 43.00 bushels per acre.

The Red Fife and the Kubanka are a little earlier and, perhaps, a little more resistant to rust than the Defiance. These seem to have been the determining factors in this year's crops. In 1915 we did not have so much rain in July as in 1913 but the two seasons were quite different; 1915 was much more cloudy; we had a succession of light rains and the dews were heavy. Rust was bad on all varieties and the Defiance was practically a failure. The biggest yield was 26.8 bushels, weight 53 pounds, the minimum 8.33 bushels, weight 47 pounds. The Red Fife grown with the application of sodic nitrate rusted very badly and yielded only about 24 bushels, weighing 56 pounds to the bushel. Most of the other plots yielded from 30 to 40 bushels, weighing from 60 to 63 pounds per bushel.

THE FACTORS WHICH DETERMINED OUR CROPS

The factors which determined our crops were evidently not the quantity of rainfall but its distribution, the degree of cloudiness, the resistance of the plant to rust, its stage of development when this attack came, the temperature, and the fertility of the soil. The plants grown with the application of nitrates were attacked more severely by rust than the others. Whether this was due to the stage of development or to the characters of the tissues may be a question. We have not been able to detect any difference in the date of the ripening of the grain due to the nitrate on the one hand or the phosphate on the other, so the question of development does not press itslf very strongly as accounting for the greater degree in which the nitrate plants were infested. There is an abnormal ripening in the case of plants grown with the application of nitrates, in that the leaves and middle parts of the plants ripen more slowly than the top and bottom, but we have found no difference in the ripening of the grain.

While these cultural results are of great importance in determining the character of the material with which we have to deal, and, unfortunately, complicate our question, they are, after all, incidental, even though their consideration cannot wholly be set aside.

THE CHARACTERISTICS OF COLORADO WHEAT

The first subject that we shall try to consider in regard to Colorado wheat is, whether the composition of the wheat shows anything characteristic.

The wheat grown in the State, even at the present time, is largely spring-wheat, though winter-wheat is being grown in larger quantity than formerly. For this reason I shall present analyses of both spring and winter-wheats. In regard to the samples sent to me from different localities, I can give no details, other than the names and localities furnished me. This pertains only to some of the general samples. These analyses appear on the pages immediately following.

GENERAL SAMPLES OF SPRING WHEATS—CROPS 1912 AND 1913

	Moisture Percent	Ash Percent	Fat Percent	Fibre Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent
Defiance, Ft. Collins, Seed used...........	9.920	1.793	1.818	2.710	2.361	13.458	61.468	1.375	30.66	11.74	8.504	.....	.....
Defiance, La Jara, Yellow-berry, 1912 very bad	10.615	1.686	1.863	2.725	1.454	8.288	64.134	1.409	14.03	6.10	4.221	0.394	0.423
Defiance, Del Norte, Yellow-berry..........	10.655	1.915	1.835	2.423	1.413	8.054	64.890	1.386	13.73	5.44	4.001	0.434	0.526
Defiance, Ft. Collins, not irr. 1913...........	11.683	1.680	1.698	2.600	2.444	13.932	62.118	1.046	35.33	13.41	9.707	0.336	0.343
Defiance, Grand Junction, 1912.............	9.063	1.500	1.670	2.492	2.442	13.917	62.964	0.924	29.73	10.90	8.430	0.271	0.431
Defiance, Clifton, 1912	9.338	1.782	1.855	2.312	2.533	14.440	62.520	1.415	28.47	11.68	8.225	0.329	0.400
Defiance, Ft. Collins, 1911..................	9.355	1.774	1.588	2.425	2.618	14.923	60.264	1.096	23.30	12.89	9.723	0.376	0.414
Sonora, Del Norte, 1912.....................	10.533	1.731	1.850	2.515	1.974	11.251	63.666	1.561	21.47	8.71	6.082	0.399	0.403
Kubanka, Limon, dry land, 1912 (starchy)....	10.235	2.094	1.893	2.455	2.278	12.985	59.490	1.513	30.00	12.49	9.120	0.363	0.440
Kubanka, Ft. Collins, 1912 (starchy).........	......	.....	.....	.....	1.847	10.527	......	.....	.....	.....	.....	.....	.....
Kubanka, Ft. Collins, 1912 (flinty)..........	11.200	1.947	1.835	2.525	2.240	12.768	62.046	1.467	25.40	10.79	7.661	.....	.....
Red Fife, Ft. Collins, not irr., 1913...........	10.495	1.507	1.933	2.525	2.667	15.204	61.686	1.006	38.00	14.83	10.900	0.293	0.357
Red Fife, Ft. Collins, fallowed, 1913..........	9.138	1.929	1.770	2.620	3.008	17.143	59.076	1.153	40.67	15.58	11.594	0.414	0.380
Marquis, Ft. Collins, fallowed, 1913..........	9.108	1.861	1.988	2.525	2.807	15.998	59.886	1.266	38.63	15.06	11.042	0.402	0.409
Minn. Spring No. 1, Minneapolis, 1912........	8.395	1.923	2.113	2.820	2.248	12.811	63.288	1.215	24.67	9.88	7.524	0.418	0.459
Minn. Spring No. 2, Minneapolis, 1912........	8.378	1.819	2.033	2.835	2.212	12.610	62.066	1.175	26.27	10.29	7.843	0.381	0.458
Minn. Spring No. 3, Minneapolis, 1912........	8.235	1.823	1.963	2.750	2.139	12.193	63.648	1.278	24.73	9.62	7.182	0.398	0.452
Red Fife, So. Dak. Expt. Sta. Seed used, 1912.	10.606	1.749	1.830	2.400	2.249	12.821	59.814	1.215	29.33	11.32	8.225	0.279	0.490
Red Fife, So. Dak. Expt. Sta. Crop, 1913.....	8.908	1.879	1.860	2.675	2.327	13.265	62.280	1.289	28.43	11.41	8.550	0.321	0.420
Kubanka, So. Dak. Expt. Sta. seed used, 1913	11.033	1.751	1.830	2.265	2.288	13.044	61.182	1.461	30.93	12.91	9.462	0.326	0.468
Kubanka, So. Dak. Expt. Sta. Crop, 1913......	8.740	1.857	1.905	2.737	2.336	13.318	60.012	1.478	29.33	12.37	9.223	0.351	0.472
Egyptian, Del Norte........................	11.199	2.250	1.810	2.462	1.323	7.538	65.610	1.404	*	*	*	0.383	0.666
Durum X Egyptian, Del Norte...............	10.843	2.032	1.715	2.900	1.575	8.976	63.972	1.198	*	*	*	0.408	0.568

*We could not determine the gluten in Egyptian wheat.

GENERAL SAMPLES SPRING-WHEATS—CROPS 1912 AND 1913

	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Ratio Gliadin to Glutenin Nitrogen	Total Nitrogen
Defiance, Ft. Collins, seed used	0.0314	0.1678	1.0031	1.0875	1:1.08	2.2898
Defiance, La Jara, 1912	0.0593	0.1328	0.5698	0.6922	1:1.21	1.4541
Defiance, Del Norte, 1912	0.0558	0.1238	0.7084	0.5548	1:0.78	1.4428
Defiance, Ft. Collins, not irrigated, 1913	0.0593	0.2377	0.7049	1.4423	1:2.04	2.4442
Defiance, Grand Junction, 1912	0.0483	0.2028	0.9955	1.1950	1:1.20	2.4416
Defiance, Clifton, 1912	0.0804	0.1958	1.0007	1.2565	1:1.26	2.5334
Defiance, Ft. Collins, 1912	0.0628	0.2377	1.1674	1.1503	1:0.99	2.6183
Sonora, Del Norte, 1912	0.1014	0.1678	0.7327	0.9718	1:1.32	1.9737
Kubanka, Limon, dry land, 1912	0.0699	0.1958	0.9879	1.0244	1:1.04	2.2780
Red Fife, Ft. Collins, not irrigated, 1913	0.0804	0.2587	1.0240	1.6444	1:1.60	3.0075
Red Fife, Ft. Collins, fallowed land, 1913	0.0804	0.2237	1.0659	1.2973	1:1.21	2.6673
Marquis, Ft. Collins, fallowed land, 1913	0.0839	0.2307	1.1417	1.3503	1:1.90	2.8067
Minn. Spring No. 1, Minneapolis, 1912	0.0558	0.2168	0.8203	1.1547	1:1.40	2.2476
Minn. Spring No. 2, Minneapolis, 1912	0.0663	0.2307	0.8564	1.0588	1:1.24	2.2122
Minn. Spring No. 3, Minneapolis, 1912	0.0558	0.1888	0.8063	1.0882	1:1.35	2.1391
Red Fife, So. Dak. Expt. Sta., Seed used	0.0663	0.1958	0.9402	1.0470	1:1.11	2.2493
Red Fife, So. Dak. Exp. Sta. Crop of 1913	0.0314	0.1608	0.8494	1.2855	1:1.51	2.3271
Kubanka, So. Dak. Exp. Sta. Seed used, 1912	0.0628	0.1818	0.9757	1.0581	1:1.08	2.2884
Kubanka, So. Dak. Exp. Sta. Crop of 1913	0.0488	0.1678	0.8040	1.3158	1:1.63	2.3364
Egyptian, Del Norte, 1912	0.1118	0.1238	0.3029	0.7840	......	1.3225
Durum (Kubanka?)X Egpt. Del Norte, 1912	0.1118	0.1538	0.3751	0.9271	......	1.5748

ANALYSES OF GENERAL SAMPLES WINTER-WHEAT—CROPS 1912 AND 1913

	Moisture Percent	Ash Percent	Fat Percent	Fibre Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent
Turkey Red, Wellington, dry land	10.545	1.988	1.900	2.725	1.929	10.996	62.17	1.355	28.50	10.34	8.020	0.470	0.457
Turkey Red, Wray, dry land	10.155	1.888	1.723	2.487	1.779	10.138	66.04	1.455	20.53	7.87	6.196	0.427	0.456
Turkey Red, La Jara, yellow-berry	10.118	1.867	1.625	2.670	1.446	8.224	66.13	1.341	16.07	6.42	4.603	0.394	0.514
Turkey Red, Las Animas	11.468	1.844	1.540	2.440	2.007	11.441	63.07	1.283	24.63	9.85	7.132	0.471	0.470
Turkey Red, Weckel	9.425	1.493	1.465	2.708	2.335	13.311	64.37	1.272	28.00	10.98	8.453	0.294	0.350
Turkey Red, Clifton	9.708	.....	1.485	2.625	2.286	13.029	61.22	1.427	32.67	12.52	9.405	.....	.....
Kharkov, Ft. Collins	10.423	1.844	1.518	2.700	2.091	11.980	64.15	1.289	25.40	9.72	7.404	0.434	0.460
Kharkov, Ft. Collins	8.848	1.654	1.348	2.337	2.685	15.302	60.95	1.113	38.67	14.00	11.035	0.351	0.385
Jaroslov, Ft. Collins	8.639	1.665	1.360	2.582	2.802	15.970	59.11	1.187	40.73	15.04	11.344	0.362	0.389
Harvest King, Grand Junction, 1912	9.575	1.484	1.778	2.738	2.545	14.508	62.23	1.204	32.17	12.06	8.738	0.327	0.375
Harvest King, Ft. Collins	8.918	1.724	1.740	2.460	2.809	16.012	59.54	1.364	39.80	14.65	11.102	0.398	0.359
Red Cross, Fruita, 1912	9.485	1.481	1.775	2.337	2.483	14.150	63.07	1.404	28.30	11.13	8.271	0.261	0.364
Red Chaff, Eckert	10.743	1.681	1.763	2.677	1.764	10.052	65.54	1.461	21.53	8.57	6.265	0.388	0.416
Fultz, Ft. Collins	9.560	1.641	1.508	2.595	2.866	16.338	59.51	0.957	42.23	14.96	11.666	.....	.....
Big Frame, Ft. Collins	8.755	1.693	1.385	2.735	2.850	16.246	59.69	0.968	42.50	14.63	11.440	0.384	0.366
Prize Taker, Ft. Collins	8.690	1.528	1.878	2.400	2.492	14.206	62.30	1.068	34.50	12.98	9.639	0.306	0.324
Advance, Ft. Collins	8.718	1.672	1.623	2.830	2.674	15.244	60.66	0.870	37.30	14.16	10.694	0.366	0.371
Canadian Hybrid, Ft. Collins	8.630	1.502	1.605	2.475	2.773	16.806	61.63	1.115	38.57	14.35	11.066	0.328	0.369
Minnesota h. w. No. 2, Minneapolis	8.438	1.762	1.795	2.587	1.987	11.324	64.44	1.029	21.73	8.64	6.392	0.379	0.449
Minnesota h. w. No. 3, Minneapolis	8.375	2.092	1.685	2.725	1.887	10.755	64.01	0.924	21.87	8.99	6.686	0.477	0.437

ANALYSES OF GENERAL SAMPLES WINTER-WHEAT—CROPS 1912 AND 1913

	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Ratio Gliadin to Glutenin Nitrogen	Total Nitrogen Percent
Turkey Red, Wellington, dry land	0.0418	0.1818	0.8390	0.8666	1:1.03	1.9292
Turkey Red, Wray, dry land	0.0418	0.1468	0.4941	1.0958	1:2.22	1.7785
Turkey Red, La Jara	0.0453	0.1398	0.4719	0.7891	1:1.33	1.4461
Turkey Red, Las Animas	0.0628	0.1538	0.7434	1.0472	1:1.41	2.0072
Turkey Red, Weckel	0.0488	0.1748	0.9391	1.1726	1:1.25	2.3353
Turkey Red, Clifton	0.0593	0.1818	0.9192	1.1255	1:1.22	2.2858
Kharkov, Ft. Collins	0.0558	0.1468	0.8250	1.0636	1:1.17	2.0912
Kharkov, Ft. Collins	0.1468	0.1468	0.9529	1.4381	1:1.51	2.6846
Jaraslov, Ft. Collins	0.0593	0.2098	1.1663	1.3664	1:1.18	2.8018
Harvest King, Grand Junction	0.0558	0.2168	0.9880	1.2847	1:1.30	2.5453
Harvest King, Ft. Collins	0.0418	0.1818	1.2163	1.3693	1:1.14	2.8092
Red Cross, Fruita	0.0593	0.2237	1.0311	1.1684	1:1.13	2.4825
Red Chaff, Eckert	0.0628	0.1588	0.6642	0.8827	1:1.33	1.7635
Fultz, Ft. Collins	0.0663	0.2168	1.2105	1.3727	1:1.13	2.8663
Big Frame, Ft. Collins	0.0558	0.2168	1.2862	1.2915	1:1.00	2.8503
Prize Taker, Ft. Collins	0.0418	0.1748	0.9554	1.3202	1:1.38	2.4922
Advance, Ft. Collins	0.0349	0.1818	1.0068	1.3508	1:1.34	2.6743
Canadian Hybrid, Ft. Collins	0.0558	0.1888	1.0952	1.4332	1:1.31	2.7730
Minn. h.w. No. 2, Minneapolis	0.0314	0.1748	0.7003	1.0802	1:1.54	1.9867
Minn. h.w. No. 3, Minneapolis	0.0384	0.1888	0.7592	0.9005	1:1.18	1.8869

GENERAL SAMPLES FOR 1914

	Moisture Percent	Ash Percent	Fat Percent	Fibre Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent
Spring Wheats													
Defiance, Eckert, yellow-berry very bad.....	9.313	1.892	1.858	3.095	1.974	11.252	64.638	1.452	28.37	12.49	8.093	0.433	0.597
Defiance, Ft. Collins, fallow, wet in shock....	8.428	1.708	1.933	3.555	2.075	11.825	60.822	1.063	31.33	13.30	9.293	0.322	0.393
Defiance, Ft. Collins, fallow, not wet.........	8.465	1.643	2.018	3.512	2.113	12.044	62.064	1.068	32.00	12.99	9.076	0.326	0.430
Marquis, Ft. Collins, fallow, wet in shock....	8.965	1.508	2.140	3.257	2.419	13.788	59.148	1.065	40.83	16.44	11.393	0.333	0.340
Marquis, Ft. Collins, fallow, not wet.........	8.460	1.448	2.165	3.320	2.468	14.065	60.210	1.157	40.40	16.40	11.589	0.338	0.364
Red Fife, Ft. Collins, fallow, wet in shock....	8.985	1.813	2.015	3.292	2.492	13.477	58.728	1.099	42.17	16.24	11.398	0.332	0.377
Red Fife, Ft. Collins, fallow, not wet........	8.184	1.588	2.015	3.447	2.596	14.794	60.486	1.241	43.20	16.90	11.781	0.350	0.502
Winter Wheats													
Red Chaff, Eckert, yellow-berry very bad....	9.855	1.587	2.145	3.062	1.411	8.043	64.458	1.352	17.63	7.20	4.935	0.367	0.535
Turkey Red, Fruita, yellow-berry in all......	10.215	1.647	1.540	2.940	1.693	9.647	64.638	1.068	24.37	10.06	7.063	0.345	0.561
Turkey Red, Fruita, yellow-berry in all......	9.213	1.566	1.610	2.952	1.765	10.050	65.250	1.215	26.66	10.67	7.750	0.309	0.539
Turkey Red, Fruita, no yellow-berry........	8.675	1.295	1.633	2.956	2.318	13.210	61.740	1.142	37.60	15.49	11.313	0.231	0.485
Big Frame, Ft. Collins, wet in shock........	9.053	1.626	1.480	3.122	2.509	14.301	59.976	1.241	42.00	15.95	11.672	0.359	0.477
Fultz Mediterranean, Ft. Collins, wet in shock	9.460	1.601	1.583	2.960	2.457	14.002	61.106	1.184	42.00	16.31	11.909	0.364	0.504
Prize Taker, Ft. Collins, wet in shock........	9.488	1.633	1.843	2.862	2,286	13.031	60.570	1.263	37.50	14.82	10.853	0.371	0.484
Harvest King, Ft. Collins, wet in shock......	9.298	1.648	1.713	2.605	2.270	12.936	62.262	1.356	41.63	16.28	11.455	0.376	0.483
Jaraslov, Ft. Collins, wet in shock..........	9.305	1.503	1.793	2.912	2.631	14.994	59.040	1.031	48.83	18.15	13.488	0.333	0.465
Kharkov, Ft. Collins, wet in shock..........	9.485	1.615	1.460	2.875	2.446	13.942	59.886	1.003	44.90	16.19	11.822	0.346	0.534

GENERAL SAMPLES SEASON 1914

Spring Wheats	Amid Nitrogen Percent	Alubmin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Ratio of Gliadin to Glutenin Nitrogen	Total Nitrogen Percent
Defiance, Eckert, yellow-berry, very bad............	0.0769	0.1888	0.7712	0.9371	1:1.21	1.9740
Defiance, Ft. Collins, fallowed ground, wet in shock	0.0384	0.2098	0.9728	0.8535	1:0.88	2.0745
Defiance, Ft. Collins, fallowed ground, not wet....	0.0384	0.2098	1.2577	0.6171	1:0.49	2.1130
Marquis, Ft. Collins, fallowed ground, wet in shock.	0.0488	0.2517	1.1954	0.9231	1:0.79	2.4190
Marquis, Ft. Collins, fallowed ground not wet in shock	0.0523	0,2587	1.2012	0.9553	1:0.79	2.4675
Red Fife, Ft. Collins, fallowed ground, wet in shock	0.0523	0.2587	1.1169	1.0636	1:0.95	2.4915
Red Fife, Ft. Collins, fallowed ground, not wet.......	0.0558	0.2517	1.0812	1.2067	1:1.12	2.5955
Winter Wheats						
Red Chaff, Eckert, yellow-berry very bad...........	0.0769	0.1538	0.4543	0.7260	1:1.20	1.4110
Turkey Red, Fruita, all affected with yellow-berry...	0.1188	0.1608	0.6175	0.7954	1:1.45	1.6925
Turkey Red, Fruita, no yellow-berry................	0.0769	0,2098	1.0787	0.9521	1:0.88	2.3175
Turkey Red, Fruita, all affected with yellow-berry...	0.1188	0.1678	0.6781	0.8003	1:1.19	1.7650
Big Frame, Ft. Collins, wet in shock................	0.0804	0.2307	0.9868	1.2111	1:1.23	2.5090
Fultz Mediterranean, Ft. Collins, wet in shock....	0.0593	0.2307	1.1383	1.0282	1:0.90	2.4565
Prize Taker, Ft Collins, wet in shock...............	0.0699	0.2447	1.0811	0.9803	1:0.82	2.2860
Harvest King, Ft. Collins, wet in shock.............	0.0558	0.2656	1.2723	1.0368	1:0.82	2.6305
Kharkov, Ft. Collins, wet in shock..................	0.0628	0.2377	1.1301	1.0154	1:0.90	2.4460

MINERAL CONSTITUENTS OF WHEAT—GENERAL SAMPLES OF 1912 AND 1913

	Sp. gr.	SiO_2 Percent	Fe Percent	Mn Percent	Ca Percent	Mg Percent	K Percent	Na Percent	Cl Percent	S Percent	Total P Percent	Inorganic P Percent	Organic P Percent	Total N Percent
Red Fife, not irrigated and not fertilized, Ft. Collins, 1913	1.4383	0.116	0.012	present	0.050	0.129	0.357	0.002	.....	0.105	0.293	0.025	0.268	2.700
Defiance, not irrigated and not fertilized, Ft. Collins, 1913	1.4317	0.053	0.009	present	0.042	0.138	0.343	0.008	.....	0.093	0.336	0.015	0.321	2.444
Harvest King, winter wheat, Fruita, 1912	1.4165	0.026	0.007	present	0.038	0.116	0.375	?	0.087	0.101	0.327	0.020	0.307	2.545
Defiance, 4½ miles east of Fruita, 1912	1.4055	0.034	0.009	present	0.033	0.119	0.431	0.007	0.118	0.141	0.271	0.012	0.259	2.442
Defiance, Clifton, 1912	1.4327	0.038	0.007	present	0.029	0.141	0.400	?	0.165	0.155	0.329	0.015	0.314	2.534
Red Cross, 2½ N.E. of Fruita, winter wheat	1.4237	0.038	0.007	present	0.025	0.120	0.364	0.009	0.086	0.175	0.261	0.014	0.247	2.483
Red Fife, So. Dak. Expt. Sta. (Seed Wheat), 1912	1.4127	0.018	0.005	0.005	0.044	0.134	0.490	?	0.072	0.133	0.279	0.011	0.268	2.248
Kubanka, So. Dak, Expt. Sta. (Seed Wheat), 1912	1.4334	0.011	0.006	0.005	0.026	0.141	0.468	?	0.064	0.145	0.326	0.012	0.314	2.282
Defiance, fallowed ground, Ft. Collins, 1912	1.4298	0.009	0.005	present	0.043	0.150	0.414	0.020	0.060	0.157	0.376	0.017	0.359	2.618
Red Fife, fallowed ground, Ft. Collins, 1913	1.4352	0.007	0.007	present	0.037	0.162	0.380	0.020	0.059	0.146	0.414	0.025	0.389	3.008
Marquis, fallowed ground, Ft. Collins, 1913	1.4334	0.006	0.007	present	0.041	0.155	0.409	0.023	0.056	0.132	0.402	0.022	0.380	2.804
Minnesota, Hard Spring No. 1, 1912	1.4195	0.029	0.005	0.006	0.044	0.135	0.438	0.008	0.071	0.128	0.418	0.027	0.391	2.248
Minnesota, Hard Spring No. 2, 1912	1.4049	0.018	0.004	0.006	0.027	0.149	0.439	0.025	0.076	0.144	0.381	0.026	0.355	2.213
Crop of 1914														
Defiance, Ft. Collins, cultivated fallow one year	1.3619	0.016	0.006	0.005	0.037	0.150	0.393	0.009	0.192	0.127	0.322	0.009	0.313	2.075
Marquis, Ft. Collins, cultivated fallow one year	1.3981	0.012	0.005	0.005	0.036	0.130	0.310	0.028	0.081	0.162	0.333	0.014	0.319	2.419
Red Fife, Ft. Collins, cultivated fallow one year	1.4252	0.018	0.005	0.007	0.030	0.117	0.377	0.028	0.119	0.184	0.332	0.015	0.317	2.517

I have given the analyses of general samples of spring- and winter-wheats in the preceding tables in order to convey a general idea of what the composition of Colorado wheats really may be. Some of the samples analyzed were from Minnesota; these have been introduced simply for comparison. It is true that I could have found analyses of Minnesota wheats, but I wanted analyses made by the same analyst, to eliminate personal equations. The South Dakota samples are introduced because we used their crops of 1912 as seed wheats. Their samples of the 1913 crop were obtained to see how their crops for this year compare in composition with the preceding, as well as with our own. I do not know how the seasons differed in South Dakota nor how they differed from ours, besides, our wheats were grown with, and theirs without irrigation.

I fully realize that it is almost useless to try to compare wheats grown in different localities, as the composition evidently depends upon so many conditions that cannot be given in the statement of the analyses, that differences in the composition cannot readily be interpreted. As an illustration of this, the three samples of Turkey Red wheat given in the table of winter-wheats, General Samples of 1914, serve very well. These are samples labeled "Fruita", which I personally collected. Two of these samples were grown within one-half mile of one another, while the third sample was grown a short distance east of these in the same district. I was informed that these growers received seed from the same lot. These three samples were produced under the same conditions of weather; they were all threshed directly from the field. The grains were all protected from the weather, in fact were stored in granaries and they were all grown with irrigation. I do not know definitely, but I think it quite safe to assume, that they were grown with one irrigation, and without any fertilization. So far, the conditions under which the three samples were grown may be considered as identical and yet their composition is very different. This is not only the case with the protein, which is 9.6, 10.1 and 13.2 percent respectively, but we find the phosphorus and potassium varying to a significant extent, but inversely with the protein content. Were it not for my personal knowledge of the soil conditions, and of the other conditions as well, the analytical results obtained in these cases would be impossible of interpretation. This pertains to all general samples with much force. I am so fully convinced that it is wholly useless to try to interpret an analysis of a wheat, without a rather full knowledge of the conditions under which the sample was grown, that I have sought no general samples during the past year and a very few in the past two years. As a further justification for this conviction I may cite the case of two samples given in the table of general samples of spring-wheats for 1913 and a sample of Red Fife to be given in a subsequent table, all grown in 1913 under identical conditions of weather and irrigation and within less than 100 feet of one another on two contiguous and uniform plots of land. We have in the first pair, Red Fife, protein 17.143; Marquis, protein 15.998. The third one is a sample of Red Fife with 13.442 percent of protein. The differences in the amounts of phosphorus and potassium present are, again, big, and roughly, inversely proportional to the protein present. I shall endeavor to explain these differences in the proper place.

It becomes a question what the value of an analysis of a general sample of wheat, as a representative of the product of a county or a state, may be. It is only by the intelligent selection and analysis of a very large number of samples that a reasonably accurate estimate of the quality of the product of a good-sized county can be obtained. In our table of general samples of spring-wheats, rejecting the Egyptian, we have a range of protein from 8.224 to 17.143 percent and of true gluten from 4.001 to 11.593 percent. These figures represent different varieties, but we find for the same variety a range from 4.001 to 9.723 percent of true gluten calculated on the air-dried wheat. These differences correspond to a wide range of conditions of climate, soil, and very probably of cultivation. In the San Luis Valley, for instance, we have an altitude of 7,500 feet with its own peculiar climate and soil, and at Fort Collins we have an altitude of 5,000 feet with its climate and soil. While the San Luis Valley is 2,500 feet higher than Fort Collins, it is about 200 miles further south. The San Luis Valley has a rainfall of about 7.0 inches and the Fort Collins section one of 14.9 inches. Neither section as a rule can grow spring-wheat without irrigation. The wheats produced cannot be compared in regard to composition unless all of the conditions are given with the samples.

The Minnesota samples, analyses of which are given in the preceding table, were kindly sent to me, on request, by Mr. G. H. Tunell of the Minnesota Grain Inspection Department. I desired to see samples of their grading and also to have our own analyses of these wheats, because the high quality of their flours, made from hard spring-wheats is, I believe, universally recognized. I, however, know nothing of the conditions under which they were grown and we do not know to what extent these samples are comparable to ours, or are representative of Minnesota wheats. I am not certain about the variety, but I would judge this to be Red Fife. So far as analytical results are concerned these samples are not equal to the majority of the Colorado samples. We have only two of the general samples of Colorado wheats which appear to be of materially lower quality than these Minnesota samples, and these two are samples of Defiance wheat grown at La Jara and Del Norte in the San Luis Valley. Both of these samples represent extreme cases of yellow-berry or mealiness and are, for this reason, perhaps, inferior to the Minnesota samples which are flinty wheats.

I have already stated in another place that the Minnesota flour is preferred by our bakers for bread-making, as it yields from 30 to 40 more loaves per barrel than our own. Assuming these samples of wheat to be representative, this opinion is contrary to the analytical results. At the present time I am inclined to accept the bakers' judgment as the more reliable criterion. The differences in the amounts of the mineral substances in the wheats are so small that it is difficult to interpret them, though they, without doubt, are significant. The range in phosphorus, for instance, in the thirteen cases in which we have given the mineral constituents, is equal to 0.151 percent of the air-dried wheat, but this is 60 percent of the minimum amount of phosphorus found in these samples and indicates a great difference in the nutrition of the plants.

While the value of general samples, without a definite statement of the conditions under which they were grown, may be small in the way of indicating the general character of the wheat grown in any considerable section of the country, still, they may have a little value in showing the range in composition. It is for this reason that I have given the 50 odd analyses of general samples, including 5 samples from Minnesota and 4 from South Dakota. The South Dakota samples were introduced for the further reason that we used their wheat of the 1912 crop as seed in our experiments.

WHAT ANALYSES SHOW

These analyses show that our wheats often contain large percentages of nitrogen and also that the true gluten is high. They are even richer in these substances than our samples' from the other two states. Further, that the ratio of gliadin nitrogen to glutenin nitrogen falls well within the limits accepted for good flours. On the other hand these samples show that some of our wheats are low in nitrogen, but these have a fairly good gliadin-glutenin ratio. This may have no more than an analytical significance, but this is all that we, at the present time, care to consider, as we intend to divorce composition and quality as far as possible in this bulletin. It may well be that these are so intimately related that they ought not to be considered separately, still our purpose is to confine our consideration to the composition of our samples and the factors that affect it, leaving the question of quality for a subsequent time.

There are only a few samples among those given, which were grown on "dry land", or without irrigation, but, so far as we can attach any value to so small a number of samples, we find no justification for the claim which is sometimes made, that dry land wheat is better, i.e., richer in nitrogen than irrigated wheat. This sentence is written with the knowledge that it is opposed by the views of very competent men either directly or by intimation. Schindler, for instance, holds that hot, dry summers produce wheats high in nitrogen as compared with the same variety grown in cooler and wetter summers or localities. This seems to be, at least it is accepted, as an established fact, but it is not applicable to our conditions, concerning which we shall have more to say at another time.

The general samples of wheat from the same locality, as well as from different localities, are readily separated into classes according to their flintiness or starchiness. The flinty kernels, on the one hand, are rich in nitrogen, the starchy ones, on the other hand, are poorer in nitrogen. I do not know when or by whom this observation was first made, but it is a very widely recognized property of wheat kernels. Ritthausen and Dr. R. Pott mentioned such kernels in 1872 * and this condition is described quite fully by Schindler in his "Getreidebau"† where he says: "'Flinty' wheat is, on account of its greater density, i.e., its high specific gravity, designated hard wheat and is, as a rule, richer in nitrogen, and the amount of gluten is greater than in the mealy, or so called soft wheats" to which he adds in a footnote "This is also the case even when the flinty and starchy kernels are of the same variety and have been produced in the same field; in this case, the kernels produced in the top and bottom portions of the head are apt to be more flinty and those in the middle portions more mealy. P. Holdefleiss§ found that in one and the same crop of Early Bastardweizens the flinty kernels contained 1.907 percent nitrogen (12.23 percent protein) the mealy ones, on the contrary, 1.566 percent nitrogen (9.79 percent protein)."

The physical property of the kernels first mentioned is not characteristic of any locality, but is found distributed everywhere throughout the State, so far as my knowledge of the wheats produced extends. We find, that the chemical composition varies with this, but this does not prove that the bread-making qualities are lessened, though the gluten content certainly varies, as well as the chemical composition. There is no doubt but that physical properties and chemical composition are dependent upon conditions of fertility which vary from place to place in small areas and even more in large ones, especially in a State of

* Die landwirtschaftlichen Versuchs-Stationen Band XVI, p. 391.
† Schindler, Der Getreidebau, 1909, p. 151.
§ P. Holdefleiss, "Mehligkeit und Glasigkeit der Weizenkoerner," "J Kuehns Berichte," XIV, 1900.

such varied physical conditions as we have in Colorado. It is not only a question of climate, especially of rainfall and seasonal differences due to altitude, but also a question of soil. The soil of the San Luis Valley, for instance, is very different from that of the Arkansas Valley, or of the Grand Valley, in its origin and in its properties. The climates, too, of these valleys are very different. The San Luis Valley has an altitude of 7,500, the Grand Valley about 4,000 and the eastern portions of the Arkansas Valley about 3,000. They differ further in this, that the San Luis Valley is surrounded by high mountains. The range on the east side of it, the Sangre de Cristo, is very high, possibly the highest in the State. Mount Blanca, its highest peak, attaining a height of 14,467 feet, while Las Animas, in the Arkansas Valley, is some 140 miles east of the mountains in the plains section and approximately 4,500 feet lower. Irrigation is necessary in both sections.

No reasonable number of general samples grown under such a variety of conditions, including both soil and climate, can give any definite information concerning the character of the wheat grown in the State. The only thing that would be feasible, would be to study the grain produced in some definite section whose conditions of soil and climate could be given. I, at first, thought that it might be possible for us to obtain enough samples from reliable parties to accomplish this broader purpose in a reasonably satisfactory manner. It would serve no good purpose to give all of the considerations which have lead us to abandon this notion. Those given must satisfy the reader, as they have sufficed to convince us that it is wise on our part to acknowledge our change of attitude. The facts stated give our reasons for presenting so few general samples in 1914 and none in 1915. Further, they explain why we have confined our efforts to the study of our own samples grown under fairly well known conditions.

YELLOW-BERRY

It will be noticed that the samples of Defiance from various localities differ by a maximum of 6.859 percent of protein or 1.206 percent of nitrogen. The physical properties of the kernels indicated a very decided difference in these samples; those from La Jara and Del Norte present large, plump, mealy kernels, that from Del Norte weighing 49.07 grains per 1,000 kernels. There were no flinty or part flinty kernels in this sample. It is an extreme case of yellow-berry wheat. The sample from Fort Collins presents smaller, somewhat shrunken, flinty kernels which weigh 30.65 grams per 1,000; in the former sample we have 8.054 percent protein (N x 5.7) and in the latter 14.923 percent. In the La Jara sample, with 8.288 percent protein, the kernels are smaller than in the Del Norte sample. There are a few berries which cannot be classed as either flinty or mealy, though the berry is uniform in appearance. This is not the case in many other samples, for in these the kernels show distinct areas of mealiness, sharply contrasting with the flinty character of the rest of the kernel. This condition is not confined to any one variety of either spring or winter-wheats. We have previously mentioned the differences in composition of three samples of a winter-wheat, Turkey Red, for which we gave the protein as 9.6, 10.0 and 13.2 percent, showing a difference of 3.6 percent in the protein present. These samples were grown, according to my information, from the same lot of seed and in the immediate neighborhood of one another—the second and third samples within one-half mile of one another. The physical properties of these samples are just as distinct as are those of the Defiance samples previously given.

It seems proper to consider this subject in this connection, because it is the most patent condition occurring in our general samples, corresponding to a marked difference in composition. Kosutany, Schindler, and such other European writers as I have read, do not formulate a definite cause for this condition, though they repeatedly refer to it. The general explanation which runs through Schindler's book, "Der Weizen in seinen Beziehungen zum Klima," is that it is dependent upon climate, particularly upon moisture. On page 76 of the work just mentioned he says:* **"The processes of carbohydrate formation, as well as the deposition in receptacles for the same, depend in the highest degree upon climatic factors, but the soil, the only source of nitrogen for the cereals, is the first of all (factors) in the (formation) of protein. The absolute quantity of protein in wheat depends upon this (the soil supply) and can be regulated by the application of nitrogen, but the relative amount is determined by the climate."** This author has previously stated, page 41: **"However fragmentary the cited material may be, one fact of fundamental significance is shown thereby, i.e., that the absolute weight of wheat (weight of 1,000 kernels) stands in a definite, independent relation to the external conditions of growth, among which, climate excels all others in influence."** These quotations suffice to show that the author considers climate as the most important factor in determining the ratio between the protein and carbohydrates in the wheat kernels. While this author designates kernels as flinty, mealy, and half mealy, he does not definitely state that climate causes mealiness, but he says, as quoted above,

* In the quotations from Schindler I have given the title and page of the German work but not the text. The translation is the author's.

that the relative amount of nitrogen is determined by the climate. Lawes and Gilbert, in an article entitled, "Our Climate and Our Wheat-Crops",* quote from a preceding article which appeared in the Journal of the Royal Agricultural Society of England Vol. IX, Part 1, p. 96: "Thus it is obvious that different seasons will differ almost infinitely at each succeeding period of their advance, and that with each variation the character of development of the plant will also vary, tending to luxuriance, or to maturation, that is, to quantity or to quality as the case may be. Thence, only a very detailed consideration of climatic statistics, taken together with careful periodic observations in the field, can afford a really clear perception of the connection between the ever fluctuating characters of season and the equally fluctuating characters of growth and produce. It is, in fact, the distribution of the various elements making up the season, their mutual adaptations, and their adaptation to the growth of the plant which throughout influence the tendency to produce quantity or quality. It not infrequently happens, too, that some passing conditions, not indicated by a summary of the meteorological registry, may affect the crop very strikingly; and thus the cause will be overlooked, unless observations also be made and the stage of progress and tendencies of growth of the crop itself at the time, be likewise taken into account." This article reviews the weather conditions and the wheat crops in England from 1816 to 1879, but more particularly from 1843-44 till 1878-79. During the latter period they select six seasons during which the yield of straw and grain were both high, four seasons with high yield of grain and low yield of straw, and four seasons during which the total produce was low. They give the total number of rainy days, i.e., days on which 0.01 inch or more of rain fell. With 140 rainy days the yield of both straw and grain was high. With 136 rainy days the yield of grain was high, of straw low. With 199 rainy days the total produce was low. In discussing the wheat crop of 1878-79 at Rothamsted, one of the poorest crops on record at that time, they had 226 rainy days, with 42.29 inches of rainfall. In comparing the two very bad seasons of 1816 and 1879 these authors conclude: "Lastly, it would appear that any defect of our climate in appropriateness for the production of full and well matured wheat crops is more connected with an excess of rain and consequent wetness of soil and humidity of atmosphere, than with any deficiency of average summer temperature." In regard to the yield of grain in 1879, it appears from the data given that it was about one-half of the average crop for the preceding 27 years. In regard to quality, the weight per bushel seems to have been taken as the measure. In fact, so far as I can gather, they use the terms "quality" and "weight per

* Rothamsted Memoirs, Vol. V. 11th Article, p. 4, or Journal Roy. Ag. Soc. Eng. Vol. XVI, s. s. Part I, p. 173.

bushel" synonymously. The weights per bushel given for the season of 1879 range from 2.7 to 5.4 pounds below the average for wheat grown under the same conditions of manuring for the preceding 27 years. That this is what is understood by quality in this case, seems apparent from the manner in which they refer to it. They say: "The defect in weight per bushel of the dressed corn was great under all the conditions cited."

"Lastly, great as was the deficiency in the produce of corn, and in the weight per bushel of dressed corn, under all the conditions, the proportional deficiency of straw was much less."

After discussing the conditions under which the crop of 1878-79 was grown they add: "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."

"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."

These authors clearly hold that the weather conditions, especially the mean temperature and rainfall, exercise a big influence upon the yield and quality of wheat, meaning by quality, primarily, weight per bushel. They further assign as one cause of this, the removal of nitrates by the leaching action of excessive rainfall. The same authors return to this subject in a subsequent article "On the Continuous Growth of Wheat, etc., from 1864 to 1883".*

"We find the two crops running a parallel course, showing great differences in their yield as the seasons are favorable or unfavorable. The Rothamsted soil, like a great many cultivated soils, contains a large amount of mineral food of plants: it also contains organic nitrogen, that is to say, nitrogen in combination with carbon, the residue of previous vegetation. This organic nitrogen does not appear to be available as food for the wheat plant, but every year a certain amount of it is converted into nitric acid, which combines with the lime in the soil. In this state it is very soluble in water, is readily washed out of the soil by heavy rain, and, further, is a most important and essential food of the wheat plant."

"The amount of nitric acid formed each year will vary, the formation being the most rapid in the hottest weather, provided the soil is sufficiently moist. The amount of nitric acid which the wheat crop can take up will also vary, and in a cold and wet winter much will be washed beyond the reach of the roots of the plants."

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* Rothamsted Memoirs, Vol. VI., 3rd Article, p. 44. This originally appeared in the Jour. Roy. Ag. Soc. Eng. Vol. XX, s. s. Part. II.

"These facts, which are of universal application, enable us to explain some of the causes which tend to the production of good or bad crops of wheat."

In discussing the good crops of 1858 and 1863, they go further in discussing the general composition of the grain than in the preceding quotations and give us another view of how the weather affects this. In the preceding quotations they speak of good and bad crops without special consideration of the composition of the grain, but in the following quotations they include the latter: "It will afterward be seen, indeed, that the total crop of 1863 contained about one and one-half time as much mineral matter per acre, and also considerably more nitrogen than that of either of the other seasons (1852, 1856, 1858): yet the percentage of both was much lower in the grain, and that of the nitrogen lower also in the straw, than in the produce in either of the other years. There is here again evidence that with favorable maturation there is low percentage of both mineral matter and nitrogen; that is, favorable maturation means the greater accumulation of non-nitrogenous organic substances, carbohydrates and especially starch,—the result necessarily being a lowering of the proportion though not of the actual amount of both the nitrogenous and mineral constituents." These authors have been quoted already as attributing the defect of their climate, in regard to the wheat crop, to an excess of rain rather than to a deficiency in the mean temperature. They attribute the effects of excessive moisture to two principal facts, first, to the preference of the plant itself for a dry rather than a wet soil, and second, to the leaching out of the nitrates.

Lawes and Gilbert, it appears, have written exclusively of winter-wheat which, in England, seems to have a very long growing period, as they speak of August as their harvest period. They make no distinction between flinty and mealy kernels, as the German writers do. I am unfortunately not familiar with the English wheats and have seen but few samples of European wheats, but the Swedish, Dutch and French wheats that I have seen were mealy wheats and that to such an extent that one could not distinguish the kernels as having distinct characteristics, as flinty and mealy. This may be the case with the English wheats, but one would scarcely think that it would be the case with all of their samples, which were grown with such a variety of manuring. Still, they use the weight per bushel as indicative of quality; the only exception to this statement is in the quotation just made defining favorable maturation, "That is, favorable maturation means the greater accumulation of non-nitrogenous organic substances,—carbohydrates and especially starch,—the result necessarily being a lowering of the proportion, though not of the actual amount of both the nitrogenous and the mineral constituents." Even in this statement it is not clear that their statement can be construed as distinguishing between flinty and mealy wheats. I am inclined to think that it is a general statement without distinction of any special physical properties. The principal point in all of this, however, is evident, that they consider the weather conditions as determining the quality and quantity of their crops.

I believe that all of the publications upon this subject that have appeared in this country have adopted the same general views, to which, in a certain measure, we must subscribe, for it is evident, without statement, that the growth of the plant and the quality of the product is dependent in a measure upon weather conditions, i.e., upon accidental conditions from year to year. There are, however, some characteristics of the grain which are neither determined nor obliterated by the weather conditions, though they have been very largely attributed to the latter. Kosutany and also Schindler attribute, in an indefinite way, influence to the soil, but the latter, especially, attributes a predominating influence to the climate, and he uses the term in its larger sense.

The writers in this country go, perhaps, even farther in attributing to climatic influences, a determining influence upon the character of the grain produced. I would like to mention all of these writers but there are too many of them. The only one among them who, so far as I know, attaches any considerable influence to soil fertility is Snyder, formerly of Minnesota. The views of the great majority of the rest of these writers are represented by the statements of Le Clerc of the Bureau of Chemistry of the U. S. Department of Agriculture in Bulletin 128, from which the following quotations are made: "Eckenbrecher* grew six varieties of barley in twelve different localities and found that the same variety showed a much larger variation in nitrogen content and in weight per 1000 grains when grown in the twelve localities than the six varieties did when grown in any one locality, that is, that climatic conditions, or environment, exerted a greater influence than did the seed or even the variety. Yet Hall in the article just quoted† makes the statement that variety is the chief factor in affecting the composition of plants, that each race or variety possesses characteristics which are modified only to a relatively slight extent by soil, seed, or climate".§

"Bogdan found that an increase of salt content of alkali soils produced an increase in the nitrogen and ash content of wheat though the absolute amount of these constituents decreased due to the fact that the grains were smaller. This, in a certain way, explains the good quality of the rather small grains of wheat grown in southeastern Russia, northwestern America, Hungary etc., where the soil is rich in soluble salts, especially nitrates. It has, however, generally been assumed that fertilizers influence the yield

* Wockenschrift Brau, 1907, 24-491.
† Science 1905-22-461.
§ Bul. 128, Bureau of Chemistry, U. S. D. A., p. 8.

considerably and to a small extent the composition. In like manner, soil is one of the lesser factors affecting the composition of wheat. This is the opinion of Lawes and Gilbert, Hall, Wiley, and others; though, of course, a nitrogen-rich soil will yield a crop of a somewhat greater nitrogen content than will a nitrogen poor soil."*

The conclusions reached in this bulletin may be taken as reflecting the opinion of, at least, a very large percentage of our writers. They are formulated as follows:

"Wheats of the same variety when grown in the same locality and under the same conditions are, therefore, seen to vary but little in composition although coming from seed differing widely in physical and chemical characteristics. These results are corroborative of Eckenbrecher's work with barley and are entirely at variance with Hall's statement that each race or variety possesses qualities which are modified only to a slight degree by seed, soil, or climate. Wheat of any one variety, from any one source and absolutely alike in chemical and physical characteristics, when grown in different localities, possessing different climatic conditions, yields crops of very widely different appearance and very different in chemical composition. The results so far obtained would seem to indicate that the soil and seed play a relatively small part in influencing the composition of crops."†

These quotations from Le Clerc may be taken as fairly representative of the views generally obtaining among our writers on this subject. The terms climatic conditions and environment are not used with such definiteness that one can always tell just what is meant, in fact they are sometimes used as alternative expressions of climatic conditions or environment. Again, the latter term is used in a more comprehensive sense, taking in rainfall, sunshine, temperature, winds, humidity of the air, soil, time of planting, cultivation, manuring, thickness of seeding, previous crops, etc.

I have deemed it wise to state these general views which are very commonly held by students of this subject.

THE EFFECT OF CLIMATE ON COMPOSITION

The explanation that I have offered for yellow-berry in wheat is not in harmony with the statements just made, nor are they in harmony with other explanations offered, which belong to several classes; for instance, the result of injury by fungi, unseasonable harvesting and exposure to the weather after cutting, to heredity or a "tendency" herit-

* Bul. 128, Bureau of Chemistry, U. S. D. A., p. 9.
† Bul. 128, Bureau of Chemistry, U. S. D. A., p. 18.

able in wheat, and to climatic conditions. Under the latter head I suppose the principal factor considered is the rainfall or supply of water. Again, I know of no one more explicit in his statements than Le Clerc, who discusses with clearness flinty and mealy wheats. He says: "Furthermore the wheat of the humid regions contains a larger percentage of mealy kernels showing that there is a very close relation between the percentage of protein and the percentage of flinty grains, that is, generally, the more flinty the kernels the higher is the percentage of protein. An excessive amount of rainfall or irrigation is almost always accompanied by a crop containing a low percentage of protein. This is further shown in the work done in 14 different localities in the far Western states, 7 of these places were irrigated and the percentage of protein averaged 12.1 while in the 7 places where no irrigation was practiced the protein content of the wheat was 15.4 percent."* In the next paragraph he describes two samples of wheat of which he says: "The non-irrigated samples consisted of flinty kernels entirely and contained 5.4 percent more protein than the original seed and 6.6 percent more protein than the irrigated sample. The irrigated sample contained, moreover, very few flinty kernels (only 20 percent)." Again, in commenting on the observations of Lawes and Gilbert he writes: " 'The six seasons of bad crops showed rain to have fallen during each of the 199 days. The seasons of good crops had but 136 days during which it rained."† The probable reason for such differences is that an excessive rainfall dilutes the nitrates in the soil too much and there being but small amounts of carbohydrates in the process of formation, owing to lack of sunshine, less protein is formed. The result is a mealy grain of low protein content."§ In the same article is given excellent illustrations of flinty, half-flinty and mealy kernels and in the legends we find "Flinty wheat grain grown under dry farming", "Starchy wheat grain grown under excessive irrigation". If there were any doubt remaining in regard to what the author considered the cause of the mealiness of some kernels this would remove it.

TOO MUCH IMPORTANCE ATTACHED TO CLIMATE

In Bulletin 205 I showed that this condition is not due to injury by fungi, nor to the time of cutting, nor to weathering, nor to climatic conditions, etc. The answer to these suggestions is given by pointing out the fact that we can produce flinty kernels by applying nitrates or increase the percentage of mealy berries by increasing the supply of potassium. While I do not for one moment doubt the importance of favorable weather conditions in the production of a good crop of wheat, I am convinced that too much importance has been attributed to this group of agents over and against the influence of the soil con-

* Yearbook, U. S. D. A., 1906, p. 203.
† Yearbook, U. S. D. A., 1906, p. 205.
§ There were 199 and 136 days respectively on which 0.01 inch or more of rain fell. These are the mean number of days for each period.

ditions. While there is no doubt but that lack of sunshine and excessive moisture, especially as rainfall, influence the composition of the wheat kernel, it is probably seldom the case that it goes so far as to determine the flintiness or mealiness of the kernel, or if it does, it is probably by its direct influence upon the food supply in the soil in washing the nitrates below the feeding area of the plant roots, rather than by its direct action upon the plant itself. There is no doubt but that these agents, frequent rains and cloudy weather, have a direct influence upon the plant which follows from the data given in our Bulletin 217,' but it is not so great nor in the direction assigned to it in these quotations. We shall further give some data to show that it is difficult to remove enough nitrates by the application of water to produce the effects attributed to it, and it is for this reason that I have just said that it is probably seldom the case that it goes so far as to determine the flintiness or mealiness of the kernel. This effect of excessive rain, the washing out or reducing the amount of nitrates in the soil, was pointed out by Lawes and Gilbert in their article "Our Climate and Our Wheat-Crops" and again, in the article "On the Rain and Drainage Waters of Rothamsted".

I wish in this connection to emphasize the statement previously insisted upon that analytical results obtained with samples of wheats unaccompanied by a full account of all of the conditions under which they were grown are too difficult of correct interpretation to justify reliance upon any interpretation offered for such analytical facts. In this connection I appreciate that the conditions under which the crops of which Lawes and Gilbert wrote, grew, were wholly different from those under which my samples were grown. They wrote of winter-wheat which seemingly had a growing period, i.e., from planting till harvest, of ten months or more. My observations have been made, principally, on spring-wheats with growing periods varying from 101 to 128 days. The rainfall given for 1878-79 at Rothamsted is 42.29 inches. The average annual rainfall at Fort Collins is 14.9 inches, in the exceptional year of 1915 it was about 22.5 inches. The rainfall during the total growing period of our spring-wheat is usually about 7 inches; in 1915 it was a little over 13 inches. Our mean temperature for the growing period is higher than the mean temperature under which their crops were grown. It would seem to be unnecessary to state these facts, but it is, perhaps, wise to do so lest it be thought that I failed to consider them.

EFFECTS OF NITROGEN AND PHOSPHORUS ON FLINTINESS OR MEALINESS

In Bulletin 205 I aimed to do exactly what is suggested by its title, to point out the cause of flintiness and mealiness in our grains and to show how this can be controlled. We did not enter into a study of the flinty and mealy berries themselves, in fact, we gave no analytical data, but confined ourselves to the direct results of field experiments, using one-tenth-acre plots. These results showed that the percentage of flinty berries was materially increased, practically to the complete elimination of the mealy berries, by the application of nitrogen in the form of nitrate. Further, that the application of potassium increased the percentage of mealy kernels, and gave to all of the kernels a less desirable appearance than the wheats produced on the check plots. I could not convince myself that phosphorus had any perceptible influence on this condition. The only analytical data given in this bulletin pertained to the main features of the soil and sub-soil in regard to the supply of plant food.

The positive and conclusive character of the proof adduced to show the cause of these characters in wheat kernels seemed to render any discussion of the chemical properties of the kernels themselves entirely unnecessary and only a few explanations, for the most part physical, were considered.

At the time I wrote Bulletin 205, I knew of but few observations similar to those I had made. The principal ones were the observations of H. von Feilitzen (Abs. Expt. Sta. Record, Vol. XVII, p. 24), F. Moertlbauer (Abs. Expt. Sta. Record, Vol. XXV, p. 33) and a private communication from Prof. A. Keyser. Quite recently, a year subsequent to the publication of Bulletin 205, I found an article published by Ritthausen and Dr. R. Pott in Die Landwirthschaftlichen Versuchs Stationen, Vol. XVI, 1873, pp. 384-399, in which identical conclusions are given, except in regard to the effects of potassium, namely, that nitrates produce small, flinty, hard kernels; and that phosphorus is without effect upon the flintiness or mealiness of the kernels. The two series of experiments are identical in plan and results, in so far as the experiments are co-extensive. I would gladly have cited these experiments made at Poppelsdorf in 1872, had I known of them at the time that I wrote Bulletin 205, as the results obtained under the conditions obtaining in the lower Rhine district in 1872 are identical with those obtained at Fort Collins in 1913 and 1914. Their observations on the effect of nitrates upon the wheat kernels, in comparison with other fertilizer, are of sufficient interest to justify their quotation in this place. These observations are:

"The variety used for seed was one which had been cultivated for a long time at Poppelsdorf. The kernels were flinty, hard and dark colored; kernels of any other character could not be found even on examining a larger quantity.

"The grain from the unmanured plots Nos. 1, 7, and 12 were mostly half-mealy or transitional, light colored, large and plump with smooth and lustrous surface; even the flinty kernels showed this latter characteristic.

"The grain from plots Nos. 4, 8, and 11 manured with superphosphate and phosphoric acid showed exactly the same characteristics, but varied more in size; the number of small, mostly flinty (glassy) kernels was apparently equal to that of the large ones.

"The nitrogenous fertilizers,* Nos. 2, 5, and 9 produced only small, but well-formed, thoroughly hard; flinty and dark colored kernels.

"The kernels obtained from the mixed manuring, Nos. 3, 6 and 10, were like those in the case of pure nitrogenous manuring, all small, hard, flinty and dark, together with no small number of shrunken and imperfectly formed kernels."

Ritthausen and Dr. R. Pott give the nitrogen contained in these grains; the maximum for the check plots was 2.78 percent, that for the phosphoric acid plots was 2.77, that for the nitrogenous manure 3.48, and that for the mixed manuring was 3.82 percent. The moisture in the samples was practically the same, the maximum variation in 12 samples given being about 0.8 percent.

FLINTY KERNELS HIGHER IN NITROGEN

It is not specifically stated in the article that the flinty kernels are higher in nitrogen than the mealy ones, but it evidently can be inferred that this is so. This, however, is generally stated to be a fact. Schindler has been quoted on a previous page as stating "This is also the case even when the flinty and starchy kernels are of the same variety and have been produced in the same field.... P. Holdefleiss found that in one and the same crop of early Bastardweizen the flinty kernels contained 1.957 percent of nitrogen (12.23 percent protein), the mealy ones on the contrary 1.566 percent nitrogen (9.79 percent protein)". The difference in the nitrogen content of flinty and starchy kernels is so thoroughly well established that it is almost, if not altogether, common knowledge. It is also quite as well known that the nitrogen content of the grain can be increased by the application of sodic nitrate or ammonium sulfate. We have so far, then, the following facts pertaining to the effects of nitrogen in the form of nitrates or an easily nitrifiable form of nitrogen; it affects the size of the kernel, tending to produce a small or even shrunken Grain;† it produces a high degree of flintiness and with this a dark,

* The nitrogenous fertilizers used were sodic nitrate and ammonic sulfate.

† A similar observation is made in regard to the effect of nitrates in producing shrunken kernels in Ohio Bul. 243, p. 587, and illustrated on p. 572, showing 60 percent of shriveled kernels.

vitreous appearance, and a higher content of nitrogen. Further, we have the fact that kernels of this character are produced in the same variety of wheat, in the same field and during the same season alongside of large, plump, mealy, light-colored, soft kernels, sometimes even much lower in their nitrogen content. It would seem evident that these results cannot be the result of any climatic conditions, even if we narrow this term down to those accidental features which constitute weather conditions. We can support this view with data of our own collecting. On the other hand, we have our direct observations that potassium increased the percentage of yellow-berry, the size of the kernel, its plumpness, and imparts to it a lighter color. In the summary of Bulletin 243 of Ohio we find this conclusion: "Potassium has increased the proportion of plump kernels, although the yield is the same as when nitrogen is applied to the soil and the composition is practically the same as that found in the wheat from unfertilized soil."* I have a few samples of Ohio wheats, which fact I owe to the courtesy of the Ohio Station, and these samples are so different from our wheats that comparisons are scarcely permissible. But one thing is very striking and this is that they are strongly affected with yellow-berry, or starchiness, and are not comparable with ours in plumpness. I take it that this enhances their observation relative to the effects of potassium upon this characteristic of the kernel. As I am almost wholly ignorant of the conditions under which these samples were grown, I would not, if I desired to do so, permit myself to judge of the causes of the characteristics of these samples further than the author has done.

THE DIFFERENCE IN COMPOSITION OF FLINTY AND STARCHY KERNELS

The physical differences between the flinty and starchy berries are very evident to the eye, much more so than can be expressed in words. We have stated that such berries differ in composition. The annotations in the tables, giving the composition of general samples, are intended to suggest an idea of the composition of yellow-berry wheat, and the table given herewith is intended to show the differences in the composition of these berries grown on our own plots under identical conditions of climate, including the water supply and known conditions of manuring, the soil being as nearly identical as can be obtained. The table contains no samples grown with the application of nitrogen, because these samples contained no mealy kernels. Analyses of such samples will be found in subsequent tables and may also be found in the tables of general samples of winter-wheats for 1914.

* Ohio Bulletin 243, p. 587.

ANALYSES OF YELLOW-BERRY AND FLINTY KERNELS GROWN UNDER IDENTICAL CONDITIONS

Variety	Fertilizer Per Acre		Moisture	Ash	Fat	Fiber	Nitrogen	Protein	Starch	Sucrose	Wet Gluten	Dry Gluten	True Gluten
Red Fife,*	60 lbs. phosphorus,	Yellow-berry	.....	.....	.....	.....	1.568	8.928	66.042	1.108	18.38	7.91	5.748
		Flinty	.....	.....	.....	.....	1.881	10.720	61.110	1.034	22.66	9.85	7.032
Red Fife,	40 lbs. phosphorus,	Yellow-berry	.....	.....	.....	.....	1.469	8.374	65.286	1.012	17.75	7.77	5.538
		Flinty	.....	.....	.....	.....	1.772	10.100	62.712	0.995	21.98	9.55	6.685
Red Fife,	20 lbs. phosphorus,	Yellow-berry	.....	.....	.....	.....	1.525	8.692	64.665	1.081	18.05	7.75	5.535
		Flinty	.....	.....	.....	.....	1.712	9.756	63.904	1.029	21.78	9.22	6.486
Red Fife,	200 lbs. potassium,	Yellow-berry	8.410	.....	2.105	3.125	1.640	9.348	65.826	1.425	19.23	8.21	5.937
		Flinty	8.348	.....	1.960	3.020	1.949	11.105	61.505	1.449	24.97	10.37	7.497
Red Fife,	150 lbs. potassium,	Yellow-berry	9.310	.....	2.008	2.920	1.600	9.117	65.952	1.016	19.23	8.21	5.914
		Flinty	9.365	.....	1.853	2.912	1.891	10.776	63.378	1.046	23.68	10.10	7.385
Red Fife,	100 lbs. potassium,	Yellow-berry	.....	.....	.....	.....	1.658	9.448	64.764	1.046	19.92	8.57	6.209
		Flinty	.....	.....	.....	.....	1.894	10.796	64.188	1.034	26.00	10.48	7.579
Kubanka,	60 lbs. phosphorus,	Yellow-berry	.....	.....	.....	.....	1.583	9.023	63.468	1.260	18.85	8.31	5.867
		Flinty	.....	.....	.....	.....	1.811	10.320	62.640	1.232	24.42	10.48	7.290
Kubanka,	40 lbs. phosphorus,	Yellow-berry	.....	.....	.....	.....	1.514	8.627	65.547	1.289	19.72	8.62	5.947
		Flinty	.....	.....	.....	.....	1.778	10.131	62.766	1.255	24.38	10.34	7.321
Kubanka,	20 lbs. phosphorus,	Yellow-berry	.....	.....	.....	.....	1.598	9.105	63.918	1.386	21.32	9.16	6.366
		Flinty	.....	.....	.....	.....	1.884	10.739	60.390	1.438	26.97	11.45	8.054
Kubanka,	200 lbs. potassium,	Yellow-berry	8.923	.....	2.113	2.995	1.564	8.910	65.502	1.278	21.47	9.24	6.398
		Flinty	9.068	.....	1.923	2.907	2.044	11.648	62.186	1.260	27.73	11.86	8.380
Kubanka,	150 lbs. potassium,	Yellow-berry	.....	.....	.....	.....	1.629	9.279	65.070	1.409	22.40	9.65	6.653
		Flinty	.....	.....	.....	.....	2.057	11.725	63.792	1.467	28.60	12.25	8.697
Kubanka,	100 lbs. potassium,	Yellow-berry	.....	.....	.....	.....	1.628	9.279	64.641	1.415	21.85	9.33	6.368
		Flinty	.....	.....	.....	.....	2.000	11.400	62.120	1.432	27.30	11.88	8.455
Kubanka,	None	Yellow-berry	.....	.....	.....	.....	1.587	9.046	65.848	1.210	21.23	9.31	6.448
		Flinty	.....	.....	.....	.....	1.921	10.947	61.812	1.278	27.53	11.87	8.425
Kubanka,	None	Yellow-berry	.....	.....	.....	.....	1.599	9.111	62.820	1.560	19.97	8.79	6.160
		Flinty	.....	.....	.....	.....	1.969	11.223	62.118	1.432	27.52	11.88	8.423
Kubanka,	None	Yellow-berry	9.113	.....	2.230	3.010	1.610	9.174	63.918	1.259	20.57	9.28	6.373
		Flinty	9.430	.....	2.010	2.835	1.936	11.092	62.172	1.369	26.33	11.58	8.193

DISTRIBUTION OF NITROGEN PERCENTAGE IN YELLOW-BERRY AND FLINTY WHEAT

Variety	Fertilizer Per Acre		Amid Nitrogen	Albumin Nitrogen	Gliadin Nitrogen	Glutenin Nitrogen	Total Nitrogen
Red Fife,	200 lbs. potassium,	Yellow-berry	0.0523	0.2028	0.6561	0.7288	1.6400
		Flinty	0.0523	0.2028	0.7166	0.9768	1.9485
Red Fife,	100 lbs. potassium,	Yellow-berry	0.0488	0.1888	0.6409	0.7210	1.5995
		Flinty	0.0488	0.1958	0.7667	0.8792	1.8905
Kubanka,	200 lbs. potassium,	Yellow-berry	0.0453	0.1958	0.7096	0.6128	1.5635
		Flinty	0.0523	0.2098	0.7260	1.0554	2.0435
Kubanka,	no fertilizer	Yellow-berry	0.0349	0.1818	0.6921	0.7007	1.6095
		Flinty	0.0663	0.2168	0.8424	0.8105	1.9360

*In the case of the Red Fife, the kernels were so generally affected by the yellow-berry that it was almost impossible to sort out a sample of flinty berries which were even for the most part entirely free from the affection, so that, in the end, it was not a question of flinty and yellow-berry kernels, but of very badly and of very slightly affected kernels selected from the same sample of wheat.

ASH CONSTITUENTS OF YELLOW-BERRY AND FLINTY WHEAT

Variety, Kubanka	Yellow-berry	Flinty	Flinty
Fertilizer, per acre	150 lbs. Potassium	100 lbs. Potassium	120 lbs. Nitrogen
	Percent	Percent	Percent
Silica, SiO_2	0.008	0.022	0.012
Iron, Fe	0.003	0.004	0.004
Manganese, Mn	0.003	0.004	0.005
Calcium, Ca	0.032	0.032	0.032
Magnesium, Mg	0.140	0.140	0.133
Potassium, K	0.444	0.408	0.418
Sodium, Na	0.041	0.022	0.016
Chlorin, Cl	0.123	0.118	0.093
Sulfur, S	0.093	0.103	0.128
Phosphorus, P (total)	0.394	0.394	0.343
Inorganic, P	0.011	0.011	0.008
Organic, P	0.383	0.383	0.335
Nitrogen, N	1.629	2.057	2.168
Specific Gravity	1.3976	1.4363	1.4241

The above results are given in percentages of the air-dried grain.

THE RATIO OF PROTEIN TO STARCH

As the protein and starch make up about 75 percent of the air-dried wheat, they must bear an inverse relation to one another, i.e., if the percentage of protein is higher it must be largely at the expense of the percentage of the starch. We find that this is, in a measure, true of our results, but it is not so great or regular as we would expect. We see that the total nitrogen is higher in the flinty berries; and this fact persists throughout the analyses for all the forms of nitrogenous substances determined. It is rather surprising that this is shown in the case of the Red Fife samples, for, as the footnote states, the distinction between flinty and starchy kernels in this case was difficult to make. The Kubanka was more easily sorted into two distinct classes. In the case of the check samples, we find that there is a difference of roughly, 0.32 percent of nitrogen in favor of the flinty berries; in the case of the samples grown with phosphorus 0.26 percent; and in the case of the samples grown with the application of potassium, 0.45 percent. We find for the true gluten a difference of 1.4 percent in favor of the flinty kernels in the case of phosphorus fertilization; 2.0 percent with potassium, and 2.0 percent in the case of the check plots. This is not the place to consider the character of the gluten, but it may be stated in a tentative and general way that this feature of the wheat is in favor of the starchy kernels. The glutenin-nitrogen is regularly higher in the flinty kernels.

The total ash is not given in the table, only the mineral, or ash-constituents in the air-dried grain. There are some differences suggested by the results given; the principal one is that the starchy wheats are higher in potassium than the flinty ones.

THE EFFECT OF IRRIGATION ON MEALINESS

Le Clerc attributes mealiness or starchiness in some instances, at least, to irrigation. He says: "It is almost always the case that irrigation tends to produce a mealy grain, although in several instances it has been noted that even under irrigation the grain has kept its flinty character. This is explainable only on the theory that the irrigation has not been excessive."*

Irrigation Had No Effect On Mealiness In Our Experiments

I do not think that this thesis can be maintained, for I have samples of dry-land wheat, winter-wheat of course, in which mealy berries are predominant, constituting 85 percent of the sample. Further, I have samples grown with the same amount of irrigation, which differ greatly in the proportion of mealy kernels present, from less than 20 to nearly 100 percent. The amount of water received during the whole life period of the plants was the same, in one year 21 and in another 19 inches, these are certainly not excessive quantities of water, especially if received as water of irrigation. Further, I have grown wheat with 19 and 31 inchs, four plots in each of two successive years. The total supply of 31 inches was at least 12 inches in excess of that required to produce a maximum crop. This excessive amount was applied on 12 July, shortly after the grain had set, and at a very great risk to the crop, for had we had a slight shower accompanied by wind, the grain would have gone down and been severely injured. The effect of this irrigation on the development of yellow-berry, or mealiness of the kernels was nil. If there be any difference in the samples of the different varieties treated in this manner, it is in favor of the heavier irrigation. These samples have been analyzed, and there are no differences that can be attributed to the difference in the amount of irrigating water applied. The four plots used in this case were checks, and had received no fertilizer, so they are thoroughly comparable with the other checks.

Through the kindness of Mr. Don. H. Bark, now with the Canadian Pacific Railroad, but formerly with the U. S. Department of Agriculture, I received a set of six samples grown under controlled conditions in regard to water applied and fertilization. The variety is Marquis. I will not give the analyses in this place, but simply state that the water applied to six one-tenth-acre plots varied from the rate of 1 to 3 feet per acre. The time from planting till harvest was 122 days; the time from the first till the last irrigation was 102 days, during which two of the six plots received 12 inches of water, two 24 inches, and two 36 inches each per acre. So far as the mealiness of these

* Yearbook U. S. D. A., 1906, p. 205.

samples is concerned, no differences are to be noted. Fortunately for our present purposes they are badly affected by yellow-berry and, apparently, equally so. It is scarcely possible that 1 foot of water applied in three applications distributed over 102 days was materially more than a necessary quantity, and yet the mealy berries are just as abundant in this wheat as in that that received 3 feet of water.

It may be well for me to state that in my own experiments I could not see that the second irrigation, applied on 12 July about 30 days before harvest, did either good or harm; it appeared to be entirely indifferent so far as my crop was concerned, and was worse than useless, because, I thereby exposed my crop to unnecessary risks of damage by wind. The growth of the plants was already luxuriant, and had only a slight shower, accompanied by wind, occured while the ground was as soft as a foot of water could make it, all manner of evils would have followed.

There is another very important feature connected with the samples Mr. Bark furnished me, i.e., three of the plots had received a heavy dressing of farmyard manure, sixteen loads to the acre, but I could not see that this had changed the character of the wheat. It increased both the amount of straw and grain, but had very little or no effect upon the character of the grain.

Irrigating Water and Rainfall May Have Entirely Different Effects

So far as mealiness and flintiness of the berries are concerned, the amount of water applied, up to 3 feet in 102 days, is without effect. I will digress to anticipate the discussion of our 1915 results to the extent of stating that *water applied to the ground in irrigation and water applied to the plant in the form of frequent light rains produce altogether different results.* Our crops in 1913 and 1915 are very different though they were grown with the same fertilization and the same amount of water, 19 inches in each case. In the former year we applied 12 inches of water and had 7 inches of rainfall, in the latter year, we applied 6 inches of water and had 13 inches of rainfall. The results are interesting, as we shall see when we come to discuss them, but so far as the question at present under consideration is concerned, they were practically without effect, which sustains my contention that these characteristics of the wheat kernel are dependent neither upon the weather nor the water applied, but upon the soil.

We have now, in addition to the facts adduced in Bulletin 205, the facts that berries grown on the same ground, under the same conditions of weather, differ in physical and chemical properties. Neither the weather nor water supply can be appealed to to account for this difference; wheat grown as dry-land wheat may be as badly affected by mealiness as wheat grown with irrigation. Water applied to the soil up to 3 acre-feet in 102 days does not produce mealiness to any greater extent than 1 acre-foot, or than may occur in dry-land wheat. It is shown, further, that when the water is applied to the plant in a succession of light rains very marked effects may be produced upon the composition of the plant and the grain, but the question of flintiness and mealiness, and the characteristics of such kernels, remain unaffected.

MEALINESS CAUSED BY TOO HIGH A RATIO OF POTASSIUM TO AVAILABLE NITROGEN

It was stated in Bulletin 205 that the cause of mealiness was an unfavorable ratio of potassium to available nitrogen, which, for the wheat plant, is equivalent to nitric-nitrogen. By unfavorable ratio of potassium in this case is meant one which is too high. Just what too high a one is we have not determined, but in our soil the application of 40 pounds of nitrogen in the form of sodic nitrate at the time of seeding spring-wheat is sufficient to change the product from a light colored one, in which plump, mealy berries, low in nitrogen are abundant, to one in which the berries are smaller, possibly shrunken, flinty, translucent, and richer in nitrogen. How much washing with irrigating water it may take to remove this nitrate beyond the reach of the plant and prevent its production of flinty grains has not been determined. Two feet of water, one applied on 12 June the other on 12 July, plus 7 inches of rainfall during the season, will not suffice to do it, nor will 6 inches of irrigating water plus 13 inches of rainfall prevent its producing flinty berries, even when no lodging takes place. Further, it has not been determined how small a quantity of nitrogen applied in this form may produce this effect, nor has it been determined at what period in the development of the plant its application will produce the most favorable result. We have demonstrated that application of nitrates made four weeks later still affect the growth of the plant, and further, that 80 pounds of nitrogen applied in two equal dressings four weeks apart will almost certainly do injury by lodging the straw, shrivelling the wheat, and inducing an attack of rust.

In Parts I and II of this study we have given much attention to the moisture, and also to the nitrates in the soil, their distribution, and the rate of their formation, because of their importance in this connection.

There is another view of the yellow-berry subject which connects it still more intimately with our experiments. This is the question whether the composition of flinty berries, such as is produced by the application of nitrogen as sodic nitrate, is desirable or not, which we will consider after we have given further data pertaining to our crops.

THE CRUSHING STRENGTH OF WHEAT

After explaining that flinty and mealy wheats differ in their structure, in that the mealy kernels contain air-filled spaces which reflect the light and cause the berries to appear white and opaque, and that the flinty berries, owing to the absence of such air-filled spaces, permit the passage of the light and therefore appear translucent or flinty, Schindler says that the flinty berries are designated as hard wheats and the mealy ones as soft wheats.* This is the clearest definition of these terms that I have met with, but they are not generally used with the sharp distinction of this definition. Attempts have been made to determine the degrees of hardness of different wheats and use the figures obtained as a means of classification. At the California Station they determined the weight necessary to cut the kernels when they were placed between the jaws of a pair of pinchers. † At the Kansas Station they used a "Grain Tester" devised in conjunction with Wm. Gaertner & Co., of Chicago, in which they determined the weight necessary to crush the kernels when placed under a steel pestle in a miniature mortar. § On page 374 of Kansas Bulletin 167, Prof. Roberts gives the following basis of classification. "In general we find that 'soft' wheats crush under a pressure of 6,000 grams or less (13 pounds), semi-hard wheats at about 9,000 grams (20 pounds) and hard wheats at 12,000 grams and over (26 pounds and over).

OUR METHOD OF DRYING

Prof. Roberts dried his samples for seven days at the boiling point of water under ordinary atmospheric pressure and preserved them in a desiccator till used. I dried our samples at 100° C., under a pressure of 75 mm. for 7 hours, corked the bottles tightly and preserved them in a desiccator. The object in this drying is to bring all of the samples to a common basis in regard to moisture, but it is a question whether there is any need of doing this, for the variation in moisture at a given locality is not great and this factor adjusts itself if wheat is transported from one place to another, and the tests are all made at the place of grading. There seems to be a more serious question raised by drying than the variation due to the moisture in the wheat, i.e., does drying at 100° C., for seven days leave the wheats in such a condition that the determination gives us the real crushing strength of the sample, or only that which it may chance to show under a purely artificial condition? Even this would not be a serious objection if we could be sure that all samples deported themselves in a similar

* Schindler, Der Getreidebau, 1909, p. 151.

† California Bul. 212, G. W. Shaw and A. J. Gaumnitz, p. 335.

§ Kansas Bul. 167, H. F. Roberts, "A Quantitative Method for the Determination of Hardness in Wheat."

manner under this treatment, for then, we could determine how much the crushing strength was decreased or increased by the drying and could make the proper addition or subtraction as necessary if deemed advisable. We have taken 36 groups of 350 kernels each, in all 12,600 kernels. Eighteen sets were dried as stated and 18 others were used in their air-dried condition. Air-dried, in our case, indicates about 10.0 percent of moisture in the wheat. The results are given in the following tabular statement:

CRUSHING STRENGTH OF SOME COLORADO WHEATS

	Air-dried	Oven-dried
Red Fife, received no irrigation	......	8.258
Defiance, received no irrigation	9.112	12.256
Harvest King, Grand Junction	......	7.420
Defiance, J. B. Hunter	......	7.496
Defiance, Red Cross Ranch, Clifton	......	11.386
Red Cross Winter Wheat, Fruita	......	7.188
Minnesota Spring No. 1	......	9.548
Minnesota Spring No. 2	......	9.094
Defiance, Agricultural College, Ft. Collins	......	12.367
Red Fife, Agricultural College, Ft. Collins	......	9.905
Marquis, Agricultural College, Ft. Collins	......	10.464
Red Fife, South Dakota Experiment Station	......	7.909
Kubanka, South Dakota Experiment Station	......	16.569
Defiance, Sect. 1800, 80 lbs. of nitrogen	10.087	10.623
Defiance, Sect. 1800, 40 lbs. of phosphorus	10.938	11.860
Defiance, Sect. 1800, 150 lbs. of potassium	11.042	12.759
Defiance, Sect. 1800, no fertilizer	11.190	12.048
Red Fife, Sect. 1800, 80 lbs. of nitrogen	11.212	10.263
Repeated	10.653	10.476
Red Fife, Sect. 1800, 40 lbs. of phosphorus	10.711	9.898
Repeated	10.235	10.184
Red Fife, Sect. 1800, 150 lbs. of potassium	10.678	9.946
Repeated	10.365	10.043
Red Fife, Sect. 1800, no fertilizer	10.971	10.082
Repeated	10.314	10.422
Kubanka, Sect. 1800, 80 lbs. of nitrogen	15.839	19.111
Kubanka, Sect. 1800, 40 lbs. of phosphorus	15.505	18.517
Kubanka, Sect. 1800, 150 lbs. of potassium	15.495	17.225
Kubanka, Sect. 1800, no fertilizer	15.364	19.122
Defiance, Sect. 1900, 100 lbs. of potassium, yellow-berry	8.213	9.197
Defiance, Sect. 1900, 100 lbs. of potassium, flinty	10.351	13.644
Kubanka, Sect. 1800, 150 lbs. of potassium, yellow-berry	......	13.056
Kubanka, Sect. 1800, 150 lbs. of potassium, flinty	......	18.234
Red Fife, Sect. 1800, 150 lbs. of potassium, yellow-berry	......	7.734
Red Fife, Sect, 1800, 150 lbs. of potassium, flinty	......	9.469

COLORADO WHEATS ARE SEMI-HARD TO HARD

According to the results obtained and adopting the suggested standard of classification, our wheats are semi-hard to hard. The Minnesota samples would be classed as semi-hard, while our Defiance would be classified as a hard wheat. My understanding of the situation is that our Defiance is classed by the millers as a soft wheat, and while the flour made from it is white and very pleasing to the eye, it is not a good bread-making flour, as it only makes from 250 to 260 loaves to the barrel.

In the case of the Defiance and also of the Kubanka, we find that drying as described, causes an increase of from 1,000 to about 3,000 grams in the crushing strength of the kernels, but in the case of the Red Fife, we find that drying has lowered the crushing strength. Of course, we base all statements on the assumption that 350 kernels, taken without choice, is sufficient to give us a close approximation to the average crushing strength of the samples. This number is adopted from the Kansas bulletin. We were surprised in the first place that the Red Fife should show a lower crushing strength than the Defiance, in the second place that its crushing strength should be lowered by the drying instead of raised, as in case of the other two varieties. It will be noticed that the whole series of experiments with the Red Fife was repeated, and that the second series corroborated the results of the first.

Further, these two series agree as closely as we have any right to expect them to agree. Feeling that I might be prejudiced in my results, i.e., the discrepancy between my results and the public estimate of the wheats experimented with, I requested a friend who is proficient in this kind of calculation to analyze the data given in the Kansas bulletin and see how closely their groups would agree; the results were more disconcerting to me than my own figures, and I am inclined to allow a variation of plus or minus 300 grams or more for single groups of 350 each. They, of course, may come much closer if the wheat is very uniform, which is seldom the case, as is evident on the most casual observation of our mixed wheats. The variation which may be found in individual samples, due to the flintiness or mealiness of the kernels, is indicated by the last six samples given in the second column of the table, or eight including the last two samples in the first column. This group of samples is given to show the difference in the crushing strength of flinty and mealy or yellow-berry kernels selected from the same sample, and consequently grown on the same soil under the same conditions of cultivation and climate. This difference for Defiance, dried at 100° C., is, in round numbers, 4,500, and in the air-dried condition 2,100 grams, and for the Kubanka, dried at 100° C., 5,200 grams. The difference shown by the table between the flinty and mealy kernels in the Red Fife sample, 1,700 grams, is altogether as significant as the greater differences found for the other varieties, because the sample grown with the application of 150 pounds of potassium was so badly affected by this condition that the selection of a flinty sample was exceedingly difficult, and the separation was only partially successful. One must acknowledge, however, that no one of the 21 samples of this variety tested showed more than a medium degree of hardness, according to this test. The maximum crushing strength, 11,212 grams, is found in the air-dried sample grown with the application of 80 pounds of nitrogen. This sample is to all appearances an unexceptional one.

PLANT'S NOURISHMENT INFLUENCES CRUSHING STRENGTH

Whether the result of classification by this method corresponds to the milling or flour-making qualities of the wheat or not, it serves to show according to the table given, that the plant's nourishment actually influences the crushing strength of the average kernel, and that yellow-berries are more easily crushed than the flinty ones. This is a conclusion at which one arrives with just as satisfactory a degree of certainty by crushing the berries between his teeth, but this method gives no measure of the difference. The differences in the cases given in the table, vary, from 1,400 to 5,000 grams, in favor of the flinty berries, and if a variation of 200 or even 300 grams from the true average exists, it scarcely lessens the value of the result, for it is only an approximation to the true average.

The results obtained with the Defiance samples, would seem to contradict all that we have affirmed concerning the effects of nitrates upon this feature of the kernels. An examination of the samples, however, suggests a ready explanation for the results. The sample grown with the application of potassium, consists of light-colored, plump kernels with a very low percentage of mealiness, while that grown with the application of nitrogen, consists of dark-colored, small, and to a large extent, badly shrunken kernels, so that the results given by the testing machine are just what one would expect from a simple examination of the samples. Had we picked out the shrunken kernels from the sample grown with nitrogen, or even sifted out the small kernels, and compared kernels of equal size we, undoubtedly, would have had a very different result. Such a procedure was, of course, not to be thought of; it would, however, have given us results for kernels more nearly normal and equal in size. How significant this factor is, may be inferred from the fact that the crushing strength of the individual kernels in the case of the nitrate sample varies from 5,000 to 17,000 grams. The difference in the size of the kernels is indicated by the weight for 1,000 kernels. The wheat grown with nitrate weighed 31.5 grams and that grown with potassium weighed 38.77, a difference of 23.0 percent. There was more difference than is suggested by these weights, for the wheat grown with the application of nitrogen is shrunken while that grown under other conditions is full and round;

this difference in form must certainly make a big difference in the crushing strength of the kernels, in whatever position they may be placed under the pestle. We placed every kernel in the same position, namely, crease downward. I do not think that there is any result obtainable by this method of investigation which is definite enough to advance the object of our investigation.

THE WHEATS GROWN AND CULTURAL METHODS USED

In the experiments planned to ascertain something definite concerning the part played by individual factors in determining the character of our wheat we have used three varieties. Defiance, a wheat of local origin, which has retained public favor in this State, for upwards of thirty years, Red Fife and Kubanka. I chose spring-wheat, because, until recently, almost no winter-wheat was grown in the State, further, because, its whole growing period, from planting till maturity, is short and without any resting period, or one principally of underground development, and also because we escape the danger of winter-killing. We grew twelve plots of each variety, three plots were dressed with sodic nitrate, three with rock superphosphate, three with potassic chlorid and three were used as check plots. This gives us 36 plots in all. The experiments with the different varieties were the same, so that the statement of them for one variety will suffice for the others.

In 1913, Sections 1700 and 1800 were plowed with a turning plow to a depth of 12 inches and with a subsoil plow to a depth of 16 inches, or 4 inches deeper than the turning plow. Section 1900 was turned to a depth of nine inches and not subsoiled. The deep cultivation was given, because the average depth to which it had previously been stirred was not more than 6 or 7 inches. The deep stirring was in some respects a mistake, but this has been discussed elsewhere and as no very serious results followed, it need not be discussed at this time. The fertilizers were applied as follows: Nitrogen at the rate of 120 pounds per acre to the plots receiving this fertilizer in Section 1700, 80 pounds to those in Section 1800 and 40 pounds to those in Section 1900. Phosphorus, at the rate of 60 pounds of soluble phosphorus to the acre, to the plots receiving this manure in Section 1700, 40 pounds to those in Section 1800, and 20 pounds to those in Section 1900. Potassium at the rate of 200 pounds per acre to those plots receiving it in Section 1700, 150 pounds per acre to those in Section 1800, and 100 pounds to those in Section 1900. There was a check plot in each section of land for each variety. It will be noticed that the plots in Section 1900 received the minimum amount. We have adhered to this order throughout the three seasons. The whole amount of phosphorus and potassium was applied at the time of planting and was harrowed in.

An application of 40 pounds of nitrogen was made to all of the plots that were treated to this manure at planting time and harrowed in just as the other fertilizers. But the plots receiving larger quantities received subsequent applications; those plots in Section 1800 another application of 40 pounds, and those in Section 1700 two other applications of this amount, 120 pounds in all. The applications of nitrogen, as sodic nitrate, were made at intervals of about four weeks. All plots received an irrigation 12-16 June and four plots received a second irrigation four weeks later, 11-13 July, in 1913 and 1914, but not in 1915, because the frequent light rains of this season kept the plants loaded with water. The characteristics of the weather, especially for 1913 and 1915, have been stated, as also have the general crop-data, yield per acre, weight per bushel, and the ratio of straw to grains. An examination of the figures giving this latter ratio will show that it is very abnormally high for the Defiance in 1914, and for all varieties in 1915. There were two causes operative in 1915 tending to bring this about. One of these causes was the presence of an unusually large amount of wild oats which increased the weight of the straw and for which no adequate compensation was made in the weight of the grain. This cause had nothing to do with this ratio for the Defiance in 1914.

RUST INCREASED RATIO OF STRAW TO GRAIN

While the following statements may not belong in this place, their misplacement may emphasize the explanation offered for the appearance of the wild oats, namely, that we distributed them over the land with the water that was applied the preceding autumn preparatory to cultivating it. This water simply washed out the ditches in which these wild oats had collected and distributed them on our land. The other cause alluded to, acted in a more direct and effective manner in increasing the ratio of straw to grain. This cause was the rust that developed on the plants. This parasite practically killed the Defiance wheat grown with the application of nitrogen in both 1914 and 1915. The grain produced in these plots could scarcely be called grain at all, and such as we got weighed as low as 52 pounds per bushel in 1914, and 47 pounds in 1915. The yield being low—it fell to less than 9 bushels in 1915—and the weight light, the ratio of straw to grain must necessarily be high. That this was wholly due to rust in 1914, and almost wholly so in 1915, there can be no doubt. The wild oats may be mixed with the wheat and increase the weight of the straw, but do not cause shrunken, light-weight grains, which is a characteristic effect of rust.

I have tried to show that we have but little justification in thinking that we can arrive at any certainty in regard to the real characteristics of our wheats by a study of general samples, because we have in them too great a variety of properties, and the effects of too many conditions, in part or wholly unknown to us. The big features of the climatic conditions have been asserted, but are not so well known that we can state exactly in what these consist. The influence of the soil-factors has been recognized in a general way, but has been considered small in comparison with climatic influences. Here again, neither the kind of effects, nor their extent have been made out. It may be, and probably is the fact, that the wheat plant is very susceptible to very slight changes in the balance of its nutritive solutions, and at the same time very sensitive, especially at certain periods in its development, to unfavorable climatic influences. Further, it is evidently very sensitive to the injury inflicted by some parasites, rust for instance. There may be differences in varieties in these respects, but there is no occasion for making modifications in these general statements, as they, in the main, seem to be correct.

COMPOSITION OF WHEATS GROWN IN 1913

The following tables present the composition of the wheats grown on our plots during the season of 1913, given by section and variety:

WHEATS GROWN ON EXPERIMENTAL PLOTS IN 1913—SECTION 1700

Variety	Fertilizer per Acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance,	Nitrogen 120 lbs......	11.825	1.921	1.598	2.362	2.630	14.989	59.788	1.142	35.37	13.98	10.340	0.442	0.440	33.50
Defiance,	Phosphorus 60 lbs.......	11.393	1.917	1.728	2.625	2.113	12.042	61.632	1.232	25.66	10.27	7.336	0.447	0.444	37.54
Defiance,	Potassium 200 lbs......	11.493	1.930	1.725	2.505	2.012	11.469	61.236	1.255	23.40	9.53	6.736	0.447	0.425	38.19
Defiance,	None	11.455	1.943	1.605	2.603	2.016	11.492	62.154	1.249	24.33	9.99	7.067	0.452	0.436	37.03
Red Fife,	Nitrogen 120 lbs.......	10.408	1.823	1.815	2.630	2.665	15.188	60.192	1.249	36.07	13.83	10.200	0.452	0.488	30.81
Red Fife,	Phosphorus 60 lbs.....	10.390	2.006	1.775	2.642	2.358	13.442	61.308	1.501	26.87	10.92	7.848	0.476	0.502	33.56
Red Fife,	Potassium 200 lbs.....	10.303	1.994	1.808	3.000	2.274	12.961	62.910	1.467	28.40	11.23	8.151	0.475	0.442	33.53
Red Fife,	None	10.910	2.053	1.778	2.708	2.270	12.936	62.338	1.289	27.10	11.06	7.990	0.449	0.453	33.75
Kubanka,	Nitrogen 120 lbs........	11.410	1.869	2.078	2.382	2.528	14.411	59.310	1.697	32.93	13.49	9.857	0.404	0.482	43.11
Kubanka,	Phosphorus 60 lbs.....	10.783	1.929	2.098	2.740	2.159	12.305	61.504	1.415	26.73	11.16	7.777	0.441	0.497	43.19
Kubanka,	Potassium 200 lbs......	10.505	1.988	1.843	2.400	2.160	12.311	62.028	1.467	26.47	11.34	7.761	0.431	0.473	42.72
Kubanka,	None	10.288	1.981	1.998	2.455	2.144	12.221	59.670	1.352	27.33	11.29	8.201	0.441	0.445	42.13

FORMS OF NITROGEN AS AFFECTED BY FERTILIZERS IN 1913—SECTION 1700

Variety	Fertilizer per acre	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Total Nitrogen Percent
Defiance,	Nitrogen, 120 lbs..	0.0699	0.2168	1.1789	1.1623	2.6297
Defiance,	Phosphorus, 60 lbs.	0.0418	0.1958	0.8756	0.9994	2.1126
Defiance,	Potassium, 200 lbs.	0.0523	0.1818	0.8238	0.9542	2.0121
Defiance,	None	0.0523	0.1958	0.8558	0.9022	2.0161
Red Fife,	Nitrogen, 120 lbs..	0.1049	0.2237	0.9855	1.3504	2.6645
Red Fife	Phosphorus, 60 lbs.	0.1328	0.2098	0.8830	1.1327	2.3583
Red Fife,	Potassium, 200 lbs.	0.1363	0.1958	0.7864	1.1554	2.2739
Red Fife,	None	0.1188	0.1678	0.8132	1.1697	2.2695
Kubanka,	Nitrogen, 120 lbs..	0.0804	0.1958	0.8755	1.3766	2.5283
Kubanka,	Phosphorus, 60 lbs.	0.0628	0.2517	0.9624	0.8818	2.1587
Kubanka,	Potassium, 200 lbs.	0.0663	0.1958	0.8704	1.0271	2.1599
Kubanka,	None	0.0593	0.1958	1.0498	0.8392	2.1441

WHEATS GROWN ON EXPERIMENTAL PLOTS IN 1913—SECTION 1800

Variety	Fertilizer per Acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance,	**Nitrogen 80 lbs.......**	**10.818**	**1.848**	1.728	3.007	2.435	13.788	60.264	1.051	31.33	12.32	9.220	0.393	0.446	32.73
Defiance,	Phosphorus 40 lbs....	10.665	**1.903**	**1.700**	**2.782**	**2.107**	**12.008**	**62.118**	**1.125**	**24.50**	**9.85**	7.038	0.442	0.437	38.76
Defiance,	Potassium 150 lbs....	10.675	1.860	1.705	2.738	2.163	12.330	63.014	1.455	24.50	10.08	7.099	0.408	0.420	39.94
Defiance,	None	11.268	1.695	1.780	2.568	2.130	12.139	61.830	1.352	25.07	10.22	7.313	0.416	0.453	38.84
Red Fife,	Nitrogen 80 lbs.......	9.828	1.928	1.810	2.684	2.616	14.909	60.002	1.329	32.20	12.84	9.487	0.405	0.466	34.36
Red Fife,	Phosphorus 40 lbs.....	9.810	2.085	1.783	2.525	2.323	13.242	61.340	1.091	27.00	11.04	8.171	0.458	0.440	34.59
Red Fife,	Potassium 150 lbs....	10.095	2.013	1.918	2.582	2.422	13.806	61.760	1.221	27.20	11.07	8.039	0.459	0.423	35.94
Red Fife,	None	10.633	2.050	1.865	2.755	2.531	14.428	61.882	1.147	28.83	11.55	8.335	0.462	0.410	35.34
Kubanka,	Nitrogen 80 lbs.......	11.780	**1.721**	**1.995**	2.830	**2.414**	13.758	60.894	1.449	30.10	12.30	8.530	0.373	0.423	42.18
Kubanka,	Phosphorus 40 lbs...	11.215	1.877	1.935	2.412	2.090	11.911	61.578	1.519	26.50	11.06	7.815	0.407	0.477	43.56
Kubanka,	Potassium 150 lbs....	11.110	1.875	1.935	2.462	2.111	12.032	62.622	1.392	25.50	10.60	7.316	0.411	0.434	43.76
Kubanka,	None	11.330	1.971	1.800	2.862	2.114	12.048	63.374	1.438	25.33	10.63	7.572	0.423	0.480	45.96

FORMS OF NITROGEN AS AFFECTED BY FERTILIZERS 1913—SECTION 1800

Variety	Fertilizer per acre	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Total Nitrogen Percent
Defiance,	Nitrogen, 80 lbs...	0.0699	0.1748	1.0764	1.1134	2.4345
Defiance,	**Phosphorus, 40 lbs.**	0.0628	0.1888	0.8506	1.0045	2.1067
Defiance,	Potassium, 150 lbs.	0.0558	0.1818	0.8716	1.0539	2.1631
Defiance,	None	0.0523	0.1678	0.8704	1.0392	2.1297
Red Fife,	Nitrogen, 80 lbs...	0.1049	0.2028	0.9855	1.3224	2.6156
Red Fife,	Phosphorus, 40 lbs.	0.0979	0.2028	0.8900	1.1324	2.3231
Red Fife,	Potassium, 150 lbs.	0.1014	0.2307	0.8771	1.2129	2.4221
Red Fife,	None	0.0944	0.2377	0.8982	1.3009	2.5312
Kubanka,	Nitrogen, 80 lbs...	0.0628	0.2168	0.9298	1.2043	2.4137
Kubanka,	Phosphorus, 40 lbs.	0.0523	0.2168	0.9356	0.8849	2.0896
Kubanka,	Potassium, 150 lbs.	0.0488	0.2237	0.7947	1.0437	2.1109
Kubanka,	None	0.0523	0.2237	0.8191	1.0186	2.1137

WHEATS GROWN WITH FERTILIZERS IN 1913—SECTION 1900

Variety	Fertilizer per Acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance,	Nitrogen 40 lbs.......	11.763	1.851	1.728	2.532	2.290	13.051	63.486	1.306	24.33	10.13	7.241	0.454	0.476	35.01
Defiance,	Phosphorus 20 lbs....	11.830	1.792	1.820	2.600	1.865	10.631	64.010	1.392	20.17	8.53	5.854	0.456	0.473	35.23
Defiance,	Potassium 100 lbs....	11.565	1.894	1.798	2.528	1.960	11.173	63.400	1.215	23.00	9.57	6.413	0.480	0.476	38.74
Defiance.	None	11.798	1.905	1.775	2.575	2.038	11.615	63.324	1.063	23.50	9.59	6.914	0.480	0.480	36.37
Red Fife,	Nitrogen 40 lbs.......	10.363	1.961	1.803	2.512	2.543	14.493	61.956	1.438	30.07	12.26	8.709	0.479	0.501	33.82
Red Fife,	Phosphorus 20 lbs....	10.653	2.065	1.860	2.600	2.394	13.646	62.334	1.478	28.40	11.67	8.305	0.522	0.496	34.18
Red Fife,	Potassium 100 lbs....	10.278	2.077	1.878	2.617	2.487	14.178	61.812	1.323	27.66	11.16	8.174	0.505	0.444	34.20
Red Fife,	None	10.378	2.060	1.750	2.675	2.470	14.079	63.290	1.352	28.57	11.58	8.305	0.506	0.454	34.22
Kubanka,	Nitrogen 40 lbs.......	11.515	1.822	1.878	2.437	2.261	12.887	61.272	1.656	28.80	11.82	8.407	0.419	0.461	46.82
Kubanka,	Phosphorus 20 lbs....	11.248	1.974	1.960	2.562	2.187	12.464	63.090	1.549	26.66	10.92	7.803	0.444	0.471	46.53
Kubanka,	Potassium 100 lbs....	10.850	1.889	1.748	2.600	2.253	12.843	61.729	1.341	25.57	10.80	7.781	0.432	0.497	45.33
Kubanka,	None	11.200	1.947	1.813	2.522	2.207	12.583	62.046	1.467	25.40	10.79	7.661	0.458	0.494	45.53

FORMS OF NITROGEN AS AFFECTED BY FERTILIZERS 1913—SECTION 1900

Variety	Fertilizer per acre	Amid Nitrogen Precent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Total Nitrogen Percent
Defiance,	Nitrogen, 40 lbs...	0.0488	0.1958	0.8599	1.1852	2.2897
Defiance,	Phosphorus, 20 lbs.	0.0453	0.1958	0.7143	0.9097	1.8651
Defiance,	Potassium, 100 lbs.	0.0384	0.2098	0.7631	0.9601	1.9601
Defiance,	None	0.0483	0.2028	0.8417	0.9449	2.0377
Red Fife,	Nitrogen, 40 lbs...	0.0909	0.2098	0.9436	1.2983	2.5426
Red Fife,	Phosphorus, 20 lbs.	0.0909	0.2517	0.8923	1.1591	2.3940
Red Fife,	Potassium, 100 lbs.	0.0909	0.2866	0.9203	1.1895	2.4873
Red Fife,	None	0.0593	0.3006	0.9472	1.1629	2.4700
Kubanka,	Nitrogen, 40 lbs...	0.0349	0.2726	0.8738	1.0796	2.2609
Kubanka,	Phosphorus, 20 lbs.	0.0349	0.2447	0.8459	1.0611	2.1866
Kubanka,	Potassium, 100 lbs.	0.0628	0.2098	0.7527	1.2279	2.2532
Kubanka,	None	0.0418	0.2377	0.8110	1.1171	2.2076

MINERAL CONSTITUENTS OF WHEAT GROWN AT FORT COLLINS, CROP OF 1913

Variety	Fertilizer per Acre	Sp. Gr.	SiO_2 Percent	Fe Percent	Mn Percent	Ca Percent	Mg Percent	K Percent	Na Percent	Cl Percent	S Percent	Total P Percent	Inorganic P Percent	Organic P Percent	Total N Percent
Defiance	Nitrogen 80 lbs..	1.4228	0.011	0.004	present	0.043	0.132	0.419	0.023	0.058	0.153	0.393	0.026	0.367	2.435
Defiance	Phosphorus 40 lbs......	1.4311	0.016	0.004	present	0.036	0.146	0.408	0.036	0.052	0.120	0.442	0.029	0.413	2.107
Defiance	Potassium 150 lbs......	1.4355	0.015	0.006	present	0.030	0.136	0.401	0.041	0.058	0.128	0.408	0.023	0.385	2.163
Defiance	None	1.4347	0.030	0.005	present	0.037	0.141	0.391	0.037	0.060	0.116	0.416	0.029	0.387	2.119
Red Fife	Nitrogen 80 lbs........	1.4405	0.044	0.005	present	0.033	0.150	0.438	0.027	0.072	0.120	0.414	0.022	0.392	2.615
Red Fife	Phosphorus 40 lbs......	1.4429	0.013	0.007	present	0.033	0.155	0.439	0.022	0.063	0.115	0.456	0.030	0.426	2.323
Red Fife	Potassium 150 lbs......	1.4468	0.009	0.007	present	0.027	0.152	0.430	0.019	0.093	0.114	0.457	0.026	0.431	2.422
Red Fife	None	1.4401	0.017	0.006	present	0.038	0.153	0.444	0.010	0.135	0.113	0.461	0.029	0.432	2.521
Kubanka	Nitrogen 80 lbs........	1.4400	0.031	0.005	present	0.048	0.133	0.453	0.002	0.117	0.124	0.364	0.014	0.350	2.442
Kubanka	Phosphorus 40 lbs.	1.4354	0.034	0.005	present	0.041	0.141	0.453	0.016	0.134	0.101	0.407	0.016	0.391	2.085
Kubanka	Potassium 150 lbs......	1.4368	0.010	0.004	present	0.035	0.122	0.458	0.011	0.129	0.104	0.411	0.017	0.394	2.111
Kubanka	None	1.4355	0.030	0.005	present	0.031	0.137	0.454	0.010	0.130	0.093	0.423	0.016	0.407	2.114

SEASON OF 1913 VERY FAVORABLE—WHAT OUR EXPERIMENTS SHOWED US

The season of 1913 was very favorable throughout the whole period of growth and ripening. The early spring was quite wet and our planting was late. The period from planting till harvest was 101 days. There was very little rust, so little that we shall consider its effects negligible. A comparison of the nitrogen found in the three samples of each variety grown on the check plots shows that there is a greater variation in them than can be attributed to errors in the determinations; further, that, corresponding to the differences in the check plots, the samples of Defiance and Red Fife are higher on Section 1800 than on the other two sections. In the case of the Kubanka, there is but little difference, especially in samples grown without the application of nitrogen. It shows, further, that there is an increase of nitrogen in those samples grown with the application of this element over that found in the check plots for each variety of wheat and in each section. This increase equals from one to six-tenths of one percent. This difference is consistent, too, throughout the statement for the wet, dry and true-gluten. It has frequently been shown that the nitrogen content of wheat can be increased by the application of sodic nitrate and also by ammoniacal salts. This statement is also made in regard to other nitrogenous manures, sheep manure for instance. This statement, according to our observation, needs the following modification: Provided the nitrogen is converted into nitric-nitrogen with sufficient rapidity. We have used only one form of nitrogen in our experiments at Fort Collins, sodic nitrate, but we have one set of samples grown with farmyard manure, which gives different results. Our samples grown with the application of nitrogen, in the form of sodic nitrate, regularly show an increase in the nitrogen content of the crops. Crops grown with farmyard manure, show a decided advantage in yield, both of straw and grain, but only a very small increase in the nitrogen content. The maximum difference in any one of the three pairs of samples was 0.20 percent nitrogen; the other two pairs show a difference of 0.01 and 0.05 percent respectively. The greatest difference, 0.20 of one percent, may be due to other causes than the manure, but as the record stands, this difference would be attributed to its effects. These samples were obtained for another purpose and will be given in connection with the subject that they are more specifically intended to illustrate. I have not used ammoniacal salts on any plots, and can only state, on the authority of others, that their effects are the same as those of nitrogen in the form of sodic nitrate.

Two other questions present themselves for consideration in this connection, namely, are there any effects produced by the other plant foods which we can recognize as specifically due to them, and are our analytical results accurate enough to justify us in assuming that the differences found are well enough established to be taken as the basis of inferences in regard to these effects? We should extend these questions to include regularity in the direction of these differences, not only for the samples of the different varieties for one year, but in these same varieties for several years.

I am very firmly convinced that minute differences as expressed in percentage composition correspond to very significant differences in the properties of the wheat, provided that we can be certain that the percentages obtained are correct within limits, as narrow as or narrower than those with which the properties of the grain actually vary. I fear that it is so difficult to attain to this degree of certainty in regard to our analytical results, that these questions in regard to the specific effects of fertilizers and the manner in which they modify one another must remain in some doubt.

The analyses given in the preceding tables are all based on the air-dried grain. The moisture in our samples is quite constant for the individual varieties grown on the same section of land. There is but one instance in nine groups of four samples each in which we find a difference as great as or greater than 1 percent, so that the differences in the percntage, of potassium, for instance, due to this variation will fall in the third decimal place and will be less than five. The ash constituents in the wheat were determined by one analyst, and the phosphorus and potassium in the general analyses of wheat by another. The methods used in the case of the phosphorus were the same, but they used different methods in determining the potassium. The difference in the percentages of the potassium due to this cause is from two to three one-hundredths of 1 percent. A comparison of the results obtained will show but one or two serious discrepancies. On the other hand, we find such agreement in the big features of the results that we can accept them as established on a pretty firm basis.

There are reasons why we should prefer not too accept the results of the 1913 crop as indicative of the effects of the soil factors upon the composition of the wheat. One reason is that the land had been in other crops during the preceding years and we do not know with as much certainty as we should the conditions preceding the growing of this crop. On the other hand, this crop grew and matured under favorable weather conditions, and probably gives us the most representative samples of our average wheat that we have obtained, but it is doubtful whether it gives us the best illustration of the influence of the soil factors upon the composition of the wheat.

EFFECTS OF FERTILIZERS ON THE THICKNESS OF THE BRAN

It is usual to take the nitrogen content as the principal criterion in judging the differences in wheat. The other constituents usually given in an analysis, moisture, ash, fat, fiber, and even starch, are of much less importance. The crude fiber as determined in the wheat corresponds roughly to the epidermal portions of the wheat, and in a rough way indicates the relative thickness of these parts. It might be interesting from an anatomical standpoint, to know whether the fertilizers influence these protective features of the grain or not, and how, but for our purposes these points are not of much interest and the results of the 36 analyses of wheat grown on our own plots, presented in the preceding tables, indicate no decisive and constant difference. The range of these determinations in the 36 samples is from 2.400 to 3.007 percent, or a maximum variation of 0.607 percent. The average percentage of crude fiber in the samples grown with application of nitrogen is, taken literally, the least of the four averages and that of those grown with potassium, the highest. The difference is 0.12 percent, too small for consideration from our standpoint. The starch, owing to its large percentage, will reflect the variation in the protein, the substance present in the next largest quantity; these two substances present in wheat in the largest quantities must bear an inverse relation to one another. There is nothing in our analyses to show that this is anything more than a numerical relation. If there be any other relation between these substances it is not shown by our results so far given. The formation of starch or carbohydrates, in general, may influence that of the protein or vice versa, but this is a physiological relation which our work does not present. The question of flinty and mealy kernels probably comes within the province of this relation. We have shown in Bulletin 205 that this is directly a question of the ratio between the nitrogen and potassium present in the soil and available to the plant. The ash in the analyses given was determined by the usual method of incineration, i.e., charring, extraction with water and subsequent ignition. There is no question but that some loss occurs in this method, but not enough to vitiate the results. The nine sets of samples agree in showing that those grown with the application of nitrates are a little lower than the others. This will be found to be the rule, but it is not altogether without exception. It is owing to difficulties in preparing the ash of grain and also of the straw that I have used the form "ash-constituents" in stating the analytical results of such determinations for both wheat-straw and grain. Leavitt and Le Clerc * have shown that there may be a very considerable loss of phosphorus in direct calcination. They found the difference between incineration at low redness and "redness" to equal 46.0 percent of the

* Journal Am. Chem. Soc., Vol. 30, pp. 391-394.

phosphoric acid, that between incineration at "redness" and the acetate method to be equal to 35.0 percent of the P_2O_5. Without any knowledge of the results obtained by these authors, I found that it is practically impossible to obtain correct results in making this determination by igniting at a very low temperature, in a partially covered crucible over a very low Bunsen flame. I made a series of 38 determinations by ignition, and by dissolving in concentrated nitric acid with the addition of a sufficient quantity of magnesic oxide and subsequent ignition, and found the differences ranging from 10.0 to 37.0 percent of the phosphorus present. The determination of phosphorus in straw by ignition is still more difficult, owing to the excess of silica and carbon which, at a comparatively low temperature, may cause the volatilization of practically the whole of the phosphorus.

Leavitt and LeClerc think that the loss of phosphorus in making the determination of total ash in grain may be neglected.* According to our observations, the method of charring and extracting with water is unsatisfactory, especially if we are to consider differences of one or two tenths, or even hundredths of 1 percent, as significant of the effects of fertilizers or weather conditions. The results given in the preceding tables were obtained by this method, and we justify the use of these results on the supposition that, the method having been worked in a uniform manner, the results have an error, but this is common to all of them and in the same direction. The ash, or mineral-constituents, given in the table under the latter caption, were not determined by preparing an ash by the usual incineration. The air-dried wheat was dissolved in concentrated nitric acid and subsequently ignited, but this is not the place for these technical details.

The standards adopted for reference are averages given by Leach in his work on "Food Inspection and Analysis". Reference will also be made to Hungarian wheats given by Kosutany.

* Loc. Cit.

AVERAGE COMPOSITION OF WHOLE WHEAT*

	Domestic		Foreign	
Weight of 100 kernels	3.866 grams		4.076 grams	
	Percent		Percent	
Moisture	10.62		11.47	
Protein	12.23	(11.16 Nx5.7)	12.08	(11.02 Nx5.7)
Fat	1.77		1.78	
Fiber	2.36		2.28	
Ash	1.82		1.73	
Carbohydrate (Diff)	71.18	(72.27)	70.66	(71.72)
Wet Gluten	26.46		25.36	
Dry Gluten	10.31		9.82	

Leach gives a somewhat fuller analysis of wheat, taken from a tabulation of the composition of the principal cereal grains by Villier and Collin†.

Water	13.65	
Protein	12.35	(11.25 Nx5.7)
Fat	1.75	
Sugar	1.45	
Gum and Dextrin	2.38	
Starch	64.08	
Cellulose	2.53	
Ash	1.81	

THE COMPOSITION OF HUNGARIAN WHEAT

The following table giving the data pertaining to the composition of Hungarian wheat is of interest, if for no other reason, because of the universally high reputation of Hungarian flour. I have preferred to give Kosutany's data for each of the six seasons rather than to average them, for this would obscure, or entirely conceal, the seasonal differences.

*Leach "Food Inspection and Analysis," p. 272.
†Leach "Food Inspection and Analysis," p. 271.

MINIMUM, MAXIMUM AND AVERAGE COMPOSITION OF HUNGARIAN WHEAT*

Harvest	Weight per 1000	Mealiness	Moisture	Ash	Fat	Fiber	Nitrogen	Protein		N-free	Wet Gluten	Dry Gluten
Minimum	24.67	20.44	10.95	1.129	1.709	1.129	1.733	10.836		64.824	15.00	5.75
Maximum	41.72	75.10	14.40	1.958	2.309	1.958	2.731	17.074		70.811	34.45	11.95
Average 50/50.......	31.424	41.857	12.612	1.735	2.056	1.735	2.106	13.162	(12.004)† (Nx5.7)	67.915	21.70	7.962
Minimum	23.11	4.50	11.602	1.38	1.673	1.860	1.846	11.534		61.34	17.00	6.85
Maximum	38.50	75.87	15.162	2.26	2.399	3.351	2.950	18.434		70.06	43.40	14.80
Average 57/57	29.38	24.56	13.545	1.73	2.051	2.471	2.298	14.366	(13.099) (Nx5.7)	65.78	26.77	9.87
Minimum	23.90	4.12	11.79	1.22	1.61	1.69	1.380	8.63		63.58	18.50	6.85
Maximum	40.24	77.87	16.86	1.96	2.30	2.43	2.600	16.25		71.77	50.75	15.30
Average 53/53.......	31.42	36.44	14.57	1.58	1.94	2.01	1.897	11.86	(10.83) (Nx5.7)	68.04	26.17	9.64
Minimum	27.60	6.24	9.99	1.40	1.41	2.02	1.667	10.42		67.40	23.95	7.32
Maximum	43.16	71.24	11.34	1.89	1.73	2.74	2.624	16.40		73.43	44.87	14.75
Average 53/53.......	34.39	33.71	10.82	1.66	1.54	2.36	1.991	12.44	(11.35) (Nx5.7)	71.17	30.30	10.21
Minimum	26.63	0.00	10.34	1.44	1.44	2.06	1.684	10.54		67.13	22.90	8.12
Maximum	42.88	62.00	11.40	1.91	1.84	2.72	2.803	17.52		72.94	52.00	15.90
Average 53/53.......	33.78	24.09	10.80	1.66	1.60	2.31	2.122	13.23	(12.20) (Nx5.7)	70.36	32.72	11.63
Minimum	27.53	0.00	10.03	1.41	1.34	2.01	1.750	10.94		61.94	24.55	8.33
Maximum	40.17	82.00	11.23	1.98	1.88	2.66	3.395	21.22		72.82	52.55	18.83
Average 53/53.......	36.62	26.08	10.91	1.73	1.61	2.30	2.319	14.37	(13.22) (Nx5.7)	69.09	37.33	12.11

*Kosutany, "Der ungarische Weizen und das ungarische Mehl"—pp. 102-108.

†I have added the product, Nx5.7, because we have used this factor, while Kosutany used 6.25.

CHECK SAMPLES OF 1913 REPRESENT NORMAL COLORADO WHEAT

In my judgment we have no set or sets of samples which are more fairly representative of normal Colorado wheat than the check samples grown in 1913. We may include with these the samples grown with the application of potassium and also those grown with the application of phosphorus, but not those grown with the application of nitric nitrogen. My reasons for including the former, but not the latter samples, are that the former differ less from those grown on the check plots in their physical properties, than samples grown in the same district differ from one another, but which is not true of those grown with the application of nitrates. It is true that we find the same kind of differences, and as great, in the samples of wheat grown in different sections of the State, as we find in our samples grown under different conditions, but the marked exceptions of this character, which have fallen under my observation, have been due to an unusual supply of nitric-nitrogen formed in the soil. We would obtain a better average for our wheats by including the samples grown with the applications of nitric-nitrogen, but our object is to present the facts, as nearly as we may see them, and not to present a good average composition for our wheat.

In the following statement, the analysis given under each section is the average of wheat from three plots, a check plot, a plot with the addition of phosphorus and one with the addition of potassium. The average in each case is really the average of nine analyses. The varieties are given and no remarks are needed in this place.

AVERAGE COMPOSITION OF WHEATS (IN PERCENT) GROWN WITHOUT THE APPLICATION OF NITROGEN IN 1913*

	Defiance				Red Fife				Kubanka				
	Sec. 1700	Sec. 1800	Sec. 1900	Avg.	Sec. 1700	Sec. 1800	Sec. 1900	Avg.	Sec. 1700	Sec. 1800	Sec. 1900	Avg.	General Avg
Moisture	11.447	10.836	11.731	11.338	10.534	10.179	10.403	10.372	10.525	11.218	11.099	11.047	10.919
Ash	1.927	1.819	1.931	1.893	2.024	2.049	2.067	2.047	1.966	1.908	1.937	1.937	1.959
Fat	1.686	1.728	1.798	1.771	1.787	1.755	1.829	1.790	1.979	1.890	1.840	1.903	1.821
Fiber	2.578	2.696	2.568	2.614	2.783	2.621	2.361	2.588	2.532	2.579	2.561	2.557	2.586
Nitrogen	2.047	2.133	1.955	2.045	2.301	2.425	2.450	2.392	2.154	2.105	2.216	2.158	2.178
Protein (Nx5.7)	11.668	12.159	11.140	11.656	13.103	13.825	13.968	13.632	12.279	11.997	12.630	12.302	12.530
Starch	61.674	62.321	63.578	62.558	62.185	61.661	62.479	62.108	61.067	62.526	62.288	61.961	62.209
Sucrose	1.245	1.311	1.223	1.256	1.419	1.153	1.384	1.319	1.411	1.450	1.452	1.438	1.338
Wet Gluten	24.450	24.690	22.220	23.790	27.460	27.680	28.210	27.780	26.840	25.780	25.870	26.160	25.910
Dry Gluten	9.930	10.050	9.230	9.770	11.070	11.220	11.470	11.250	11.260	10.760	10.840	10.950	10.680
True Gluten	7.045	7.150	6.394	6.863	7.996	8.182	8.261	8.146	7.913	7.567	7.748	7.743	7.584
Phosphorus	0.445	0.422	0.472	0.446	0.467	0.460	0.511	0.479	0.438	0.414	0.445	0.432	0.452
Potassium	0.435	0.437	0.476	0.449	0.466	0.424	0.465	0.452	0.472	0.463	0.487	0.473	0.458

* Each analysis in this table is an average of three analyses.

THE EFFECT OF NITRATES ON NITROGEN CONTENT

That the nitrogen content of wheat may be increased by the application of sodic nitrate or ammonia salts, has been known a long time, so there is nothing new in the statement of the fact. The nitrates impart characteristic physical properties to wheat grown with their application. These properties are usually considered desirable if the nitrate is not added in too large quantities. The following analyses are given to show to what extent the chemical composition was affected, and also to show why we omitted them from the samples taken as representative of our wheats. The reason, for the present time at least, may be stated to be that they are quite different from the average of wheats grown without it. The statement of the analyses will show how different they are, and to what extent the composition of the wheat responds to the application of various amounts of this salt. The results in this respect increase with the amount applied, but the effect produced is not proportional to the amount, i.e., the minimum amount produces a certain result; three times this amount will not necessarily produce three times this effect, it may be more or less than three times. The same is true of the physical characteristics of the berries, the larger amounts showing a strong tendency to produce shrunken berries.

AVERAGE COMPOSITION OF WHEATS (IN PERCENT) GROWN WITH APPLICATION OF NITROGEN—1913

	Deflance				Red Fife				Kubanka				
	Nitrogen Per Acre				Nitrogen Per Acre				Nitrogen Per Acre				
	120 lbs. Sec. 1700	80 lbs. Sec. 1800	40 lbs. Sec. 1900	Avg.	120 lbs. Sec. 1700	80 lbs. Sec. 1800	40 lbs. Sec. 1900	Avg.	120 lbs Sec. 1700	80 lbs. Sec. 1800	40 lbs Sec. 1900	Avg.	General Avg.
Moisture	11.825	10.818	11.763	11.469	10.408	9.828	10.363	10.200	11.410	11.780	11.515	11.568	11.079
Ash	1.921	1.848	1.851	1.873	1.823	1.928	1.961	1.904	1.869	1.721	1.822	1.771	1.849
Fat	1.598	1.728	1.728	1.685	1.815	1.810	1.803	1.809	2.078	1.995	1.878	1.984	1.826
Fiber	2.362	3.007	2.532	2.634	2.630	2.684	2.512	2.609	2.382	2.830	2.437	2.550	2.598
Nitrogen	2.630	2.435	2.290	2.452	2.665	2.616	2.543	2.608	2.528	2.414	2.261	2.401	2.487
Protein (Nx5.7)	14.989	13.788	13.051	13.943	15.188	14.909	14.493	14.863	14.411	13.758	12.887	13.719	14.175
Starch	59.788	60.264	63.486	61.179	60.192	60.002	61.956	60.717	59.310	60.894	61.272	60.492	60.796
Sucrose	1.142	1.051	1.306	1.166	1.249	1.329	1.438	1.339	1.697	1.449	1.656	1.601	1.369
Wet Gluten	35.370	31.330	24.330	30.343	36.070	32.200	30.070	32.780	32.930	30.100	28.800	30.610	31.244
Dry Gluten	13.980	12.320	10.130	12.150	13.830	12.840	12.260	12.980	13.490	12.300	11.820	12.540	12.560
True Gluten	10.340	9.220	7.241	8.934	10.200	9.487	8.709	9.465	9.857	8.530	8.407	8.931	9.110
Phosphorus	0.442	0.393	0.454	0.423	0.452	0.405	0.479	0.445	0.404	0.373	0.419	0.399	0.422
Potassium	0.440	0.446	0.476	0.454	0.488	0.466	0.501	0.485	0.482	0.423	0.461	0.455	0.465
Weight per 1000		32.730				34.360				42.180			

NITRATES CAUSE A DEPRESSION OF PHOSPHORUS

The physical characteristics of the berries produced by the application of nitrogen have already been mentioned. These kernels are relatively small, flinty, translucent, hard, and often shrunken. The marked feature of the composition is the increase in the nitrogen content; and with this, in the wet, dry, and true gluten. The differences between the phosphorus in the general averages given in the last two tables differ only a few hundredths of 1 percent, but a comparison of the phosphorus given in the other analyses shows that this element is regularly lower in the nitrate samples, than in the others. In other words, assuming that the check plots give us wheat of normal phosphorus content, the nitrates have caused a depression of this element.

NITRATE-FERTILIZED PLANTS MORE SUSCEPTIBLE TO RUST

In Bulletin 208, and again in Bulletin 217, it was shown that nitric-nitrogen produces marked effects upon the composition of the plant in that it increases all forms of nitrogen in the plant throughout the season; further, that it exercises a decided influence upon the mineral constituents of the plant; first in depressing the silicon, second in increasing the calcium, potassium and magnesium, but does not effect the phosphorus. Its effect upon the phosphorus in the grain is to depress it. This is quite evident in the table entitled "Mineral Constituents of Wheat, Crop of 1913". The difference in the general averages given in the two preceding tables is small, but this difference is persistent and, with few exceptions, plainly appears in individual analyses. The effect upon the amount of potassium is in the same direction in both plant and grain, namely to increase it, but this is less marked in the grain than in the plant. The whole character of the plant and its products, as well as its appearance, is, according to this, greatly affected by the supply of nitric-nitrogen in the soil. This conclusion is entirely in harmony with the deportment of the plant, which lodges easily, and when not lodged often shows marked abnormality in ripening, the middle portions of the plants and leaves remaining green, or at least very immature, while the top and bottom portions appear, and I think are, ripe. Further, I do not think that any doubt can be entertained that these plants are much more readily attacked by rust, than others of the same variety grown with other fertilizers or with none. There are differences which are known and really need no mention, such as the softness of the straw, a feature which is evident to persons handling it. There is a marked depression of silicon ranging from 14 to 29 percent of the total in the plant. I do not know how significant this difference may be, nor do I know that the weakness and softness of the straw is dependent upon this difference; I do not intend to attempt to give an explanation of these facts. It is, however, clear that both the plants and grain grown with the application of nitrates are different in chemical composition as well as in physical properties from those grown without them. These latter, and, in fact, the former also, are those ascribed to hard wheats, small, translucent, dark amber, flinty berries with high nitrogen content, at least, higher nitrogen content than wheat of the same variety grown under otherwise identical conditions, including both soil and climate.

COMPARISON OF STANDARDS ADOPTED AND RESULTS GIVEN

It may now not only be permissible, but advisable, to point out some of the relations between the standards adopted and the results given by our general samples, as well as with our wheats grown under more definitely known conditions.

I take it that the average given by Leach in his work includes both spring and winter-wheat, and some allowances should be made for this fact, though it does not appear from our general samples that there is any distinction to be made in regard to nitrogen content or degree of mealiness. Nevertheless, it is proper to remember that the wheats experimented with are all spring-wheats, though I do not believe that emphasis should be laid upon this fact. The weight per 1,000 kernels varies with the varieties. The average for the Defiance grown without nitrate is 39.18, for Red Fife 35.29 and for Kubanka 44.42 grams. Two of them are higher than the averages given for domestic wheats and one lower. The Red Fife is a small-kerneled wheat and the Kubanka, as it ordinarily grows with us, a large-berried one. In these counts all kernels were taken, and the wheat had not been screened after threshing. Carefully screened wheat should give a higher weight per thousand. The chief feature in the statement of the composition is the close agreement between the standards given and our averages, even the protein differs less from that given in the standards than some of our individual samples not grown with the application of nitrogen differ from one another. The standard for domestic wheats is 11.16 percent (N x 5.7), for foreign wheats 11.02 (N x 5.7); we obtain 12.53 percent. The starch is quoted from Villier and Collin as 64.08; we obtain 62.20 percent. The wet gluten is so dependent upon the manipulator that its value is but small; the dry gluten is a much better criterion and this we find given as 10.31 percent for domestic wheat, ours gives 10.68 percent. If we average the six crops of Hungarian wheat given by Kosutany, we obtain for protein 12.10 (N x 5.7) and for dry gluten 10.24; figures very close to those given by our Colorado wheats, 12.53 and 10.68 respectively. The Hungarian wheats do not average so high in their absolute weight as ours, 1,000 grains averaged for the six years 32.83 grams. One of these six years yielded grain apparently somewhat smaller in kernel than usual and was, perhaps, an abnormal one, still the maximum average is only a little above the maximum for our smallest grained variety, the Red Fife, i.e., 36.62 against 35.94.

The general samples of winter-wheat average 13.31 percent protein and 11.59 percent dry gluten, the general samples of spring-wheat average 13.32 percent protein and 11.74 percent of dry gluten. Each of these pairs of averages is higher than the corresponding data for our spring-wheats, but lower than for our samples grown with nitrates; 14.18 percent protein, 12.56 percent dry gluten. Objection has been offered in previous paragraphs to accepting general samples, because it is practically impossible to ascertain a correct statement of the conditions under which they were grown, and quite as difficult to learn the extent to which the samples are representative as the quality of the samples will depend upon the judgment of the sender. The averages given above for the general samples have but little value for these very reasons. The lowest percentage of protein found in the 1912 crop of winter-wheat, grown at Fort Collins, was 14.15, while Turkey Red, grown at La Jara, contained only 8.22 percent, and Red Chaff, grown at Eckert, contained 10.05 percent. These differences are indicated by the physical properties of the kernels, but this is not enough to make known the conditions under which the wheats were grown. These low-protein wheats are extreme cases of mealy wheats, whereas, our Fort Collins samples are fairly flinty wheats, though mixed. Could we but know the soil conditions under which the various samples were grown, these differences, in most cases, would be explicable, as I have pointed out in the case of three samples of Turkey Red, grown in the same section of country, from the same lot of seed, under the same climatic conditions, and also, it is safe to assume, of irrigation, which, as we have already stated, has but little influence, provided the plants have a sufficient supply of water at the critical period in their development. We shall come back to the question of the effect of irrigation, not to that of a critical period which is here refered to, perhaps, in too general a manner. I feel entirely justified in referring to such a period by the marked effects, which I have seen produced by a delay of a few days in the application of water, upon the development of the crop. Returning to the general samples, which include some dry-land wheats, it is proper to state that these are not, as is often, if not usually, considered richer in protein than the irrigated wheats. The few samples that we have analyzed would rather support the opposite view. The same is true of the physical properties, for we find samples of dry-land wheat badly affected by mealiness, which is equivalent to saying relatively low in protein.

COLORADO WHEAT EQUAL TO BEST IN CHEMICAL COMPOSITION

So far as chemical composition is concerned, the data given indicates that our average wheat, which shows a varying percentage of mealiness, is equal to the very best of wheats. Further, that the two extremes, small-grained flinty wheat, on the one hand, and mealy wheat on the other, differ materially from the average wheat which is a mixture of these two kinds, the former may be taken as carrying not far from 2 percent more protein and the latter 3 percent, or more, less than the average.

We have intentionaly chosen conditions which present the results obtained under favorable weather conditions to as great an extent as possible, allowing the effects of our fertilizers upon the physical and chemical characteristics of our wheats to come out in the fullest, possible light. These effects have been shown to be determinative of those physical properties designated as hard and soft, which is in agreement with the conclusions given in Bulletin 205. Further, that these physical properties correspond to very deep-going differences in the composition of the plants and kernels, but the effects upon the composition of the kernels are even more radical, so far as we are able to interpret the results, than upon that of the plant. This is particularly apparent in the effects of nitric-nitrogen upon the crop. While the effects of potassium are quite evident, they are not so striking as those of the nitrogen. The effects of these fertilizers or plant-foods are antagonistic, in that, one increases the nitrogen content while the other tends to depress it, regularly in the stems and leaves of the plants, and in the case of a sufficient predominance to produce yellow-berry, to depress it greatly in the kernels. The phosphorus showed no regular and consistent effect upon the amount of nitrogen and was, in general, surprisingly indifferent in its results.

One of the reasons assigned for taking the samples grown in 1913 as representative of the normal wheat crop in Colorado was that the weather conditions throughout the season were more nearly normal than those of 1914 and 1915.

In some respects the season of 1914 was as favorable, if not more so, than that of 1913. But there was one feature which seriously affected our results; this was a short period of wet weather near the end of July, just before the ripening period of the grain. At the very end of this period we had a shower of short duration, but very heavy. How this injury suffered by the crop is to be apportioned between the whole period and the closing feature of it, I do not know, nor do I know how much to attribute to the direct injury caused by the weather, and how much to the indirect injury caused by the development of rust. I think that a very large amount of the injury should be attributed to the latter.

TIME AND MANNER OF RAINFALL, RATHER THAN QUANTITY, IMPORTANT TO CROP

The experiments were conducted on the same land and were in all respects duplicates of those of 1913. This means that we had wheat after wheat on the check and other plots with the same fertilizers as were applied the season before. The land was irrigated after the crop of 1913 had been removed. The stubble was disced in and the land plowed a few weeks later. The promise of the crop of 1914 was most flattering up to the end of July, at which time, as stated above, untoward conditions intervened, the most serious of which was, probably, the rust, but this was undoubtedly the result of the weather conditions. The rainfall during the last 10 days of July, 1914, was 1.38 inches, of which 0.87 inches fell on the 30th in less than two hours. The mean temperature during this period was 69.3 degrees F. In 1913 we had in the last 11 days of July, 1.53 inches and a mean temperature of 62. Nearly the whole of this fell on the 22, 23, and 24th and was followed by bright, cool weather. The grain was not beaten down and did not rust. It is evident that the time and manner of the rainfall and the conditions following it, rather than the amount of water, are the factors which come into play, for the rain in 1913 exceeded that of 1914, but was not followed by any bad results, whereas, the rainfall of 1914, the greater part of which fell on 30 July, was quite disastrous to the Defiance and injured the other varieties. Rust developed freely, especially on the Defiance, which it very seriously damaged, in fact, ruined.

We have given the average composition of our samples for 1913, excluding those in which the nitrogen had been increased by the application of nitrates because we do not consider them truly representative. The average protein content (N x 5.7) was 12.53 percent and that of the plots receiving nitrogen was 14.18, a difference of 1.65 percent. The physical properties of these wheats, as well as their composition, are so different that their elimination from the average is not only justified, but necessitated as a matter of fairness.

We have not given the meteorological details of the season of 1914, but we have stated that they were favorable up to 30 July, and that the promise of an excellent yield of good grain was all that could be desired.

A point suggested in a preceding paragraph relative to the order of the crops, i.e., wheat after wheat without and also with fertilizers, may occur to the reader as important in regard to the effect of this fact upon the wheat, its growth and composition. I willingly acknowledge that this point is not covered by my data, and that we are dependent on observations upon the growth and development of the plants, together with the yields obtained to answer this. The growth and development of the plants up to 30 July was more vigorous than in 1913. The plants were large, the head long, and the kernels were already well filled out but still soft when the rain came.

The correlation table given in Bulletin 217, p. 22, gives data setting forth the size of plants, length of heads, etc., and, with the table of yields, the weight per bushel, and the ratio of straw to grain given in this bulletin, shows that the check plots, except in the case of the Defiance, gave materially higher yields in 1914 than in 1913, and the weight per bushel was very high. In 1913, the Defiance check plots yielded 41.4, 40.6, and 41.3 bushels per acre, average 41.1 bushels, weight per bushel 62.3 pounds; in 1914, the average yield was 31.1 bushels, weight per bushel 56.7 pounds; in 1915, yield 19.5 bushels, weight per bushel 49.6 pounds. The Red Fife check plots averaged in 1913, 33.2 bushels, weight per bushel 64.0 pounds, anl in 1914, 47.2 bushels, weight per bushel 63.7 pounds; in 1915, 32.6 bushels, weight per bushel 60.8 pounds. The Kubanka checks averaged in 1913, 34.2 bushels per acre, weight per bushel 63.2 pounds, in 1914 the same plots averaged 47.8 bushels per acre and the weight per bushel was 64.9 pounds; in 1915, 32.8 bushels and weight per bushel 62.3 pounds. The data given in the correlation table and the comparative yields and weights per bushel, given for the three seasons answer fully the questions arising in connection with the succession of crops and exhaustion of the soil. The plants were well developed, the yields good and the weight per bushel, except in the case of the Defiance, above the average in each of three years.

The total rainfall in July, 1913, was 2.63 inches and the mean temperature 66.8 degrees F.; in 1914 the rainfall was 1.68 inches and the mean temperature 68.3 degrees F.; and in 1915 the rainfall was 2.12 inches and the mean temperature 64.74 degrees F.

In 1913 and 1914, we had but little cloudy weather, while in 1915 it was prevalent. We had only 11 days in July, 1913, which are recorded as clear. The weather conditions in August were good, especially in 1913 and 1914, but were not quite so favorable in 1915. In 1913, we had no rain in August prior to harvest, in 1914 we had 0.29 inches and in 1915, 0.57 inch. This 0.57 inch of rain did not interfere with our harvest, and it is a question whether it made our conditions any worse than they were already. I am quite certain that it would have done us no harm had it not been preceded by bad conditions in July, for the grain would have been so mature by this time that practically no injury would have resulted. We can, I think, with entire justice, neglect the weather conditions in August, not that I wish to assert that the one-half inch of rainfall in early August might not have injured our crop, but, as will appear later, bad conditions in the latter part of July, with very good conditions in early August, will produce very bad results, so I feel justified in neglecting the August conditions. Two things, of course, are here assumed as the causes of the bad results, one is the unfavorable weather conditions already mentioned, and the other is the condition of development of the plant at this time. That this latter factor cannot be too strongly emphasized is evidenced by the effects of these bad conditions on the Defiance wheat, compared with the same upon the Red Fife. That there may be a difference in the ability of these two varieties to withstand unfavorable conditions is very probable, still it is a fact that the Fife matures several days earlier than the Defiance when sown on the same date, and by the end of July is usually quite mature. I have, in a preceding paragraph, given the results of the seasons on the comparative yields of our check plots and it will be noticed that the effects of the same conditions were much less upon the Red Fife than upon the Defiance, which fact I attribute largely to the stage of development of the plants at the time the weather conditions caused the injury to the crop.

In the statement for the rainfall for July of each season, it will be noticed that we had the heaviest rainfall in 1913 and the next heaviest rainfall in 1915. The former crop was excellent in quality, so far as weight per bushel and chemical composition are concerned; and the latter, as we shall later see, while good in yield and weight per bushel for the Red Fife and Kubanka, was of inferior chemical composition. In these cases, it was not the amount of water that fell during the month that produced the inferior wheat, for the larger amount of rainfall was followed by the better quality of wheat. The distribution of the rainfall in the two seasons was quite different. In 1913 practically the whole of the rain fell between the 18th and 23rd, and during the month we had but one wholly cloudy day. In 1915 we had very different conditions, the rainfall was distributed more evenly throughout the month, especially through the last few days of it, and there was much cloudy weather. We also had heavy dews. The difference in mean temperature during the month in the two seasons was comparatively small, 66.8 degrees F., in 1913 and 64.7 degrees F., in 1915, or a difference of 2.1 degrees F. This statement relative to the difference in mean temperature is, perhaps, not quite sufficient, for the character of the grain is determined, or may be, by a much shorter period than the 31 days composing the month; for this reason the mean temperature during the last 10 days of the month may be given; this was 62.4 in 1913, and 65.9 in 1915. This difference, though small, only 3.5 degrees, together with the continuous wet weather, with cloudiness and heavy dews, and with the vigorous growth of plants, favored an abundant development of rust. We had somewhat the same conditions in 1914 as in 1915 with the difference that in 1914 the rain came mostly in one violent shower, which beat the grain down so that it formed a thick mat of green plants through which the ventilation was considerably impeded, with the result that rust developed with special abundance on the Defiance, and quite abundantly on the other varieties. I have unfortunately, no means of conveying a definite idea of the comparative severity of these attacks. The composition of the crops for the two seasons is given in the following tables, which also give the sections of land, the fertilizers and the amounts used:

WHEATS GROWN ON EXPERIMENTAL PLOTS—CROP 1914

Variety	Section 1700 Fertilizer per acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance	120 lbs. nitrogen..........	8.755	2.086	1.855	3.812	2.203	12.557	59.832	1.175	30.17	12.31	9.129	0.429	0.547	21.15
Defiance	60 lbs. phosphorus........	9.220	1.675	1.938	3.391	1.578	8.995	63.900	1.125	18.50	7.87	5.529	0.410	0.466	27.19
Defiance	200 lbs. potassium........	9.420	1.585	1.863	3.229	1.501	8.585	65.177	1.113	20.50	8.59	6.013	0.377	0.484	31.01
Defiance	None	8.555	1.880	1.775	3.480	1.547	8.816	66.330	1.136	18.23	7.66	5.435	0.404	0.442	26.97
Red Fife	120 lbs. nitrogen.........	9.488	1.690	1.878	3.020	2.099	11.964	63.216	1.218	29.80	12.61	8.908	0.409	0.415	32.50
Red Fife	60 lbs. phosphorus........	9.058	1.884	1.890	2.891	1.668	9.508	65.340	1.332	23.13	9.67	6.848	0.420	0.413	33.88
Red Fife	200 lbs. potassium........	9.250	1.772	1.915	2.845	1.780	10.143	63.576	1.335	24.57	10.21	7.087	0.420	0.412	35.69
Red Fife	None	9.385	1.938	1.920	3.017	1.661	9.468	64.602	1.260	22.40	9.31	6.637	0.398	0.425	33.85
Kubanka	120 lbs. nitrogen..........	9.130	1.704	1.925	2.995	2.106	12.001	61.002	1.341	33.17	13.57	9.386	0.352	0.455	38.15
Kubanka	60 lbs. phosphorus.......	9.375	1.922	1.995	2.995	1.713	9.764	65.567	1.341	25.00	10.57	7.266	0.391	0.452	41.18
Kubanka	200 lbs. potassium........	9.858	1.762	1.888	2.932	1.842	10.499	64.494	1.409	26.17	11.02	7.632	0.386	0.461	44.20
Kubanka	None	8.535	1.752	2.018	3.002	1.842	10.499	64.728	1.467	26.97	11.38	8.048	0.394	0.440	42.68

FORMS OF NITROGEN AS AFFECTED BY FERTILIZERS—CROP 1914

Variety	Section 1700 Fertilizer per acre	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Total Nitrogen Percent
Defiance	Nitrogen, 120 lbs...	0.0699	0.2517	1.0439*	0.8375	2.2030
Defiance	Phosphorus, 60 lbs..	0.0523	0.1888	0.5954	0.7415	1.5780
Defiance	Potassium, 200 lbs..	0.0453	0.1678	0.5977	0.6902	1.5010
Defiance	None	0.0453	0.2168	0.4952	0.7892	1.5465
Red Fife	Nitrogen, 120 lbs...	0.0734	0.2028	0.7467	1.0761	2.0990
Red Fife	Phosphorus, 60 lbs..	0.0488	0.1888	0.6736	0.6568	1.6680
Red Fife	Potassium, 200 lbs..	0.0488	0.1818	0.6736	0.8753	1.7795
Red Fife	None	0.0734	0.1678	0.4671	0.9427	1.6610
Kubanka	Nitrogen, 120 lbs...	0.0523	0.2307	0.9030	0.9195	2.1055
Kubanka	Phosphorus, 60 lbs..	0.0523	0.1888	0.7539	0.7180	1.7130
Kubanka	Potassium, 200 lbs..	0.0418	0.2028	0.7038	0.8936	1.8420
Kubanka	None	0.0488	0.2098	0.7853	0.7981	1.8420

*This was repeated with same results.

WHEATS GROWN ON EXPERIMENTAL PLOTS—CROP 1914

Variety	Section 1800 Fertilizer per acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance	80 lbs. nitrogen...........	8.453	1.755	1.960	3.380	2.092	11.924	60.732	1.074	31.07	12.38	8.691	0.346	0.436	23.77
Defiance	40 lbs. phosphorus.........	8.933	1.825	1.925	3.265	1.644	9.367	64.206	1.081	19.37	8.14	5.687	0.393	0.431	27.05
Defiance	150 lbs potassium..........	9.060	1.760	1.838	3.279	1.578	8.995	64.566	1.068	21.07	8.82	5.815	0.375	0.412	30.04
Defiance	None	8.918	2.017	1.913	3.571	1.835	10.460	63.144	1.057	24.40	10.09	7.000	0.426	0.437	25.67
Red Fife	80 lbs. nitrogen..........	8.783	1.697	1.860	3.135	1.922	10.955	62.280	1.139	28.73	11.80	8.377	0.364	0.398	30.42
Red Fife	40 lbs. phosphorus.........	8.703	1.812	1.930	3.113	1.668	9.468	62.910	1.272	21.67	8.78	6.304	0.399	0.405	33.39
Red Fife	150 lbs. potassium.........	9.140	1.867	1.838	3.062	1.724	9.824	63.774	1.335	23.03	9.46	6.764	0.403	0.403	34.34
Red Fife	None	8.485	1.947	1.903	2.960	1.794	10.223	63.144	1.221	25.77	10.42	7.459	0.412	0.437	31.50
Kubanka	80 lbs. nitrogen..........	9.455	1.703	1.933	2.992	2.168	12.358	61.255	1.386	32.83	13.72	9.520	0.343	0.418	40.02
Kubanka	40 lbs. phosphorus.......	10.043	1.903	2.115	3.221	1.714	9.767	65.214	1.455	24.73	10.57	7.316	0.397	0.436	42.19
Kubanka	150 lbs. potassium.........	9.613	1.712	1.875	2.970	1.925	10.972	64.206	1.461	27.33	11.62	7.665	0.366	0.451	42.78
Kubanka	None	9.640	1.692	1.945	3.012	1.751	9.981	62.586	1.392	26.30	10.96	7.440	0.385	0.442	43.72

FORMS OF NITROGEN AS AFFECTED BY FERTILIZERS—CROP 1914

Variety	Section 1800 Fertilizer per acre	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Total Nitrogen Percent
Defiance	Nitrogen, 80 lbs.....	0.0453	0.2517	0.8774	0.9176	2.0920
Defiance	Phosphorus, 40 lbs..	0.0453	0.2028	0.5977	0.7877	1.6453
Defiance	Potassium, 150 lbs..	0.0453	0.2028	0.6071	0.7228	1.5780
Defiance	None	0.0558	0.1888	0.7084	0.8820	1.8350
Red Fife	Nitrogen, 80 lbs....	0.0523	0.1888	0.6654	1.0155	1.9220
Red Fife	Phosphorus, 40 lbs..	0.0453	0.1678	0.6164	0.7383	1.6680
Red Fife	Potassium, 150 lbs..	0.0453	0.1748	0.6527	0.8507	1.7235
Red Fife	None	0.0488	0.1818	0.7015	0.8614	1.7935
Kubanka	Nitrogen, 80 lbs....	0.0488	0.2307	0.9162	0.9727	2.1680
Kubanka	Phosphorus, 40 lbs..	0.0488	0.1888	0.7061	0.7698	1.7135
Kubanka	Potassium, 150 lbs..	0.0663	0.2028	0.7445	0.9114	1.9250
Kubanka	None	0.0418	0.2168	0.7318	0.7706	1.7510

WHEATS GROWN ON EXPERIMENTAL PLOTS—CROP 1914

Variety	Section 1900 Fertilizer per acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance	40 lbs. nitrogen	8.650	1.630	2.045	3.473	1.842	10.499	62.568	1.040	26.87	10.96	7.464	0.355	0.421	24.47
Defiance	20 lbs. phosphorus	8.730	1.849	1.998	3.282	1.586	9.015	64.818	1.099	20.00	8.24	5.861	0.392	0.446	26.05
Defiance	100 lbs. potassium	8.950	1.617	1.905	3.125	1.550	8.835	63.648	1.074	20.73	8.61	5.800	0.362	0.419	29.48
Defiance	None	8.855	1.845	1.895	3.273	1.557	8.875	63.216	1.181	25.83	10.54	7.254	0.415	0.443	25.41
Red Fife	40 lbs. nitrogen	8.903	1.605	1.825	3.937	1.953	11.132	63.180	1.161	29.57	12.01	8.336	0.370	0.414	30.64
Red Fife	20 lbs. phosphorus	8.973	1.807	1.863	2.915	1.647	9.388	64.917	1.260	22.00	8.94	6.433	0.399	0.430	33.70
Red Fife	100 lbs. potassium	9.140	1.865	1.868	3.152	1.751	9.981	63.414	1.289	26.50	10.72	7.486	0.411	0.415	35.60
Red Fife	None	8.925	1.861	1.870	3.051	1.821	10.380	64.044	1.147	27.50	10.80	7.528	0.421	0.451	32.37
Kubanka	40 lbs. nitrogen	9.485	1.614	1.835	2.950	1.960	11.172	63.540	1.472	30.30	12.52	8.212	0.351	0.558	40.27
Kubanka	20 lbs. phosphorus	8.673	1.677	2.048	2.907	1.786	10.273	63.190	1.438	27.40	11.66	7.929	0.380	0.572	42.84
Kubanka	100 lbs. potassium	8.753	1.587	1.985	2.980	1.866	10.636	63.792	1.553	28.13	11.81	7.915	0.391	0.555	42.18
Kubanka	None	10.053	1.862	2.190	2.962	1.731	9.867	64.917	1.488	27.07	12.19	8.111	0.416	0.582	40.97

FORMS OF NITROGEN AS AFFECTED BY FERTILIZERS—CROP 1914

Variety	Section 1900 Fertilizer per acre	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Total Nitrogen Percent
Defiance	Nitrogen, 40 lbs.	0.0628	0.2098	0.6921	0.8773	1.8426
Defiance	Phosphorus, 20 lbs.	0.0453	0.1888	0.5931	0.7543	1.5815
Defiance	Potassium, 100 lbs.	0.0523	0.1958	0.5695	0.7324	1.5500
Defiance	None	0.0593	0.2098	0.7329	0.5550	1.5570
Red Fife	Nitrogen, 40 lbs.	0.0593	0.1888	0.7981	0.9068	1.9530
Red Fife	Phosphorus, 20 lbs.	0.0384	0.1678	0.7212	0.7196	1.6470
Red Fife	Potassium, 100 lbs.	0.0523	0.1888	0.6794	0.8305	1.7510
Red Fife	None	0.0488	0.1748	0.7154	0.8820	1.8210
Kubanka	Nitrogen, 40 lbs.	0.0418	0.2237	0.8156	0.8789	1.9600
Kubanka	Phosphorus, 20 lbs.	0.0488	0.2098	0.7853	0.7421	1.7860
Kubanka	Potassium, 100 lbs.	0.0280	0.2098	0.7828	0.8454	1.8660
Kubanka	None	0.0453	0.2098	0.7376	0.7383	1.7310

ASH CONSTITUENTS OF WHEAT—CROP 1914

Variety	Fertilizer per acre	Sp. gr.	SiO_2 Percent	Fe Percent	Mn Percent	Ca Percent	Mg Percent	K Percent	Na Percent	Cl Percent	S Percent	Total P Percent	Inorganic P Percent	Organic P Percent	Total N Percent
Defiance	80 lbs. nitrogen..........	1.3991	0.016	0.005	0.005	0.033	0.146	0.436	0.012	0.179	0.135	0.346	0.009	0.337	2.092
Defiance	40 lbs. phosphorus........	1.4166	0.021	0.005	0.004	0.035	0.142	0.431	0.011	0.172	0.133	0.393	0.017	0.376	1.643
Defiance	150 lbs. potassium.......	1.4128	0.016	0.003	0.004	0.033	0.135	0.412	0.009	0.116	0.124	0.375	0.008	0.367	1.578
Defiance	None	1.4174	0.018	0.003	0.004	0.041	0.147	0.437	0.014	0.121	0.137	0.426	0.013	0.413	1.828
Red Fife	80 lbs. nitrogen..........	1.4253	0.011	0.004	0.004	0.030	0.142	0.398	0.011	0.160	0.092	0.364	0.009	0.355	1.922
Red Fife	40 lbs. phosphorus........	1.4282	0.012	0.004	0.005	0.029	0.145	0.405	0.017	0.123	0.140	0.399	0.016	0.383	1.668
Red Fife	150 lbs. potassium........	1.4171	0.011	0.004	0.005	0.034	0.146	0.403	0.013	0.112	0.093	0.403	0.014	0.389	1.724
Red Fife	None	1.4241	0.015	0.005	0.005	0.030	0.156	0.437	0.016	0.114	0.119	0.412	0.017	0.395	1.794
Kubanka	80 lbs. nitrogen..........	1.4241	0.012	0.004	0.005	0.032	0.133	0.418	0.016	0.093	0.128	0.343	0.008	0.335	2.168
Kubanka	40 lbs. phosphorus........	1.4147	0.005	0.003	0.004	0.029	0.134	0.436	0.004	0.093	0.108	0.397	0.008	0.389	1.714
Kubanka	150 lbs. potassium........	1.4097	0.006	0.003	0.005	0.033	0.143	0.451	0.004	0.144	0.109	0.366	0.005	0.361	1.925
Kubanka	None	1.4171	0.010	0.004	0.005	0.033	0.140	0.442	0.041	0.142	0.123	0.385	0.008	0.377	1.751

WHEATS GROWN ON EXPERIMENTAL PLOTS—CROP 1915

Variety	Section 1700 Fertilizer per acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance	Nitrogen, 120 lbs.	10.583	2.125	1.875	4.180	2.1040	11.993	58.520	1.090	29.00	10.88	7.257	0.405	0.537	16.17
Defiance	Phosphorus, 60 lbs.	10.185	1.958	1.970	3.837	1.5374	8.763	61.632	1.075	18.17	7.03	4.423	0.402	0.447	18.35
Defiance	Potassium, 200 lbs.	10.480	1.870	1.985	3.732	1.5378	8.765	62.806	0.095	20.00	7.78	5.000	0.391	0.453	22.00
Defiance	None	9.833	1.945	1.923	4.175	1.5447	8.805	62.330	1.022	19.00	7.26	4.586	0.394	0.460	17.77
Red Fife	Nitrogen, 120 lbs.	9.663	2.025	1.825	3.802	1.9711	11.235	58.605	0.848	30.80	11.82	7.681	0.373	0.516	19.27
Red Fife	Phosphorus, 60 lbs.	10.233	2.180	1.940	3.195	1.4189	8.088	62.136	0.824	18.30	7.38	4.834	0.410	0.486	23.63
Red Fife	Potassium, 200 lbs.	9.853	2.246	1.913	3.325	1.5160	8.641	62.551	0.860	21.17	8.39	5.452	0.426	0.506	25.40
Red Fife	None	9.728	2.045	1.920	3.227	1.4119	8.084	62.154	0.842	18.17	7.51	4.926	0.397	0.476	23.54
Kubanka	Nitrogen, 120 lbs.	9.835	1.855	2.090	3.050	2.2383	13.247	55.093	1.049	41.70	15.48	10.126	0.367	0.487	33.85
Kubanka	Phosphorus, 60 lbs.	9.655	2.003	2.013	2.940	1.6142	9.721	59.508	0.983	28.90	11.39	7.251	0.398	0.455	35.30
Kubanka	Potassium 200 lbs.	10.598	2.060	2.023	3.015	1.7401	9.998	59.400	0.955	27.40	10.65	7.065	0.400	0.457	38.85
Kubanka	None	10.603	2.120	2.110	2.955	1.6702	9.645	54.128	1.023	28.70	10.91	7.338	0.384	0.441	36.97

FORMS OF NITROGEN AS AFFECTED BY FERTILIZERS—CROP 1915

Variety	Section 1700 Fertilizer per acre	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Total Nitrogen Percent
Defiance	Nitrogen, 120 lbs.	0.0699	0.1600	0.7627	1.0213	2.1040
Defiance	Phosphorus, 40 lbs.	0.0418	0.1398	0.5312	0.6845	1.4953
Defiance	Potassium, 200 lbs.	0.0210	0.1328	0.5149	0.7573	1.5378
Defiance	None	0.0349	0.1328	0.5289	0.7502	1.5447
Red Fife	Nitrogen, 120 lbs.	0.0839	0.2307	0.6360	0.8737	1.9711
Red Fife	Phosphorus, 60 lbs.	0.0558	0.1600	0.4318	0.6671	1.4189
Red Fife	Potassium, 200 lbs.	0.0593	0.1818	0.4659	0.6865	1.5160
Red Fife	None	0.0663	0.1678	0.4380	0.6383	1.4119
Kubanka	Nitrogen, 120 lbs.	0.0628	0.1188	0.8504	1.2361	2.3241
Kubanka	Phosphorus, 60 lbs.	0.0558	0.0908	0.6641	0.8597	1.7054
Kubanka	Potassium, 200 lbs.	0.0558	0.1048	0.6176	0.9268	1.7054
Kubanka	None	0.0558	0.0978	0.6246	0.8713	1.6915

WHEATS GROWN ON EXPERIMENTAL PLOTS—CROP 1915

Variety	Section 1800 Fertilizer per acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance	Nitrogen, 80 lbs..........	10.690	1.865	1.818	4.322	2.0128	11.552	58.826	1.071	28.80	11.08	7.292	0.366	0.466	16.97
Defiance	Phosphorus, 40 lbs.......	10.180	1.959	1.965	3.780	1.4814	8.523	61.128	1.027	18.30	7.09	4.252	0.401	0.448	18.42
Defiance	Potassium, 150 lbs........	8.625	1.777	1.998	3.855	1.4814	8.523	62.946	1.030	20.70	7.97	5.027	0.375	0.416	21.37
Defiance	None	9.953	1.905	1.980	3.912	1.5934	9.162	60.174	1.051	20.50	8.35	4.982	0.383	0.465	18.05
Red Fife	Nitrogen, 80 lbs..........	9.203	1.987	1.860	3.587	1.7679	10.077	60.480	0.794	24.70	9.28	6.244	0.378	0.466	22.05
Red Fife	Phosphorus, 40 lbs.......	9.528	2.022	1.993	3.365	1.4050	8.009	61.988	0.813	18.00	7.27	4.913	0.390	0.471	23.02
Red Fife	Potassium, 150 lbs........	9.975	1.965	1.813	3.385	1.5478	8.822	62.982	0.829	22.17	8.99	5.829	0.390	0.468	25.30
Red Fife	None	10.085	2.005	2.063	3.312	1.4707	8.383	62.044	0.755	19.40	7.73	5.053	0.390	0.447	24.63
Kubanka	Nitrogen, 80 lbs.........	9.658	1.985	2.088	3.280	2.2383	12.758	54.126	1.046	39.07	15.00	10.089	0.336	0.441	34.14
Kubanka	Phosphorus, 40 lbs.......	9.738	1.835	2.048	3.045	1.6142	9.201	59.436	0.933	26.40	10.81	6.965	0.374	0.425	37.97
Kubanka	Potassium, 150 lbs........	11.683	1.880	1.850	3.052	1.7401	9.919	60.480	0.941	26.70	10.71	7.011	0.384	0.432	39.75
Kubanka	None	10.898	2.003	1.895	2.950	1.6702	9.520	59.778	0.909	27.50	11.10	7.060	0.391	0.427	38.13

FORMS OF NITROGEN IN WHEAT AS AFFECTED BY FERTILIZERS —CROP 1915

Variety	Section 1800 Fertilizer per acre	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Total Nitrogen Percent
Defiance	Nitrogen, 80 lbs.....	0.0558	0.1740	0.7374	1.0440	2.0267
Defiance	Phosphorus, 40 lbs..	0.0418	0.1398	0.5312	0.6845	1.4953
Defiance	Potassium, 150 lbs..	0.0349	0.1460	0.5250	0.6783	1.4953
Defiance	None	0.0488	0.1538	0.4706	0.8291	1.6073
Red Fife	Nitrogen, 80 lbs....	0.0669	0.1958	0.5498	0.8265	1.7679
Red Fife	Phosphorus, 40 lbs..	0.0628	0.1678	0.4240	0.6454	1.4050
Red Fife	Potassium, 150 lbs..	0.0663	0.1678	0.4981	0.7141	1.5478
Red Fife	None	0.0663	0.1678	0.4380	0.6971	1.4707
Kubanka	Nitrogen, 80 lbs....	0.0699	0.1398	0.8621	1.0966	2.2383
Kubanka	Phosphorus, 40 lbs..	0.0523	0.1048	0.5569	0.8477	1.6142
Kubanka	Potassium, 150 lbs..	0.0628	0.0978	0.5681	0.9764	1.7401
Kubanka	None	0.0628	0.1048	0.5611	0.8995	1.6702

WHEATS GROWN ON EXPERIMENTAL PLOTS—CROP 1915

Variety	Section 1900 Fertilizer per acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance	Nitrogen, 40 lbs..........	9.653	1.730	1.905	3.895	1.8800	10.716	59.543	0.960	27.17	10.71	6.612	0.350	0.449	19.00
Defiance	Phosphorus, 20 lbs.......	9.940	1.785	1.985	3.700	1.5378	8.765	62.985	0.999	18.50	7.47	4.752	0.375	0.443	20.92
Defiance	Potassium, 100 lbs.......	10.203	1.577	2.100	3.330	1.4814	8.444	62.895	0.994	20.00	7.92	4.954	0.353	0.462	23.62
Defiance	None	10.085	1.826	1.920	3.797	1.5795	9.003	62.228	1.024	18.70	7.37	4.680	0.380	0.444	19.44
Red Fife	Nitrogen, 40 lbs..........	9.990	1.818	1.869	3.560	1.8521	10.557	59.678	0.963	28.70	10.88	7.478	0.343	0.472	20.96
Red Fife	Phosphorus, 20 lbs.......	10.245	1.820	1.935	3.355	1.4777	8.423	63.094	0.896	19.70	7.82	5.258	0.367	0.457	24.75
Red Fife	Potassium, 100 lbs.......	9.700	1.965	1.943	3.225	1.5409	8.783	63.828	0.833	22.30	8.65	6.219	0.383	0.453	26.89
Red Fife	None	10.043	1.862	1.978	3.347	1.4814	8.444	62.478	0.795	21.00	8.22	5.399	0.361	0.443	25.08
Kubanka	Nitrogen, 40 lbs..........	11.368	1.675	2.005	3.207	1.9919	11.354	57.654	1.051	28.00	11.55	8.073	0.400	0.407	35.35
Kubanka	Phosphorus, 20 lbs.......	11.968	1.785	2.005	2.995	1.6984	9.681	59.004	0.968	25.30	10.36	6.900	0.375	0.430	36.23
Kubanka	Potassium, 100 lbs.......	11.118	1.755	1.910	3.237	1.7262	9.839	60.678	0.959	25.17	10.38	6.851	0.363	0.444	93.13
Kubanka	None	11.425	1.805	1.958	3.000	1.7123	9.760	61.596	0.971	26.07	10.63	7.028	0.396	0.439	36.61

FORMS OF NITROGEN IN WHEAT AS AFFECTED BY FERTILIZERS —CROP 1915

Variety	Section 1900 Fertilizers per acre	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Total Nitrogen Percent
Defiance	Nitrogen, 40 lbs....	0.0418	0.1740	0.6508	0.8812	1.8800
Defiance	Phosphorus, 20 lbs..	0.0349	0.1398	0.4753	0.7829	1.5378
Defiance	Potassium, 100 lbs..	0.0280	0.1328	0.4890	0.7268	1.4814
Defiance	None	0.0418	0.1538	0.5172	0.6547	1.5795
Red Fife	Nitrogen, 40 lbs....	0.0769	0.2028	0.6266	0.8199	1.8521
Red Fife	Phosphorus, 20 lbs..	0.0628	0.1538	0.4520	0.7181	1.4777
Red Fife	Potassium, 100 lbs...	0.0628	0.1460	0.5250	0.7239	1.5409
Red Fife	None	0.0699	0.1740	0.4690	0.6644	1.4814
Kubanka	Nitrogen 40 lbs.....	0.0769	0.1328	0.6408	1.0855	1.9919
Kubanka	Phosphorus, 20 lbs..	0.0628	0.1048	0.5569	0.9319	1.6984
Kubanka	Potassium, 100 lbs..	0.0769	0.0978	0.6106	0.9200	1.7262
Kubanka	None	0.0593	0.0978	0.6153	0.9014	1.7123

ASH CONSTITUENTS OF WHEAT—CROP 1915

Section 1800

Variety		SiO_2	Fe	Mn	Ca	Mg	K	Na	Cl	S	P	N
Defiance	$NaNO_3$	0.018	0.005	0.004	0.046	0.149	0.466	0.010	0.083	0.143	0.366	2.0128
Defiance	P_2O_5	0.094	0.010	0.004	0.061	0.132	0.448	0.037	0.073	0.103	0.401	1.4814
Defiance	Kcl	0.018	0.005	0.004	0.040	0.141	0.416	0.018	0.084	0.101	0.375	1.4814
Defiance	Check	0.019	0.005	0.004	0.054	0.162	0.465	0.022	0.085	0.100	0.383	1.5934
Red Fife	$NaNO_3$	0.058	0.008	0.004	0.038	0.153	0.466	0.024	0.094	0.115	0.378	1.7679
Red Fife	P_2O_5	0.012	0.004	0.004	0.085	0.114	0.471	0.027	0.072	0.094	0.390	1.4050
Red Fife	Kcl	0.012	0.004	0.004	0.037	0.147	0.468	0.021	0.090	0.087	0.390	1.5478
Red Fife	Check	0.014	0.004	0.004	0.046	0.141	0.447	0.034	0.063	0.087	0.390	1.4707
Kubanka	$NaNO_3$	0.018	0.007	0.004	0.043	0.128	0.441	0.026	0.061	0.102	0.336	2.2383
Kubanka	P_2O_5	0.028	0.006	0.004	0.034	0.133	0.425	0.055	0.048	0.078	0.374	1.6142
Kubanka	Kcl	0.026	0.004	0.004	0.032	0.134	0.432	0.026	0.063	0.068	0.387	1.7401
Kubanka	Check	0.022	0.007	0.004	0.035	0.135	0.427	0.029	0.053	0.106	0.391	1.6702

SHRUNKEN KERNELS NOT NECESSARILY HIGH IN PROTEIN

In the preceding tables we have the samples grown during two years of experimentation. Many of these samples, practically all those of 1915, the Defiance samples of 1914, and the samples of both the Fife and Kubanka grown with the application of nitrate are shrunken. These latter samples are not shrunken to anything like the extent of some of the others. I think that it is generally accepted as a fact that shrunken grains are higher than normal in protein. I acknowledge that I thought that this was an established fact. But there is no difference between the badly shrunken samples and the plumper ones that cannot justly be explained in some other manner. The samples grown with the application of nitrates in 1913, carried, in round numbers, 2.0 percent more protein than samples from the other plots. We find on an average a little greater difference in 1915. Our samples of 1913 are all fine, plump wheats, as the weights per 1,000 kernels show. In 1915 they were all more or less shrunken. The Defiance was so badly shrunken that we could sell it only for chicken feed. It would seem unreasonable to consider the excess of protein in the nitrate samples of 1915 due to their shrunken condition, when essentially the same difference existed in the 1913 crop, which was not shrunken. The other shrunken samples of 1915 are all low in protein but they are neither higher nor lower than the less shrunken samples of the same variety grown that season. In fact, the very badly shrunken samples of 1915, differ but little in their protein content from the plump, full-weight samples of 1914. The difference is in favor of the plump samples of 1914. The fact is that the shrunken condition of the samples seems to have nothing to do with the composition, but simply indicates that the process of filling was cut short, and that which would have been a large kernel, remained an incompleted structure. The character of the material, and the amount of it, with which the kernel was filled, was in these cases determined by the rust. The similarity in the composition of the crops of 1914 and 1915 is remarkable. Rust was very abundant in both seasons. The plants were a little more fully developed in 1914 than in 1915 at the time that the rust attacked the plants. The crop was materially better in 1914 than in 1915, but the composition of the wheat was, as stated, very similar. It is not to be understood that we had no fair crops in 1915, for this is not the case. We had as high as 40.8 bushels per acre, weighing 60 pounds to the bushel, and it was only the plots treated with nitrates that yielded crops of either Red Fife or Kubanka that weighed less than 60 pounds to the bushel, some of the Kubanka weighed 63 pounds, but the composition of the wheat was essentially the same as that of the badly shrunken Defiance, weighing from 49 to 53 pounds per bushel.

These results seemed to make it worth the while to determine whether there is any difference in the composition of the large and small kernels of the same samples grown in a favorable season. The samples that we have, which will fulfill this condition, are those grown in 1913. We have arranged in the following table analyses of large and small kernels:

COMPOSITION OF LARGE AND SMALL KERNELS—CROP 1913

Variety	Fertilizer per Acre		Percent of Wheat	Average Wt. per Kernel	Nitrogen Percent	Protein Nx5.7 Percent	Phosphorus Percent	Potassium Percent
Defiance	80 lbs. nitrogen...	large	56.00	0.0397	2.349	12.390	0.395	0.422
		small	44.00	0.0239	2.342	13.347	0.390	0.475
Defiance	40 lbs. phosphorus	large	77.75	0.0417	2.210	12.595	0.444	0.439
		small	22.25	0.0284	1.982	11.299	0.435	0.426
Defiance	150 lbs. potassium	large	74.30	0.0433	2.207	12.582	0.406	0.423
		small	25.70	0.0303	2.014	11.479	0.412	0.413
Defiance	None	large	71.50	0.0425	2.228	12.700	0.412	0.457
		small	28.50	0.0293	2.077	11.837	0.426	0.450
Red Fife	80 lbs. nitrogen..	large	51.60	0.0398	2.637	15.032	0.405	0.467
		small	48.40	0.0289	2.496	14.226	0.405	0.464
Red Fife	40 lbs. phosphorus	large	49.60	0.0391	2.365	13.481	0.456	0.425
		small	50.40	0.0301	2.295	13.079	0.456	0.454
Red Fife	150 lbs. potassium	large	53.10	0.0390	2.447	13.945	0.454	0.413
		small	46.90	0.0318	2.394	13.644	0.426	0.437
Red Fife	None	large	41.00	0.0388	2.457	14.001	0.455	0.440
		small	59.00	0.0306	2.414	13.759	0.462	0.390
Kubanka	80 lbs. nitrogen...	large	45.00	0.0532	2.442	13.920	0.387	0.416
		small	55.00	0.0332	2.433	13.867	0.365	0.423
Kubanka	40 lbs. phosphorus	large	63.66	0.0490	2.141	12.202	0.413	0.463
		small	36.34	0.0339	2.046	11.659	0.396	0.502
Kubanka	150 lbs. potassium	large	65.30	0.0502	2.135	12.167	0.408	0.433
		small	34.70	0.0300	2.068	11.788	0.416	0.438
Kubanka	None	large	69.65	0.0529	2.118	12.073	0.427	0.482
		small	30.35	0.0298	2.085	11.885	0.412	0.474

The table has purposely been made full in the points essential in this case. These small kernels come from the top and bottom of the head and from the middle of the spikelet. We find, in the twelve pairs, a maximum difference of 1.30 percent. There is one other case with a difference of 1 percent. The other ten pairs differ by lesser amounts. The difference, however, is always in the same direction, in favor of the larger kernels. According to these results, neither the shrunken crops, nor the small berries, contain more protein than the large, plump ones.

We have now given the composition of the seed used, that of the three crops so far obtained, and the conditions under which the latter were produced. The Defiance was seed of our own growing, the Red

Fife and Kubanka was seed obtained from the South Dakota Experiment Station. Our own seed was wheat which had been grown on the college farm for many years. The strain is accepted as pure and the variety well established. The Dakota seed was true to variety and pure. It is stated that acclimatization has but little or no influence upon the composition of the crop produced when the seed is transported, as in this case, from one locality to another. I accept this as established and attribute any changes in the character of the crop to local conditions, either of soil, or climatic, or both. The physical characteristics of the first crop were very different from the parent seed, this, however, was true of the crop from our own seed in a certain measure, but not to the same extent as for the crops produced from the Dakota seed. Both the Fife and the Kubanka berries were much larger and different in color. Being curious to learn how the 1913 crops grown in South Dakota would compare in composition with my crops, grown from the same seed, I obtained, through the courtesy of their Department of Agronomy, samples of this crop. My object was not simply to test the effect of change but to assure myself in regard to the effects of my fertilizer experiments, which I shall present later. At the present time I shall endeavor to present the general composition.

GENERAL COMPOSITION OF WHEATS IN 1913, 1914, AND 1915

Under the general consideration of the weather conditions I have pointed out one result which did very great injury, i.e., that these conditions brought about a very severe attack of rust. I have already touched upon the effects of this on the yield and weight per bushel, giving for the latter 62.3, 56.7, and 49.6 pounds in the respective years of 1913, 1914 and 1915. This was for Defiance from the check plots of Section 1800. The weight per bushel of the other varieties was not depressed in 1914 but was slightly depressed in 1915. This indicates that some of the wheat was badly shrunken. Each of the three varieties was severely attacked by the fungus.

Before I give the composition of the wheat for these three years, I wish to again state that my data do not answer the question relating to the effect of planting wheat after wheat on the composition of the second or third crop, and I cannot recall having seen any answer to this question. The growth of the plants, the yield per acre and the weight per bushel have been mentioned as indicating that there was no lack of plant food, but it must be admitted that all of these taken together lack in conclusiveness when we consider the composition.

For our present purpose, i.e., to give a general idea of the composition of these crops, we shall confine ourselves to the amounts of protein, starch, wet, dry and true gluten, and phosphorus. The variation in the moisture, ash, fat, and crude fiber is too small to play any important part in our present discussion. We shall give the ash constituents to show how little they vary in the three seasons, although the wheats are of very different composition. We shall confine these to the check plots of a single section to avoid, as far as possible, varying conditions and confusion due to different fertilization, and also for the further reason that we have determined the ash constituents in the kernels of one section only. The series of checks given in the following table runs north and south through our land; had it been taken east and west, the individual data would have been different, a fact which we do not wish to evade; but the general results would have been the same, so far as the data actually acquired may be depended on to show:

GENERAL COMPOSITION OF THE SEED USED AND THE CROPS OF 1913, 1914 AND 1915

	Protein Percent	Starch Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Sp. gr.
Average for Domestic Wheats	12.23	.....	26.46	10.31	.....	.....	......
Average for Foreign Wheats	12.08	.....	25.36	9.82	.....	.....	......
Red Fife, South Dakota, seed crop 1912	12.82	59.81	29.33	11.32	8.225	0.279	1.4127
Red Fife, South Dakota, crop 1913	13.27	62.28	28.43	11.41	8.550	0.320	......
Kubanka, South Dakota, seed crop 1912	13.04	61.18	30.93	12.91	9.462	0.326	1.4334
Kubanka, South Dakota, crop 1913	13.32	16.01	29.33	12.37	9.220	0.351	......
Red Fife, Section 1800, check crop 1913	14.43	61.88	28.83	11.55	8.340	0.462	1.4401
Red Fife, Section 1800, check crop 1914	10.22	63.14	25.77	10.42	7.460	0.412	1.4241
Red Fife, Section 1800, check crop 1915	8.38	62.04	19.40	7.73	5.050	0.390	......
Kubanka, Section 1800, check crop 1913	12.05	63.37	25.33	10.63	7.570	0.423	1.4355
Kubanka, Section 1800, check crop 1914	9.98	62.59	26.30	10.96	7.440	0.385	1.4171
Kubanka, Section 1800, check crop 1915	9.52	59.78	27.50	11.10	7.060	0.391	......
Defiance Seed used	13.46	61.47	30.66	11.74	8.504	.....	......
Defiance, Section 1800, check crop 1913	12.14	61.83	25.07	10.22	7.313	0.416	1.4355
Defiance, Section 1800, check crop 1914	10.46	63.14	24.40	10.09	7.000	0.426	1.4174
Defiance, Section 1800, check crop 1915	9.13	60.17	20.50	8.35	4.980	0.383	......

ASH CONSTITUENTS CALCULATED ON THE AIR-DRIED GRAIN FOR THE THREE YEARS 1913, 1914 AND 1915

	SiO_2 Percent	Fe Percent	Mn Percent	Ca Percent	Mg Percent	K Percent	Na Percent	Cl Percent	S Percent	P Percent
Red Fife, South Dakota seed	0.018	0.005	0.005	0.044	0.134	0.490	?	0.086	0.175	0.267
Kubanka, South Dakota seed	0.011	0.006	0.005	0.026	0.141	0.468	?	0.064	0.145	0.326
Red Fife, Section 1800, check crop 1913	0.017	0.006	present	0.038	0.150	0.444	0.010	0.135	0.113	0.461
Red Fife, Section 1800, check crop 1914	0.015	0.005	0.005	0.030	0.156	0.437	0.016	0.114	0.119	0.412
Red Fife, Section 1800, check crop 1915	0.014	0.004	0.004	0.046	0.141	0.447	0.034	0.063	0.087	0.390
Kubanka, Section 1800, check crop 1913	0.030	0.005	present	0.031	0.137	0.454	0.010	0.130	0.093	0.423
Kubanka, Section 1800, check crop 1914	0.010	0.004	0.005	0.033	4.140	0.442	0.041	0.142	0.123	0.385
Kubanka, Section 1800, check crop 1915	0.022	0.007	0.004	0.035	0.135	0.427	0.029	0.053	0.106	0.391
Defiance, Section 1800, check crop 1913	0.030	0.005	present	0.037	0.141	0.391	0.037	0.060	0.116	0.416
Defiance, Section 1800, check crop 1914	0.018	0.003	0.004	0.041	0.147	0.437	0.014	0.121	0.137	0.426
Defiance, Section 1800, check crop 1915	0.019	0.005	0.004	0.054	0.162	0.465	0.022	0.085	0.100	0.383

A COMPARISON OF COLORADO AND SOUTH DAKOTA WHEATS GROWN IN 1913

The preceding table gives the most important features in the composition of wheat and the averages for domestic and foreign wheats. Further, it gives the composition of the South Dakota seed and of the crop grown from it in South Dakota, also the same for the crops grown under our conditions. An unbiased comparison of these results leads to the conclusion that in 1913 no changes were produced, which might not have been found in samples grown from our own seed, under our own climatic conditions and on contiguous pieces of land, one-tenth of an acre in area. This is true in the case of all of the data given to show the composition of the samples. The nitrogen determinations were not made by the same analyist that did the earlier work and the ash-analyses were all made by a third one. All nitrogen and starch determinations were done in duplicate, so that neither the differences nor the uniformities which occur are attributable to accidents or errors. The methods used, except those used in determining the mineral constituents, were conventional ones.

The products of the three seasons, grown on the same plots of land and without fertilizers of any kind, vary greatly in their protein, much more markedly so than in their starch content. The highest percentage of starch found in our nine samples of crops grown is 63.37, the lowest 59.78, a range of 3.55 percent for the samples of three varieties of wheat in three years, with an average starch content of 61.9 percent. On the other hand, we have a maximum range of 6.05 percent in the protein, with an average of 10.7 percent. The ratio of starch to protein varies between relatively wide limits from 4.3 to 7.4. This high ratio is evidently due to the suppression of the protein and not due to any unusual increase in the amount of starch. The samples so far considered were grown on check plots and for reasons given above.

The results given for this series of checks taken year by year agree fairly well with the averages obtained for all of the plots, excluding those fertilized with nitrogen.

AN AVERAGE OF THE VARIETIES SECTION BY SECTION

In order to set forth more fully the general composition of the crops, the variation due to variety, and the effects of nitrates, I have averaged the varieties section by section including the check plots with those which received phosphorus and potassium respectively; this fact is indicated by the expression 3/3, meaning the average of these three plots each time. The averages for the nitrates have been made for the sections only. The three varieties are included in each average which is designated in the same manner as the other averages.

AVERAGE COMPOSITION OF WHEAT—CROP 1913

		Protein Perct.	Starch Perct.	Wet Gluten Perct.	Dry Gluten Perct.	True Gluten Perct.	Phosphorus Perct.
Section 1700	Defiance 3/3	11.67	61.67	24.45	9.93	7.05	0.445
Section 1700	Red Fife 3/3	13.10	62.19	27.46	11.07	8.00	0.467
Section 1700	Kubanka 3/3	12.28	61.07	26.84	11.26	7.91	0.438
Average		12.35	61.64	26.25	10.75	7.65	0.450
Section 1800	Defiance 3/3	12.16	62.32	24.69	10.05	7.15	0.422
Section 1800	Red Fife 3/3	13.84	61.66	27.68	11.22	8.18	0.460
Section 1800	Kubanka 3/3	12.00	62.53	25.78	10.76	7.57	0.414
Average		12.66	62.17	26.05	10.68	7.63	0.432
Section 1900	Defiance 3/3	11.14	63.58	22.22	9.23	6.34	0.476
Section 1900	Red Fife 3/3	13.97	62.48	28.27	11.47	8.26	0.465
Section 1900	Kubanka 3/3	12.63	62.29	25.28	10.87	7.75	0.487
Average		12.58	62.78	25.26	10.51	7.45	0.476
General average all plots without nitrates		**12.53**	**62.19**	**25.85**	**10.65**	**7.58**	**0.453**
Section 1700	Nitrate plots 3/3	14.89	62.24	34.79	13.77	10.13	0.433
Section 1800	Nitrate plots 3/3	14.15	60.80	31.21	12.49	9.08	0.446
Section 1900	Nitrate plots 3/3	13.48	59.76	27.73	11.40	8.12	0.451
General average for the nitrate plots		**14.17**	**60.93**	**31.24**	**12.55**	**9.11**	**0.413**

AVERAGE COMPOSITION OF WHEATS—CROP 1914

		Protein Perct.	Starch Perct.	Wet Gluten Perct.	Dry Gluten Perct.	True Gluten Perct.	Phosphorus Perct.
Section 1700	Defiance 3/3	8.799	65.14	19.08	8.04	5.66	0.397
Section 1700	Red Fife 3/3	9.706	64.51	23.33	9.73	6.86	0.413
Section 1700	Kubanka 3/3	10.254	64.93	26.05	10.66	7.65	0.390
Average		9.586	64.86	22.82	9.48	6.74	0.400
Section 1800	Defiance 3/3	9.607	63.97	21.61	9.02	6.17	0.398
Section 1800	Red Fife 3/3	9.838	63.28	23.49	9.55	6.84	0.405
Section 1800	Kubanka 3/3	10.240	64.00	26.12	11.05	7.47	0.383
Average		9.895	63.75	23.74	9.87	6.83	0.395
Section 1900	Defiance 3/3	8.908	63.60	22.52	9.13	6.31	0.386
Section 1900	Red Fife 3/3	9.913	63.13	25.33	10.15	7.15	0.410
Section 1900	Kubanka 3/3	10.280	63.63	27.53	11.89	7.99	0.399
Average		9.700	63.45	25.13	10.39	7.15	0.398
General average all plots without nitrates		**9.416**	**64.02**	**23.90**	**9.91**	**6.91**	**0.398**
Section 1700	Nitrate plots 3/3	12.174	61.35	31.05	12.83	9.14	0.395
Section 1800	Nitrate plots 3/3	11.746	61.42	30.88	12.63	8.86	0.351
Section 1900	Nitrate plots 3/3	10.901	63.10	28.91	11.83	8.00	0.359
General average		**11.607**	**61.96**	**30.28**	**12.43**	**8.67**	**0.368**

AVERAGE COMPOSITION OF WHEAT—CROP 1915

		Protein Perct.	Starch Perct.	Wet Gluten Perct.	Dry Gluten Perct.	True Gluten Perct.	Phosphorus Perct.
Section 1700	Defiance 3/3	8.78	62.26	19.06	7.36	4.67	0.396
Section 1700	Red Fife 3/3	8.27	62.28	19.21	7.76	5.07	0.411
Section 1700	Kubanka 3/3	9.79	57.71	28.33	10.98	7.22	0.394
Average	....	8.95	60.75	22.29	8.70	5.65	0.400
Section 1800	Defiance 3/3	8.70	61.42	19.83	8.47	4.75	0.398
Section 1800	Red Fife 3/3	8.40	62.34	19.86	8.00	5.27	0.390
Section 1800	Kubanka 3/3	9.55	59.90	20.20	10.70	7.01	0.383
Average	....	8.89	61.62	19.96	9.06	5.68	0.390
Section 1900	Defiance 3/3	8.74	62.37	19.07	7.59	4.46	0.369
Section 1900	Red Fife 3/3	8.55	63.47	21.00	8.23	5.63	0.334
Section 1900	Kubanka 3/3	9.76	60.43	25.51	10.46	6.93	0.378
Average	....	9.01	62.09	21.86	8.76	5.67	0.360
General average all plots without nitrates	....	**8.95**	**61.35**	**21.34**	**8.84**	**5.67**	**0.383**
Section 1700	Nitrate plots 3/3...	10.88	58.99	27.99	10.71	7.39	0.364
Section 1800	Nitrate plots 3/3...	11.46	57.81	27.86	11.79	7.87	0.360
Section 1900	Nitrate plots 3/3...	12.16	57.41	33.83	12.73	8.36	0.382
General Average for the Nitrate plots	....	**11.50**	**58.07**	**29.89**	**11.74**	**7.87**	**0.369**

There is one big fact evident, namely, that there is a great difference in the composition of the products obtained, whether taken by variety, or by plot. There was a depression of the proteids in 1914, and a further one in 1915. This is not true of the starch, for we find very similar figures for 1913 and 1915, the best and the worst crop. The samples produced with the application of nitrates have been averaged by themselves for the purpose of bringing out the effects of the nitrates in contrast with the more normal samples grown either without any fertilizer, or with such as do not radically disturb the composition of the products.

The data presented in the various tables make it clear that we may safely consider the nitrogen as the element most susceptible to the causes of these differences, and at the same time the most important one. There are differences in the mineral constituents, some of which can be explained, and the ratio of gliadin to glutenin is much closer in the best than in the worst of the three. These may, however, be neglected for the present time and the protein alone be taken into consideration. The starch varies too little in amount and too irregularly to be of much significance, though this too may be affected by the nitrogenous compounds in the wheat. The wet, dry and true gluten are so closely and regularly connected with the total protein that there would be no object in attempting to consider them at all in this connection. It seems probable, then, that, if we can make out what has caused the differences in the protein content of the three crops we will be justified in asserting that this is the cause that has determined the character of our wheats for 1914 and 1915.

The yield, weight per bushel, and the physical properties of the 1914 crop were all that we could wish, and I had no notion of the existence of any such facts as we find, pertaining to the composition, till the analyses revealed them. This was also in part true of the 1915 crop, for even in this crop 21 of the 24 plots planted to Red Fife and Kubanka yield from 21.95 to 40.83 bushels per acre, and the wheat from these 21 plots weighed from 60 to 63 pounds per bushel, but as appears from the average composition exhibited in the preceding table, the wheat is very inferior.

CAUSES OF INFERIOR WHEAT GROWN IN 1914

The causes which may have produced these results are, in the first place, lack of fertility, in the second place, excess of water and improper temperature which we will include under the term climatic conditions, and in the third place, the rust that developed upon the plants.

Lack of Fertility Not Responsible

In regard to the first cause, we have previously stated that we have no data of such convincing force that we feel entirely satisfied to assert that there might not have been something lacking in this respect, either in the quantity present or in its ratio to other plant foods. Nevertheless, these data convince me most thoroughly that this was not the case. The facts that appear to me as really conclusive that the very low protein content of the wheat in 1914 and 1915 was not due to this, i.e., lack of fertility, are the luxuriant growth of the plants, the yield of wheat, and its weight per bushel.

On the theory that the carbohydrates are deposited at or near the end of the plant's activity, and that the plumpness and weight per bushel depend upon the degree of perfection with which this process is carried out at the time of maturity, it may be suggested, as is frequently stated in the literature of this subject, that the volume of the crop would necessarily correspond to a low protein content. This suggestion does not apply, for in 1913 our Defiance check plots yielded an average of 41.1 bushels, weighing 62.3 pounds per bushel, with 11.86 percent of protein; the same plots in 1914 yielded an average of 31.1 bushels, weighing 56.7 pounds per bushel, with 9.383 percent protein. We need not confine this statement to the Defiance. The Fife plots treated with potassium in 1913 yielded 32.67 bushels per acre, weight per bushel 63.75 pounds, average protein 13.81 percent; the same plots with the same treatment yielded in 1915, 32.16 bushels per acre, weight per bushel 60.6 pounds, average protein 8.30 percent. The Kubanka check plots yielded in 1913 an average of 34.1 bushels per acre, weight per bushel 63.1 pounds, average protein 12.28 percent; the same plots in 1915 yielded 32.8 bushels per acre, weight per bushel 62.6, average protein content 9.64 percent. An explanation of the difference in the protein content can not be based on the ground that the volume of the crop corresponded to a large increase in the percentage of the starch or other carbohydrates. The percentages of starch remain constant within very narrow limits.

If any deficiency in fertility actually existed, it would probably correspond to the deficiency in the grain and this is in the nitrogen content. The growth and color of the plants ought to reveal any so great a deficiency as would correspond to the depression of the nitrogen that we find. Further, we find direct proof that this is not the case, in that we find a depression in the average amount of the protein present in the grain grown on the respective plots to which a liberal application of nitrogen had been made. We have for the average amount of protein in the grain produced on such plots in 1913, 14.17 percent, in 1914, 11.50 percent and in 1915, 11.50 percent. Some of the samples included in these averages, especially in 1914 and 1915, were badly shrunken and, according to the accepted theory, should have been very high in nitrogen; others of them were, from the physical standpoint, perfect wheats. The amount of nitrogen applied to these plots varied from 40 to 120 pounds per acre, so there could not possibly have been any dearth of nitrogen.

The considerations here presented may fail to satisfy some, but they appear to me to prove conclusively that the cause of the inferior composition of the wheats produced in 1914 and 1915 can not be attributed to lack of fertility.

Cannot Be Charged to Climatic Conditions

The question of climatic influences resolves itself into several phases each of which may be of varying importance, i.e., the total amount of water received by the crop, the manner of application, as irrigating water or as rain, or, stated otherwise, whether the soil alone or both the soil and the plant is wet, the time of application or distribution of the rain, the temperature, cloudiness, winds, etc. The mean temperature and air movement in the years of good and bad wheat were so similar, especially during the month of July and the early part of August, including the period from blossoming till maturity, that it is difficult to believe that these factors were responsible for the differences in the quality of the grain. The mean temperature for July, 1913, was 66.8 degrees, and in 1915 it was 64.7 degrees. The early part of the month in 1915 was warmer than in 1913, but there were great deviations from the mean in either year. There was a difference in the amount of cloudy weather and the distribution of the water. The amount of water received by the crop during the respective seasons was the same, 19 inches, in 1913 we applied to most of the plots 12 inches of water and the rainfall was 7 inches (6.77), in 1915 we applied 6 inches and the rainfall was 13 inches. This fact relieves me from the necessity of considering the quantity of water used as a cause of these differences, but if it were necessary to do so, I would take the ground that a variation in the amount of water from 12 to 36 inches would not produce these results. We shall discuss this subject later. For the cases in hand, I shall consider the question of the effect of the amount of water eliminated by the fact that the water received during the months of May, June, July and the early part of August, or throughout the growing period of the crop, was so nearly the same that we are justified in neglecting the difference, especially as this difference pertains largely to the month of April, the time of seeding. The fact is that the total water received by the crop of 1915, was less than in 1913, the season when we obtained wheat of the best quality. These considerations justify us in dismissing the direct influence of the climatic conditions as the cause of the poor quality of our 1914 and 1915 crops. It is not intended to deny that the climatic influences affect the quality of wheat crops in some measure, but it is intended to assert that the inferior quality of the crops here considered was not due to the direct influence of climatic conditions.

Rust Chiefly To Blame For Poor Quality

I ascribe the poor quality of the wheat almost wholly to the effects of the rust that developed during the early days of August in 1914 and during the latter part of July in 1915. The earlier varieties of grain apparently escaped serious injury in 1914, when our maximum yield reached 55.5 bushels of wheat, weighing 64.5 pounds per bushel, and our next highest was 54.5 with the same weight per bushel. These two are given because they were obtained with different fertilizers. The rust appeared a few days earlier in 1915 and there was no question about its affecting the yield of each of the varieties. The Defiance was very seriously injured, the yield on one plot was reduced to less than 9 bushels per acre and the kernels were no more than dried out, empty sacks, which, contrary to the statements that I have found on this subject, were not remarkably high in protein, but were 20 percent lower than good kernels grown with the same fertilization on this ground the preceding year. I have found but one analysis of rusted wheat; this was published by Mr. F. T. Shutt, Chemist, Dominion Experimental Farms, Canada, Abstract in Experiment Station Record, Vol. XVI, p. 585. Mr. Shutt gives analyses of rusted and rust-free straw and also of grain. The grain from rust-free wheat contained 10.50 percent proteid, that from rusted wheat 13.69 percent. Mr. Shutt says of this: "In other words the growth of the rust arrests development and induces premature ripening, which, as we have seen, means a straw in which still remains the elaborated food and a grain small, immature, rich in protein and deficient in starch."

Prof. H. Snyder, in Minnesota Station Bulletin No. 90, Abstract E. S. R., Vol. XVI, p. 1074, gives the analyses of some rusted wheat-straws from which it appears that rust-free straw contains a little over one-half as much protein as badly rusted straw. The Abstract continues: "Wheat from rusted plants contained a higher percentage of protein, fiber and ash than some fully matured grain from rust-free plants grown under the same conditions. The percentage of carbohydrates was highest in the sound samples. Some of the rusted wheat samples contained as high as 19.30 percent of protein." These are the only references to the effects of rust upon the composition of the plant and the grain produced that I have found. McAlpine, in his book "The Rusts of Australia", p. 65, quotes the preceding statement of Shutt's with approval, but adds nothing to it.

Our Results Contrary To Prevailing Opinion

The fact is that we have in 1914 and 1915 wheat which is very similar in composition but very different from wheat produced on the same ground in 1913, and so far I have not given any cause for the difference, but have stated that I believe it to be due to the severe attacks of rust which prevailed during these years. It will be noted that the prevailing opinion is that wheat grown on affected plants is richer in protein than such as is matured on unaffected plants; it is also stated that shrunken wheat is higher in nitrogen than well-filled wheat. This may be correct, but it is certainly not the case with our wheat nor is the percentage of starch perceptibly affected, as is shown by the percentages of starch in the crops of 1913 and in 1915 grown without application of nitrates. The average percentage of starch in the 27 samples of 1913 is 62.2, and for the same number of samples in 1915, grown under the same conditions of fertilization, the average is 61.5. There is a difference of only 0.7 of 1 percent in favor of the crop of higher quality. We must frankly admit that our results are contrary to the prevailing opinion on this subject.

THE NITROGEN CONTENT

In 1913 we studied the development of the nitrogen compounds in the plant from time of blooming till maturity. It is entirely sufficient for our present purposes to follow the course of the total nitrogen. This will be found in detail for the crop of 1913 on page 36 of Bulletin 208. The percentages are given for the fresh plants, but the percentages of dry matter are given on page 34. The variety used for these may be used to recognize the corresponding sample of grain given in this bulletin. The samples grown with the application of nitrogen are again left out of consideration. The total nitrogen in the stems and leaves remained fairly constant till the end of July, when they showed a very decided decrease, in spite of the fact that the plants were drying out, amounting to from approximately 30 percent to 50 percent. On the other hand, the total nitrogen in the heads ran fairly constant till the end of July, when it suddenly increased from an average of 0.6967 to 0.9868 percent, practically 0.3 of 1 percent in five days (29 July to 4 August) and the head at that time was rapidly increasing in weight. There must have been a very active movement of nitrogen from the plant to the seed at that time. The wheat was cut on 6 and 7 August when it was fully ripe. This wheat averages 12.58 percent protein (N x 5.7).

Low Nitrogen Content In 1915 Due to Rainfall Causing Leaching or Impairing Transpiration

It was impossible for us to repeat this portion of our study in 1914 but we were fortunately able to take it up again in 1915. The full record of this work is given in Bulletin 217. The plants were from 10 to 14 days later in their development and were more succulent than in 1913. The succulency of the plant was probably due to the frequent light rains and heavy dews. The plants are poorer in nitrogen irrespective of the fertilizer applied, even after allowance has been made for the greater quantity of water in the plant. This might be due to three causes, exhaustion of the soil, leaching due to the almost continuously wet condition of the plant, or to a greatly retarded transpiration. Inasmuch as this difference is as great in the case of the plants that were grown with a continuous, artificial supply of nitrogen as in those which were grown without any, it is probably not due to deficiency in nitrogen, and if there be no other causes than those suggested, it must be due either to leaching or to impaired transpiration. This is, in either case, an effect of the weather. The samples of stems and leaves taken from the same set of plots on 29 July, 1913, and 30 July, 1915, were quite close to one another in their nitrogen content, but this was not true of the heads which in 1915 were materially lower than in 1913. It is evident that in both years about this time a very active transference of nitrogen from the plant to the head began. On 27 July, 1915, the heads on the Fife check plot contained 0.5247 percent and on 30 July, 0.6324 percent nitrogen. The drying out of these plants had not yet begun to take place. At about this time in both 1914 and 1915 the wheat became very rusty, but the wheat in 1914 was more advanced, by 5 or 6 days, than in 1915. In fact, we had had up to this time a very favorable season in 1914. This date is the turning point in the character of our respective crops. In 1913 the nitrogen in the plants decreased regularly till the wheat was ripe. The stems and leaves dried out and the dry matter increased very greatly, but it was poorer in nitrogen than the plant had been at an earlier date. The heads increased in weight and dry matter, but most of all in nitrogen. On 25 July the heads of plants from plots which had received no dressing of nitrogen contained 0.8495 and the heads of plants from the same plots on 5 August contained 1.2463 percent of nitrogen. Samples taken from other plots between these dates indicate that practically the whole of this change took place between 29 July and 4 August. This wheat was free from rust, ripened naturally and was cut on 6 and 7 August. The average protein content of the samples of this variety grown without the application of nitrogen was 13.63 percent (N x 5.7).

I have pointed out that on 30 July the plants of the 1915 crops contained approximately the same amount of nitrogen as in 1913. From this date till that of full ripeness of the grain, the crops acted entirely differently. There was some increase in the nitrogen of the heads, but it was in no measure comparable to the change that took place in 1913. On 30 July the heads from a check plot averaged 0.6486, on 12 August heads from the same plot averaged 0.7828 percent nitrogen. During 11 days in 1913 we found that the nitrogen in the heads increased from 0.85 to 1.25 percent; in 1915 we found that they increased from 0.65 to 0.78. This apparent increase itself is doubtful when we consider the drying out which took place. On the other hand, we found that the stems and leaves did not diminish in their nitrogen content from this date on till that of ripeness as in 1913. On 6 August, the earliest date on which the leaves and stems were taken together, the average nitrogen content of the plants grown without the application of nitrogen was 0.2371 percent and that of the heads 0.6834 percent; on 12 August the plants and leaves contained an average of 0.2703 and the heads 0.7825 percent. The increase in the heads is at best very small, and, owing to the drying out and relative increase in dry matter, is a little doubtful. This wheat was harvested 16 August in good condition, except for the rust. The average protein content of this wheat was 8.41 percent. This average is 5.22 percent below that for the season 1913.

Rust Was Severe In 1915

We unfortunately were not able to follow this feature of our study in 1914. We can, however, record the fact that we had very favorable conditions up to the end of July, when we had a heavy shower which beat down our grain and rust followed. The grain was more advanced in its development when this happened than it was in 1915 when the rust attacked it. We do not know that the nitrogen transfer was practically stopped in 1914 as it was in 1915. The effect, however, on the composition of the wheat was almost the same. The average protein content of the 1914 crop for this variety of wheat was 9.82 percent against 13.63 in 1913. This is a very surprising result considering the advanced stage of development of the wheat at the time of the attack. My opinion at the time was that the crop was almost safe against this kind of injury, but it evidently was not. According to our observations of 1913 and 1915 this effect is very probable if the attack took place, as it must have done just at, or during the period of most active transfer. In 1915 the rust was very bad, I have no measure by which I can express the severity of the attack, but it is evident from the data given that it practically stopped the transfer of nitrogen to the heads, which is equivalent to saying the kernels. If it did this in 1915, we argue that it did the same in 1914, and that this is the cause of the low protein content of the grain.

It may be true that the weather influenced the course of the development; it may also be true that the succession of crops may have been ill-advised, still, on 30 July, 1915, the nitrogen in the plants compared favorably in quantity in the stems and leaves with that present in 1913, and had the normal transfer taken place we should have had excellent wheat, for the plants were at this time large and thrifty, and the nitrogenous material already accumulated appeared ample to produce wheat of good quality, but, as we have seen, this did not take place, and we had wheat with 8.41 percent of protein. The observations of Shutt and Snyder on the high proteid content of rusted wheat-straw are in harmony with this view.

We have many samples of shrunken wheat in the crops of 1914 and 1915, but these samples are not high in nitrogen, which we interpret as the natural result of the stoppage of the transfer of the nitrogen. It seems that the movement of the carbohydrates is also interfered with and the shriveled wheat represents practically the condition of the kernel at the time of the attack. Some growth of the kernel takes place after the attack but it is so much less than would normally take place that it does not make the above statement wrong.

Deposition of Nitrogen and Starch Takes Place Simultaneously

This is not the view generally held, so far as I have been able to gather. The prevalent view is that the nitrogenous components of the kernel are the first and the carbohydrates the last to be laid down, so that shrunken kernels are considered to be caused by deficiency of carbohydrates, chiefly starch. I have already called attention to the fact that the percentage of starch in the samples of 1913 and 1915 are very nearly alike, though the weight of the kernels is very different, as the average weight per 1,000 kernels for the respective years may indicate in a general way. The weight per 1,000 kernels in 1913 averaged 38.35 grams, in 1915 26.61 grams, a difference of 11.74 grams per 1,000 kernels, or 44 percent in favor of the 1913 crop. The difference in the average percentage of starch, taking all the samples except those grown with nitrates, is 0.84 percent. One hundred grams of the shrunken wheat contained practically the same amount of starch as a like quantity of the good wheat, and it contained less protein by 3.58 grams. This would seem to indicate that deposition of nitrogen and starch takes place at the same time—or if the deposition of one was hindered more than the other, the deposition of the nitrogen was hindered more than that of the starch.

VARIATION IN AMOUNT OF CRUDE FIBER

No feature in the composition of the crops produced during these three seasons is more marked in its variation than the percentage of crude fiber. In 1913 it was, perhaps, a little below the average for wheat in general—it may be taken roughly at 2.60 percent for 1913—in 1914 it was higher, about 3.00 percent, and in 1915 it was very high, about 3.7 percent. It will be observed that this is roughly inversely proportional to the absolute weight of the wheat. In other words, the frame-work of the cells had been completed and probably but little or no cellulose would under any conditions have been added to the kernels subsequent to the period at which the rust attacked the plants. The rust stopped the transfer of the filling material from the plant to the kernels, and left the ratio of cellulose to the other constituents abnormally high and the kernels shrunken.

The ash, as determined, is probably about 0.1 percent too low, owing to the losses in making the determination, but this loss is common to all the determinations and in the same direction, so that the averages are not very much disturbed. The individual determinations are comparatively close together, ranging in the case of Section 1800 from 1.700 to 1.995 for the year 1913, from 1.692 to 2.017 in 1914, and from 1.777 to 2.022 in 1915. These data include the three varieties and the different fertilizations. The averages for the three years, 1913, 1914 and 1915 are, for the grain grown on Section 1800, 1.925, 1.817 and 1.778 percent of ash respectively. The statement of the ash constituents has been given in percentages of the air-dried grain instead of percentages of the ash, which reduces the numbers given in the statement. Disregarding the chlorin and sulphur in the present statement, the greatest variations will be found in the phosphorus and potassium. These two are perhaps the most important ash constituents, at least they are in our problem, so far as now developed. The average amount of phosphorus in the grain (all three varieties taken) grown on Section 1800 in 1913, 1914, and 1915, was 0.432, 0.388 and 0.382 percent respectively, and the average amount of potassium was 0.441, 0.448 and 0.426 percent. While these averages conceal the differences in the individual samples, they serve to show that the different seasons, including all the factors, made but little difference in the average percentages of these elements in the grain, though the development of the kernels and their composition, especially in regard to nitrogen, was very different. While I believe, and have so stated, that very small differences expressed in percentages of air-dried grain, very probably have a big significance in regard to the properties of the wheat, and in relation to the effects of fertilizers, and perhaps, also of the seasons. I doubt, however, that we have any data which can be properly so interpreted, still the above averages justify the inference that the relative amounts of ash were not affected greatly by the different conditions prevailing during the three seasons; in other words, the whole development of the plant moved forward in the same manner and relative measure up to the time that the rust interrupted the transfer of matter to fill out the grain. We have no analyses of the plants, giving the ash constituents at such periods in their development that we can use the results in this connection. This is to be regretted, for had we analyses representing plants before and after this period of rapid transfer, it might give us some further useful data.

These results are in close agreement with the conclusions of Brenchley and Hall, who say: **"For the filling of the endosperm, each plant possesses as it were a special mould, and continually moves into the grain uniform material cast into that mould, possessing always the same ratio of nitrogenous to non-nitrogenous materials and ash."***

THE EFFECTS OF IRRIGATION

Our object in this work was to ascertain what we may consider characteristic of Colorado wheats and the factors to which this may be due. I have presented the crop of 1913 as probably the most nearly normal wheat that we have grown up to the present time, and I have justified myself in doing so by presenting the abnormal characteristics of the crops for 1914 and 1915, and the causes for the same. One of the factors which enters into our problem is the effect of water, particularly when applied as irrigating water. This question has already occurred in the consideration of the causes for the inferior quality of our 1914 and 1915 crops. In this connection I treated it in the most summary manner, principally because it is a definite and distinct problem. During the seasons of 1913 and 1914 I selected four plots to which I applied a second irrigation four weeks subsequent to the first one and equal in quantity, namely, I aimed to apply 1 acre-foot at each irrigation and to see what effects it produced upon the yield and character of the grain.

* W. E. Brenchley and A. D. Hall, "Development of the Grain of Wheat," Journal Agricultural Science, Vol. 3, Part 2, p. 215; also Rothamsted Memoirs, Vol. 8.

Our experiments yielded no results that we could interpret as showing conclusively that this amount of water made any difference in the yield, weight per bushel, or composition of the grain. There were differences in the composition of the grain from the different plots, but they were small and irregular, so that we attributed the differences observed to the differences in the plots themselves and not to the differences in the amount of water applied.

I learned, very fortunately, that a systematic study of the effects of the fertility of the soil upon the duty of water and at the same time the effects of different amounts of water upon the amount of grain and dry matter produced, was being made at Boise, Idaho, by the U. S. Department of Agriculture, Irrigation Investigations. I further learned that they were not studying the effects of these conditions upon the composition of the grain. Mr. Don H. Bark, the irrigation engineer in charge, was kind enough to furnish me with samples of the grain produced, together with detailed cultural notes. The samples represent two years work and constitute most excellent material illustrative of this subject, especially the samples of the second year, which were grown wholly under Mr. Bark's supervision.

The samples representing the first year's work were produced under a co-operative system. The variety grown in 1913, the first year, was Dicklow spring-wheat. There was no perceptible difference in the physical properties of these kernels. They were all plump, but many of them were small or only medium in size and the weight per bushel was generally less than 60 pounds; some samples were as low as 52 pounds. The time from planting till harvest was in most cases 128 days.

DICKLOW SPRING-WHEAT, BOISE, IDAHO—CROP 1913

Spring-Wheat	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent
Dicklow, 0.76 ft. water applied	9.508	1.953	1.778	2.982	1.427	8.133	65.542	1.249	14.27	5.79	4.036	0.404	0.479
Dicklow, 1.31 ft. water applied	9.503	1.905	1.710	2.817	1.532	8.687	66.076	1.656	15.83	6.33	4.446	0.432	0.488
Dicklow, 2.28 ft. water applied	9.388	1.908	1.718	2.875	1.464	8.343	64.926	1.703	14.40	5.96	4.207	0.392	0.490
Dicklow, 0.71 ft. water applied	9.015	1.907	1.828	2.875	1.662	9.476	64.746	1.484	17.90	7.42	5.307	0.410	0.494
Dicklow, 1.00 ft. water applied	9.223	1.840	1.890	2.900	1.477	8.417	65.304	1.644	16.73	6.68	4.807	0.397	0.546
Dicklow, 1.24 ft. water applied	9.163	1.922	1.833	3.057	1.508	8.596	66.258	1.519	17.37	7.00	5.079	0.401	0.534
Dicklow, 0.99 ft. water applied	9.535	1.949	1.783	3.062	1.556	8.864	66.592	1.602	15.53	6.27	4.435	0.381	0.491
Dicklow, 1.62 ft. water applied	9.575	1.920	1.660	2.912	1.573	8.966	64.602	1.525	16.50	6.69	4.708	0.399	0.512
Dicklow, 2.33 ft. water applied	9.428	1.896	1.738	2.933	1.555	8.864	65.178	1.549	16.73	6.62	4.771	0.389	0.491
Dicklow, 0.66 ft. water applied	9.093	1.771	1.878	2.810	1.584	9.028	66.492	1.715	17.79	7.06	5.101	0.363	0.498
Dicklow, 1.39 ft. water applied	9.390	1.839	1.765	2.962	1.337	7.181	66.150	1.495	14.47	5.79	4.194	0.353	0.457
Dicklow, 2.19 ft. water applied	9.355	1.795	1.713	2.905	1.410	8.037	66.744	1.421	15.20	5.94	4.115	0.322	0.504
Dicklow, 2.34 ft. water applied	9.618	2.141	1.760	3.412	1.568	8.939	65.898	1.404	16.20	6.67	4.752	0.427	0.501
Dicklow, 2.68 ft. water applied	9.493	1.984	1.830	3.037	1.522	8.675	64.314	1.432	16.33	6.39	4.497	0.414	0.560
Dicklow, 3.28 ft. water applied	9.453	2.030	1.755	3.112	1.608	9.156	63.486	1.415	17.23	6.99	5.016	0.433	0.551
Average	.....	.....	.....	.....	.....	......	......	.....	.....	....	.....	0.395	0.506
Winter Wheat, Boise, Idaho													
Turkey Red, 0.47 ft. water applied	9.078	1.918	1.485	2.763	1.853	10.563	64.116	1.455	21.33	8.49	6.302	0.407	0.546
Turkey Red, 0.89 ft. water applied	9.138	1.913	1.520	2.712	1.855	10.573	64.602	1.507	20.44	8.19	6.105	0.393	0.517
Turkey Red, 0.93 ft. water applied	9.870	1.943	1.505	2.800	1.869	10.653	65.734	1.136	20.63	8.20	6.014	0.412	0.526
Average	.....	.....	.....	.....	.....	......	......	.....	.....	....	....	0.404	0.530

SPRING-WHEAT, BOISE, IDAHO

Spring-Wheat	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Total Nitrogen Percent
Dicklow, 0.76 ft. water applied.......	0.0140	0.1328	0.4892	0.7909	1.4269
Dicklow, 1.31 ft. water applied.......	0.0245	0.1258	0.5021	0.8798	1.5322
Dicklow, 2.28 ft. water applied.......	0.0280	0.1328	0.4892	0.8137	1.4637
Dicklow, 0.71 ft. water applied.......	0.0558	0.1678	0.5660	0.8728	1.6624
Dicklow, 1.00 ft. water applied.......	0.0314	0.1748	0.3880	0.8824	1.4766
Dicklow, 1.24 ft. water applied.......	0.0280	0.1748	0.5825	0.7228	1.5081
Dicklow, 0.99 ft. water applied.......	0.0245	0.1608	0.4974	0.8728	1.5555
Dicklow, 1.62 ft. water applied.......	0.0245	0.1818	0.5300	0.8367	1.5730
Dicklow, 2.33 ft. water applied.......	0.0245	0.1818	0.3806	0.9681	1.5550
Dicklow, 0.66 ft. water applied.......	0.0245	0.1608	0.5440	0.8546	1.5839
Dicklow, 1.39 ft. water applied.......	0.0280	0.1398	0.4194	0.7493	1.3365
Dicklow, 2.19 ft. water applied.......	0.0245	0.1748	0.4361	0.7946	1.4100
Dicklow, 2.34 ft. water applied.......	0.0349	0.1748	0.4917	0.8669	1.5683
Dicklow, 2.68 ft. water applied.......	0.0280	0.1748	0.4986	0.8206	1.5220
Dicklow, 3.28 ft. water applied.......	0.0314	0.1888	0.5184	0.8694	1.6080
Winter-Wheat, Boise, Idaho					
Turkey Red, 0.47 ft. water applied...	0.0628	0.1398	0.5383	1.1122	1.8531
Turkey Red, 0.89 ft. water applied...	0.0488	0.1468	0.5756	1.1836	1.8548
Turkey Red, 0.93 ft. water applied...	0.0384	0.1818	0.5721	1.0766	1.8689

Amount of Water Applied Does Not Affect Protein Content

These wheats are not shrunken, but the kernels are very uneven in size. It will be noticed that these wheats are a little higher in starch than our samples for 1913, when our Defiance on Section 1900 averaged 63.58 percent though the other varieties averaged lower, 61 and 62 percent. The percentage of true gluten is very low. The average percentage of phosphorus is lower than in our wheats and that of the potassium is markedly higher. These differences are consistent throughout the series of samples representing the Dicklow variety. To what these differences may be due is not the question that the samples are presented to answer, the question is: "What has been the effect of different amounts of water?" The table shows that the range in the percentage of crude protein is from 7.181 to 9.476, a difference of 2.3 percent. Is this difference due to the amount of water added, or is it due to differences in the land on which the wheat was grown? The wheat carrying 9.476 percent protein was grown with 0.71 foot of irrigating water, which is the lowest amount applied, except in one case, and this, with the least amount of water, produced wheat with 9.028 percent protein. The lowest percent of protein, 7.181, is found in wheat produced with the application of 1.39 acre-foot; with these exceptions the wheat runs uniformly within a limit of 1 percent, which may be due to differences of soil, for these samples were grown by different parties who were co-operating. We have pointed out that two of the wheats with high percentages of crude protein were produced with less than 0.75 foot of water to the acre. On the other hand, the second highest percentage of protein, 9.156 percent, is found in wheat produced with the application of the maximum amount of water, 3.28 feet to the acre, and the next highest percentages occur with the application of 1.62 and 2.34 feet. The total range of the percentages of protein is so limited and the differences that we find being no greater than is found on different plots of land of the same character, and receiving the same treatment, we consider that these experiments, in so far as they are conclusive, indicate no relation between the amounts of water applied and the percentage of protein contained in the kernels. The total lack of any relation between the water applied and the variation of the percentage of protein produced, supports this view.

The winter-wheat given was harvested 340 days from planting. How much water fell as rain during the autumn and winter months is not given in the notes, nor is the date of ripening, but I take it that this date and that of harvesting were close together. This wheat is plump, with a great deal of yellow-berry or mealy wheat. The yields for irrigated wheat were very low, 3.7, 12.29 and 17.5 bushels to the acre. The amounts of water applied as irrigating water were 0.47, 0.89 and 0.93 acre-foot, and the analyses throughout are almost identical, showing a low percentage of protein for this variety, 10.6 percent, but it is very near the percentage that we have found for samples of dry land wheat, and higher than some exceedingly mealy samples of this variety. We have found, generally, about 13.0 percent of protein for this variety of wheat grown with irrigation.

The experiments of 1913 were not entirely satisfactory to Mr. Bark, so he endeavored to make those of the next year more satisfactory to himself and, for my purposes they are much more conclusive.

An Additional Test at Boise, Idaho, In 1914

The experiments here described were made on six plots of land, each approximately one-tenth of an acre in area. These plots were arranged in two series of three each, the series abutting on one another. One series was not fertilized, the other received an application of well-rotted horse and cow manure at the rate of 15.67 loads to the acre. The land was plowed in November, harrowed and disced in the spring, seeded 2 April, and corrugated 4 April. Wheat practically all up by 25 April. One plot in each series received the same amount of water, i.e., they were paired, one manured and one unmanured. One of these pairs received one acre-foot, one 2 and one 3 acre-feet of water. The manured plots yielded as follows per acre: With 1 acre foot of water, 4,033 pounds of straw and 1,467 pounds of wheat; with 2 acre-feet of water, 4,228 pounds of straw and 1,663 pounds of wheat; with

3 acre-feet of water, 3,489 pounds of straw and 1,826 pounds of grain. The unmanured plots yielded as follows: One foot of water, 1,713 pounds of straw and 1,000 pounds of wheat; 2 feet of water, 2,183 pounds of straw and 1,144 pounds of wheat; 3 feet of water, 2,511 pounds of straw and 1,266 pounds of wheat. The distribution of the water was as follows: Those plots that received 1 foot of water were irrigated 2 June, 19 June, and 16 July, those that received 2 feet of water were irrigated 21 May, 11 June, 26 June, 8 July and 15 July; those that received 3 feet of water were irrigated 11, 20 and 29 May, 12 and 25 June, 3 and 15 July. The grain was ripe by the 24th or 25th of July, or 114 days from planting. The plots were harvested as soon as ripe and the grain threshed 11 August. The variety used this season was the Marquis. The grain without exception was good. The individual kernels were of good size and well filled, 1,000 kernels from the unmanured plot that received 2 feet of water weighed 33.90 grams, and from the corresponding manured plot 35.77 grams. I judge the latter to be the very best of the six samples. All of the samples contain many half-mealy or mealy berries. No distinction can be made in this respect between the grain grown with or without manure, without a very careful count which, owing to the color of the berries, would be very difficult to make with any high degree of accuracy. If any distinction can be made between the samples in this respect, the second sample given above may be the least affected of the six. This was grown on a manured plot with 2 feet of water. The analyses of these samples including the ash constituents follow:

SAMPLES OF WHEAT GROWN WITH DIFFERENT QUANTITIES OF WATER, BOISE, IDAHO—CROP 1914

Variety	Water applied Per acre	Manure applied Per acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent
Marquis,	1 foot (1.05)	None	8.833	1.857	2.103	3.185	1.839	10.423	63.198	1.249	26.50	11.37	7.669	0.450	0.406
Marquis,	1 foot (1.07)	15.7 loads manure	8.398	1.804	2.175	3.140	1.853	10.557	61.794	1.507	25.33	10.94	7.381	0.449	0.422
Marquis,	2 feet (1.94)	None	8.790	1.878	2.075	3.120	1.846	10.519	62.820	1.178	27.73	12.44	8.079	0.454	0.401
Marquis,	2 feet (2.01)	15.7 loads manure	8.608	1.943	2.068	3.170	1.897	10.813	63.144	1.249	27.30	11.75	7.864	0.452	0.408
Marquis,	3 feet (2.99)	None	8.608	1.928	2.120	3.062	1.846	10.519	62.406	1.306	27.67	11.83	8.005	0.456	0.422
Marquis,	3 feet (3.05)	15.7 loads manure	8.648	2.009	2.090	3.035	2.047	11.931	61.472	1.346	27.33	11.42	7.904	0.458	0.405

WHEAT GROWN WITH AND WITHOUT MANURE AND WITH DIFFERENT QUANTITIES OF WATER, BOISE, IDAHO

Variety	Water applied per acre	Manure applied per acre	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Total Nitrogen Percent
Marquis	1 foot (1.05)	None	0.1223	0.1958	0.6372	0.8831	1.8385
Marquis	1 foot (1.07)	15.7 loads	0.0453	0.1888	0.6975	0.9227	1.8525
Marquis	2 feet (1.94)	None	0.0628	0.1958	0.7014	0.8855	1.8455
Marquis	2 feet (2.01)	15.7 loads	0.0593	0.1958	0.7003	0.9316	1.8970
Marquis	3 feet (2.99)	None	0.0453	0.1818	0.7330	0.8854	1.8455
Marquis	3 feet (3.05)	15.7 loads	0.0523	0.2307	0.7260	1.0375	2.0465

MINERAL CONSTITUENTS OF WHEAT GROWN WITH AND WITHOUT MANURE AND WITH DIFFERENT QUANTITIES OF WATER, BOISE, IDAHO—CROP 1914

Variety	Water applied Per acre	Manure applied Per acre	Sp. gr.	SiO_2	Fe	Mn	Ca	Mg	K	Na	Cl	S	Total P	Inorganic P	Organic P	Total P
Marquis	1 ft. water	None	1.4204	0.032	0.006	0.006	0.038	0.154	0.406	0.027	0.086	0.104	0.455	0.034	0.421	1.839
Marquis	1 ft. water	15.7 loads manure	1.4283	0.028	0.005	0.006	0.043	0.150	0.422	0.035	0.100	0.114	0.447	0.036	0.411	1.853
Marquis	2 ft. water	None	1.4307	0.028	0.007	0.005	0.042	0.156	0.401	0.053	0.089	0.123	0.454	0.040	0.414	1.846
Marquis	2 ft. water	15.7 loads manure	1.4336	0.050	0.006	0.006	0.047	0.156	0.408	0.056	0.072	0.119	0.452	0.036	0.416	1.897
Marquis	3 ft. water	None	1.4193	0.045	0.006	0.005	0.038	0.161	0.422	0.067	0.101	0.124	0.456	0.032	0.424	1.846
Marquis	3 ft. water	15.7 loads manure	1.4173	0.054	0.006	0.005	0.036	0.158	0.405	0.035	0.096	0.078	0.458	0.029	0.429	2.047

Owing to the prevalence of mealiness in the kernels, mentioned in the last paragraph before the table, we would expect a rather low percentage of crude protein, but, according to our previous observations, we would not expect any noticeable increase in the starch. We have given, among our general samples, three of this variety grown at Fort Collins on fallowed ground, and with one irrigation. These are higher in protein but quite similar, in regard to the starch, to the Idaho samples. The protein in our samples is 13.8, 14.0, and 16.0, while the starch is 59.1, 60.2, and 59.9 percent. Our samples received but one irrigation, about 12 June, which was probably at the rate of 1 foot to the acre, or perhaps less. The Idaho samples received from three to seven applications of water, aggregating from 1 to 3 feet. At the present we will consider the Idaho samples by themselves. The applications of 2 and 3 feet of water increased both the yield of straw and wheat, and the manure effected a further increase. The unmanured plots yielded 1,000, 1,144 and 1,266 pounds of wheat per acre with 1, 2 and 3 feet of water; the manured plots yielded 1.467, 1.663 and 1.826 pounds with the respective applications of water. The effects upon the amounts of straw were relatively the same. From the standpoint of dry matter produced, it is evident that there is an increase due to the more liberal application of water. The manure produced an increase in crop and the application of larger quantities of water produced its own effect, which was slightly enhanced by the influence of the manure. This phase of the question is mentioned merely for the purpose of taking cognizance of the facts in the case and not for the purpose of discussing them. The feature that I want to present is: What, if any, was the effect of the different quantities of water applied upon the composition of the grain? The preceding statements will be deemed as sufficient so far as the crop is concerned.

Experiments of 1914 Give Practically the Same Results as In 1913

These analyses, when compared with one another, do not show any differences in composition which can be attributed to either the water or the manure. By common consent, justified by the facts, we look to the nitrogen content as the key to the solution, but we may in this case take all of the constituents one by one, and we will arrive at the same conclusion, i.e., that there is no variation due to these factors of sufficient size to justify serious consideration. It is true that there is a shadow of difference in the amount of protein present in favor of the produce from the manured plots reaching 1.4 percent in the case of the manured plot that received 3 feet of water. That 15.67 loads, probably not far from 16 tons, of well-rotted manure per acre should have so little, practically no effect upon the composition of the grain, is a little surprising at first sight. The water was applied, as has been stated, at different intervals up to within ten days of full maturity.

This, as we have learned from the study of the changes of the nitrogen in the plant, would be just about at the beginning of the period of most active transfer of the nitrogen from the plant to be berry. The plots that received 1 foot of water had three irrigations, those that received 2 feet had five, and those that received 3 feet had seven. These latter had an irrigation at intervals of nine or twelve days. The ground must have been quite wet all of the time, as the average amount applied at one time must have been about 5 inches, but the wheats from these plots do not differ in their nitrogen content; the plot that received 1 foot of water in three applications produced wheat containing 10.423 percent of protein and the one that received 3 feet of water in seven applications produced wheat with 10.519 percent protein. Neither the amount of water nor the distribution of it has affected the protein content of the wheat. It might be better to state that both together have produced no effect upon the composition of the wheat. It goes without saying that this wheat was kept growing all the time and never suffered for moisture. The supposition is that the weather was bright and favorable. The element next to nitrogen in its sensitiveness to the relative food supply is probably phosphorus, which rises and falls inversely with the nitrogen; in this series it is uniformly very high, and just as high in the manured plots as in the unmanured ones. Attention is called to this particular feature at this time, for the good reason that I intend to point out that comparatively small amounts of nitrogen in the form of nitrates produce marked effects upon the composition of the wheat.

Results In Colorado and Idaho Identical

The results of these two seasons of experimentations are altogether consistent with the results obtained with our own samples of 1913 and 1914, one a season of high and the other of low quality in our wheat. As these Idaho experiments were carried out in a much more systematic manner than ours, I shall content myself with these and omit ours.

These facts and results apply in answering the question relative to the effects of the distribution of the moisture, raised in discussing the causes for the poor composition of our 1915 crop, in which, after citing the fact that our crops of 1913 and 1915 were grown with practically the same amounts of water, I said: **"This fact relieves me from the necessity of considering the quantity of water used as the cause of these differences, but if it were necessary to do so, I would take the ground that a variation in the amount of water from 12 to 36 inches would not produce these results."**

Water and Manure Affect Volume of Crop, But Do Not Affect Composition

If we admit the samples of Turkey Red grown in Idaho to a place in these series of experiments, we have a range in the water used from

0.41 foot to 3.28 feet, without discovering that the amount of water *per se,* provided that the plant does not actually suffer for the want of water, has any influence upon the composition of the wheat, or this influence is so small that it is concealed by the influence of the other soil factors. Both the amount of water and the manure had an influence upon the volume of the crop, but no influence upon its composition.

Knowing nothing to the contrary, I assume that the weather was bright and the plants themselves were uniformly dry exteriorly, and grew in sunshine and with good ventilation, that is, there was no lodging and the air circulated freely between the plants. The total rainfall at Boise, Idaho, for May, June, July and August, 1914, was 2.39 inches.

WHY PROTEIN CONTENT IS MOST SIGNIFICANT FACTOR IN THIS STUDY

I have followed others in considering the amount of protein contained in the grain the most significant compound for the purposes I have had in view. This is justified, both by the important part that it plays in the use to which the grain is put, principally bread-making, and also by the fact that it varies greatly in quantity in proportion to the amount present. The starch, which in its total quantity exceeds the protein by four or five times, varies less as a rule than it. The method of determining the nitrogen is, probably, the most accurate one used in the ordinary analysis of the grain, so that it forms the best single analytical criterion for the estimation of the probable quality of the wheat. The other compounds are present in relatively small proportions and small percentage variations may really have great significance in regard to the living processes of the plant, but they are more difficult both to establish and to interpret. A plant physiologist, perhaps, might make out the reasons for, and the significance of the fact that the crude fiber in the Marquis wheat may vary 0.70 percent when grown in different localities. But, considering the difficulties in making this determination a real close one, and the fact that the amount of the fiber which is largely contained in the bran varies but little from 2.8 percent, it would seem, in the main, unwise to give this constituent any prominence. The same may be said of the phosphorus, but not with the same justice, for the determination can be made with an exceedingly high degree of accuracy and though its quantity is small, this quantity can be shown to bear a general relation to the amounts of other substances present in the grain and eventually in the soil. In Ohio Bulletin 221, p. 22, for instance, the author, J. W. Ames, says: "Phosphorus applied to the soil, showing a deficiency of this element as measured by crop yields, increases the amount of phosphorus in the grain. Associated with this increased amount of phosphorus there is an increased quantity of potassium and a decreased amount of nitrogen." Another conclusion is formulated as follows: "The percentage of nitrogen in the wheat plant varies with the supply at its disposal, and is also influenced to a considerable extent by the supply of phosphorus." p. 23. This observation of Ames is undoubtedly correct, but I have omitted, in the preceding discussion, reference to these facts, preferring to consider the more evident and commonly considered features, though not necessarily the more important ones.

THE EFFECTS OF THE VARIOUS ELEMENTS OF PLANT FOOD UNDER OUR CONDITIONS

Nearly all of our data has been presentel but up to the present time I have given consideration to such subjects as have been forced upon me by the questions arising from the conditions that prevailed in the different seasons. There has been no neglect of the object had in view when we planned the experiments, but the questions presented had to be answered in some manner before we could discuss those which our experiments were made to answer. Without first answering the questions that we have present we could not answer the ones that we wished to discuss, i.e., What are the effects of the respective elements of plant food under our conditions? The answer to this question is necessary in order to approach the primary question of our investigation, to-wit: Why do wheats soften, if they do, under our conditions?

At the present time we can discuss only the questions of composition and physical properties, and if to any degree at all, only incidentally, any matter pertaining to the baking qualities of the flour. Our experiments resolve themselves into three experiments repeated four times with each of three varieties of wheat each year; namely, a check plot and three others, one of which received an application of potassium, one phosphorus and one nitrogen. The fundamental data are, of course, taken to be those furnished by the check plots. In making this choice of arrangements I fully appreciated that it was a purely gratuitous assumption that our check plots would yield normal wheat for our conditions. But this seemed to be a matter of some indifference, for the character of the wheat produced on the plots receiving the individual fertilizer would be like that produced on the check plot or they would be either better or worse, and as we repeated this nine times a year with each of the fertilizers we hoped to find out what effect the individual plant foods produce under our conditions. As has already been pointed out, climatic and pathological conditions intervened which produced very serious results. I have presented these results to the best of my ability and I hope in an entirely unprejudiced manner. It remains for me to present the effects produced by these fertilizers as I believe them to be shown by our data.

In planning this work, I of course, proceeded on certain assumptions. I firmly believed, and still believe, that the development of unusual amounts of nitrates in our soils in the Arkansas Valley accounted for the deterioration in the quality of the sugar beets between the years of 1898 and 1910. I succeeded in showing that the application of nitrates produced those properties in the sugar beets that constituted the points of inferiority in the deteriorated beets—late ripening, characteristically shaped beets, low sugar content, and juices that produced much molasses and which crystallized with difficulty.

There is no reason for concealment of the fact that I thought it probable that this characteristic of our soil might be in part or wholly responsible for the weakness complained of in our wheat. Any collection of samples of Colorado wheats, taken at random, will make it perfectly evident that some other factor than climate or irrigation is at work in determining the character of the wheat, for samples of the same variety from the same locality vary exceedingly in the color, size, shape and hardness of the kernels, and further, in their protein content.

It is very common to characterize wheat kernels according to their appearance as flinty and mealy. This mealiness is designated in many of our states as yellow-berry. I cannot state that the general complaint of softening referred specifically to the yellow-berry kernels, but rather to a general fact that our flour does not yield enough bread. Nevertheless, I am sure that some millers regard the two terms as indicating the same condition. At the present time I do not intend to present the milling and baking qualities of these wheats, as these constitute distinct problems, though incidental reference to some features of them may be almost unavoidable.

Mealy Kernels Result If Available Nitrogen Is Too Low

There is no question but that this difference in the appearance of the kernels of the same variety corresponds to a difference in composition, a fact recognized, so far as I know, everywhere at the present time. Schindler in "Der Getreidebau" (1909) p. 151, cites P. Holdefleiss as showing in 1900 that such kernels differ by 2.44 percent in protein. We have discussed this condition in regard to its cause in Bulletin 205 and from the physical results alone came the conclusion that this condition in the kernel was to be attributed to the ratio between the available nitrogen and available potassium. If the available nitrogen is too low, mealy berries are produced. In previous pages of this bulletin I have discussed the view put forward by some that this condition is due to the amount of water applied as irrigation, and have given my reasons for rejecting it.

There is one statement in that discussion, however, that deserves further consideration. It is the statement asserting the manner in which an excess of water may act in bringing about this mealy condition of wheat, namely, by diluting the nitrates.

Lawes and Gilbert, discussing the effects of rain on the wheat crop, say: "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 clearly made out; namely, the great loss of nitrogen carried off by drainage in the form of nitrates."*

I have shown, in Bulletin 208 and again in Bulletin 217, the extent to which the nitrates may be washed out of the soil by an irrigation. Further, it has been stated that the application of 40 pounds of nitrogen per acre applied at the time of planting produced the characteristic effects of the nitrates though an irrigation of 1 acre-foot was applied on 12 June, nearly a month before the plants came into bloom. We have also demonstrated how efficient such an irrigation is in removing the nitrates from the upper portions of the soil, and further, the rate at which they are re-established in our soil, knowing very well, that this rate depends upon the nitrifying efficiency of the soil with which we are dealing.

VARIATION OF NITRIC-NITROGEN IN SOIL AFFECTS MEALINESS OR STARCHINESS OF CROP

There is another way of looking for the cause of this mealiness and flintiness in the kernels; this is to ascertain whether the characteristic differences in the composition of these kernels can be produced at will by the fertilizers applied. If so, the cause will be more firmly established. We have given, in the table "The Composition of Yellow-berry and Flinty Kernels Grown Under Identical Conditions", fifteen pairs of analyses made on kernels of these characters selected from the same sample of grain. We find that the flinty berries are uniformly higher in total nitrogen, true gluten, gliadin and glutenin than the yellow-berry kernels. We find the same difference, only in a slightly greater degree, between the wheats grown with the application of nitrates and the averages for all the other samples. In 1913 we have, for the average of all the samples grown without the application of nitrates, 12.53 percent protein and 7.55 percent of true gluten, for the samples grown with nitrates 14.17 percent protein and 9.11 percent true gluten; in 1914 we have 9.42 percent protein and 6.91 percent true gluten for the samples grown without and 11.61 percent protein and 8.67 percent true gluten for those grown with the application of the nitrates. In 1915 we have 8.95 percent protein and 5.67 percent true gluten for the samples grown without and 11.50 percent protein and

* "Our Climate and our Wheat Crops," Rothamsted Memoirs, V.

7.87 percent true gluten for those grown with the application of the nitrates. We have, then, a characteristic distinction in the composition of these wheats which is independent of the weather conditions, at least within the extent that they varied in these three seasons, and also independent of the pathological effects produced by the rust. I have explained that I attribute the depression of the average percentage of protein from 12.53 in 1913 to 8.95 in 1915 to the direct influence of the rust and do not believe that the weather has much direct influence upon it. Of course, I do not assert that it had no influence, but I think that this influence was negligible compared with that of the rust. The effect of the rust was certainly as severe in the case of the grain produced with the application of nitrates as in that of the others, in fact it was certainly much more severe if the effect is proportional to the abundance of the parasite on the plant. The differences given for the protein in the wheats grown with and without nitrates are 1.64 percent in 1913, 2.22 in 1914, and 2.55 in 1915. These figures represent the crop. There were almost no mealy berries in the samples grown with the nitrate, but in the other samples there were a great many, up to 96 percent, mealy or half-mealy berries. The differences found in the crops, taken in mass, are about the same as those found for the flinty and mealy berries selected out of the same samples. The table given to show this difference shows that the Kubanka, in which a much sharper division of the flinty and mealy kernels is possible than in the case of the Fife, presents a variation of this difference, ranging from 1.9 to 2.7 percent. We produced the flintiness in one crop, and with it the increase of nitrogen, by the application of sodic nitrate or nitric-nitrogen. The same difference is found in the flinty kernels selected from the produce of the other plots. I attribute it to the same cause. If it be asked whether I assert that the nitric-nitrogen varies enough from place to place in a piece of land to produce this result, I answer yes. This is the explanation that I offer for the facts presented by Prof. Montgomery in Bulletin 269 of the Bureau of Plant Industry, and is my answer to the questions which he formulates as follows: "Why should one plant growing under practically the same enviroment as another, collect from the soil two or three times as much nitrogen?" Prof. Montgomery continues, giving answer to suggested, but unexpressed questions: "The three plants are from the same mother growing in the same centgener probably less than two feet apart, yet the actual grams of nitrogen gathered differ more than 100 percent. This difference is not inherited as these plants rarely transmit this qualiy." The uniformity of enviroment, the fertility of the soil being included, was only apparent. The temperature, moisture, winds, sunshine may have been identical, but not the supply of available nitrogen. The witnesses to this fact are the percentages of nitrogen in the mature wheat. This is in perfect accord with the facts that we find pertaining to the distribution of both total and nitric-nitrogen within limited areas. We selected 150 square feet, forming an area 5 x 30 feet, and took from the middle of each foot a core 2 inches in diameter to a depth of 1 foot, and determined the total and nitric-nitrogen in each sample. We found but few samples from adjacent square feet that did not vary both in the total and nitric-nitrogen, sometimes by significant quantities. We found, for instance, in two contiguous square feet, total nitrogen 0.13600 and 0.14552 percent, and nitric-nitrogen 8.33 and 14.18 p. p. m. We found as low as 6.02 p. p. m. nitric-nitrogen in 1 square foot. This gives us a difference of 5.83 p. p. m. nitric-nitrogen in contiguous areas, 1 foot square, and a maximum range of 8.16 parts in 150 square feet. I made the statement, just above, that the total and nitric-nitrogen varied by significant quantities. In using this expression I am not begging the question by using general terms. The fact is that I do not know, and no one else, so far as has come to my knowledge, has even made an attempt to determine, how small a quantity of nitric-nitrogen in the soil may affect either the quantity or quality of the wheat produced. But we have shown the effects of 10 p. p. m. of nitric-nitrogen, reckoned on the surface-foot, applied to the wheat at planting time. That a less quantity will affect the growth and composition of the crop is very probable, for this quantity was sufficient to produce plants showing the effects of over-feeding in a very marked degree. This amount produced lodging to the very line to which it was applied, it produced broad-leaved, green plants with weak lower nodes, small, often shrunken, kernels and increased the protein in the grain by approximately 2 percent in every case of its application, excepting one or two, in the three years that we have been conducting these experiments. Twice the amount of nitric-nitrogen, 20 p. p. m., produced a greater effect by about 0.7 percent and three times the amount, 30 p. p. m., produced a further increase of about the same amount in the average composition of the crops. The variations, then, in the amounts of nitric-nitrogen within an area of 150 square feet, being about 8 p. p. m., are sufficient to account for the variations observed by Prof. Montgomery, and also to account for the occurrence of flinty and starchy kernels in the same lot or sample of wheat.

MANURE HAS NO EFFECT ON AMOUNT OF YELLOW-BERRY OR COMPOSITION OF GRAIN

There is one feature made evident by the Marquis samples grown at Boise, Idaho, in 1914, which requires discussion in this connection. I have pointed out that the application of water in quantities varying from 1 to 3 feet made no difference in the composition of the wheat, and had no effect upon the prevalence of the yellow-berry in the samples. At the same time, as will not escape the notice of some, the application of 15.67 loads of well-rotted manure produced no effect either on the amount of the yellow-berry, or upon the composition of the wheat in two out of the three cases. The third case, standing against the two others, and being moderate in amount, is not sufficient to preclude almost any other explanation.

It is not a new observation that the application of farmyard manure may increase the yield of both the straw and grain without affecting the composition of the latter. Ritthausen and Dr. R. Pott, after stating that it has been frequently observed that the liberal application of nitrogenous manures generally increases the protein in the mass of the plant produced, and adding that this has been proven beyond doubt, for root crops, potatoes, beets, etc., continue: "The results that have been obtained in growing grains (Samen) have proved much less definite. While the older investigations of Hermbstaedt * and Boussingault † show that wheat and rye seed increase notably in their protein content on the liberal manuring of the soil with substances rich in nitrogen, those of John in Hohenheim and further those instituted by Lawes and Gilbert yield contrary results, according to which the content of these substances (protein) in the seeds is more or less depressed, and A. Mueller finds in the analyses of barley, grown after different manuring, no essential difference in the composition.§

"It accordingly appears doubtful that manuring with nitrogenous substances exercises a definite influence upon the protein content of the seed."‡

Ritthausen and Pott used sodic nitrate and ammonic sulphate as nitrogenous manures in their experiments and found an increase of 32.0 percent in the amount of nitrogen in the harvested grain. They take the average percentage of nitrogen present in the unfertilized plots as 100 and the average found for those fertilized with nitrogen was 132.

Some of these experiments were made eighty-odd years ago, but we have the same results now as then. The effect of farmyard manure is at best doubtful, so far as the composition is concerned, but not at all in regard to the crop. The data given by Kosutany || show that farmyard manure does not always increase the nitrogen contained in the berry. The increase shown in his two pairs of analyses is 0.31 and 1.69 percent of protein respectively. The latter difference may have been due to the effects of the manure, but Ritthausen and Pott obtained an increase of 5.19 percent of protein by the use of nitrogen as sodic nitrate or ammonic sulphate.

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* Schweigger Journ., 46-278-285; Erdmann Journ. fuer tech u oekonon, Chemie XLL, 1-53 (1832). See also Wolff die chemischen.

† Boussingault, die Landwirthschaft, 1. p. 290-291

§ Stockhardt Zeitschrift, fuer deutche Landwirthe (1855) p. 172-174.

‡ H. Ritthausen and Dr. R. Pott. Die landwirthschaftlichen Versuchs-Stationen Vol. XVI. p 385, Author's translation.

|| Kosutany Der ungarische Weizen und das ungarische Mehl pp. 171-172.

NITRIC-NITROGEN INCREASES NITROGEN CONTENT AND PRODUCES FLINTY KERNEL

Our results in 1913, a favorable year, showed a gain from 0.57 to 3.36 percent of protein, but there was in every case in which the sodic nitrate was applied a greater or smaller increase. Similar results were obtained in 1914 and 1915, but the maximum differences were a little greater. The different results obtained with farmyard manure, amounting in some experiments to contradictions, may be due to the form in which the nitrogen is present, or to the nitrifying efficiency of the soil. It appears to be certain that nitric-nitrogen, or easily nitrifiable ammonic nitrogen, increases the nitrogen content of the grain and produces flinty berries; this is not the case with farmyard manure, or if farmyard manure ever produces flinty berries with an increase in the nitrogen content, it is not uniform in its action, for it certainly does not always do it, while the nitric-nitrogen does.

The statements previously made, regarding the composition of flinty and yellow-berry wheats selected out of the same samples, and concerning the composition of flinty wheat grown with the application of nitric-nitrogen, and yellow-berry wheat grown with the application of potassium, justify me in making the following statements without going into the details of many analyses. The application of nitric-nitrogen produces flinty kernels, an increase of protein, amounting in some cases, to more than 2.0 percent, and a corresponding increase in the true gluten. The same relation exists between the starch present in the flinty wheat produced by the nitric-nitrogen and in the wheat grown with the application of potassium as exists between the percentages of this substance in flinty and mealy kernels sorted out of the same sample. In regard to the mineral constituents, there is usually a little more potassium in the mealy samples than in the flinty, especially in normally developed berries. The phosphorus is depressed by the application of nitrogen, to which statement we have found but few exceptions; on the other hand, it cannot be said that potassium has increased it. This suppression of phosphorus is exhibited, not only by our samples grown with the application of nitric nitrogen, but also in samples of flinty wheats from other sections when compared with yellow-berry wheat from the same section. This statement applies to the crop and is not based on selected kernels. The samples here referred to were grown in the immediate neighborhood of one another and on the same type of soil, so the questions of climate and type of soil are eliminated. The flinty wheat, in this case, contained 0.114 percent less phosphorus than the yellow-berry sample. The flinty sample was grown on land so rich in nitrate that an ordinary aqueous extract of the soil reacted strongly for nitric acid with ferrous sulphate and sulphuric acid. The yellow-berry crop in this case contained 50.0 percent more phosphorus than the flinty crop. These two crops, grown with irrigation, show in a very marked manner the composition characteristic of the two classes of wheat. Our dry-land wheats are usually winter-wheats, but they show this difference in physical properties and these characteristics in their composition, so it is not a question of water supply. Another dry land sample of Turkey Red presents as marked a case of yellow-berry as any sample of this wheat in my possession, and contains only 9.04 percent of protein, while the other samples of yellow-berry wheat of the same variety, grown with irrigation, contained 9.65 and 10.05 percent protein. Irrigated wheat of the same variety, grown in the same section of country as the latter two, and from the same lot of seed, contained 13.21 percent of protein, but it was all flinty. The mills willingly accepted this sample, but objected to the former. These samples are good illustrations of my previous statement that the phosphorus is usually lower in the flinty wheats, in which the flintiness is directly due to the influence of nitric-nitrogen. We have in the last two yellow-berry wheats, 0.309 and 0.345 percent phosphorus; the flinty wheat, which undoubtedly owed its flintiness to nitrates in the soil, contained 0.231 percent. They also serve to illustrate the other statement that the potassium is usually a shade higher in the yellow-berry wheats than in the flinty ones, in the yellow-berry samples we have 0.539 and 0.561 percent potassium, in the flinty samples we have 0.485 percent. The statement previously made was based upon results with spring-wheats. These Turkey Red wheats were grown with a water supply ranging from 6 inches of rainfall to 6 inches of rainfall plus one good irrigation during the season in which the wheat ripened.

We have just seen that a scarcity of water does not prevent yellow-berry, which is used in this connection as indicative of composition, as much as to indicate a physical condition. We have also shown that much water does not produce it, and further does not affect the composition of the wheat under ordinary conditions. I am at the present time satisfied that under some conditions, a too liberal supply of water would produce changes in the composition of the wheat, but for all ordinary conditions I let the above statement stand unmodified. I will repeat some data already given to show to how great an extent I am justified in making this statement. I have two samples of spring-wheat, one of Defiance, the other of Red Fife, which were grown without irrigation and with a rainfall of 6.77 inches. These samples contained 13.92 and 15.20 percent protein respectively. A sample of the latter variety grown with irrigation and grown close to the last one given, within 150 feet, contained 17.14 percent protein, while the seed from which the Defiance sample was produced, grown with irrigation, contained 14.92 percent of protein. A very much fairer test of the effects of the amount of water upon the prevalence of yellow-berry and the composition of wheat is the Marquis wheat grown at Boise, Idaho, of which I will give in this place only three samples; the one grown with 1 foot of water contained 10.423 percent, the one grown with 2 feet of water contained 10.557 percent and the one grown with 3 feet of water contained 10.519 percent of protein. The other features of their composition were just as close to one another as are the percentages of protein. The other three samples in this series were heavily manured with farmyard manure and two of them are identical with the three already given. The third one differs slightly in its percentages of crude protein, but is the same in its true gluten, so that five of the six samples are identical in their composition, and the sixth one is at most uncertain. These samples are all strongly affected with yellow-berry and are very high in both phosphorus and potassium, but the potassium is not quite so high as in the Dicklow spring-wheat, which is very mealy and very rich in potassium. The averages for the Marquis are, potassium 0.416, and phosphorus 0.454, for the Dicklow, the potassium is 0.506 percent.

The question may be raised whether 1 foot of water may not suffice to produce the maximum amount of change in the composition of the wheat. In this case the results obtained by the addition of the second and third foot of water would be wholly inconclusive. Again, it may be asked whether the distribution of the water was such as to make the test of the different quantities of the water conclusive. I think that the data given affords an affirmative answer to the latter and to the former also. But I may give the results obtained with a plot of Marquis wheat at this place. This plot was fallowed ground. It received one irrigation, 1 foot or less of water. The yellow-berry was less than 15 percent, protein 15.998 percent and phosphorus 0.374 percent. The Boise samples, manured and not manured, that received 1 foot of water were practically 100 percent mealy and half-mealy, contained 10.42 and 10.56 percent protein and 0.450 and 0.449 percent phosphorus respectively. The weather conditions were equally favorable in the two cases.

In addition to this, the fact that we can grow, on the same tract of land, using the same quantity of water, either flinty or starchy crops with their characteristic composition as we will, proves that flintiness and starchiness are not products of the weather, or dependent upon the water supply in quantities up to 36 inches, we may say 42 inches, for we should add six inches of rainfall.

We have now discussed the effects of potassium and nitrogen without separating them or specially designating them. We have also considered fully the effects of water applied as irrigating water. We have further considered the effects of farmyard manure, which has the effects of a potassic rather than those of a nitrate manure. Further we have suggested that frequent light rains and heavy dews may have a different action on the plant than many times their volume applied to the soil. We have shown in Bulletin 217 that the transfer of nitrogen from the plant to the head is practically inhibited by an attack of rust. We have shown in this bulletin that the protein content of the grain is greatly depressed by such an attack. We have also pointed out that the composition of the shriveled wheat is not different from plumper wheat produced under similiar conditions, and that the protein and starch are transferred to the kernel at the same time. Further, that the period of rapid transfer is brief; in 1913 it apparently extended over a period of five days. Further, that in 1915 this transfer did not take place, not directly because of the weather, but because of the rust, *Puccinia graminis*, which attacked the plants severely at this time. We have given the gluten, especially the true gluten, to show its intimate relation to the crude protein, also the phosphorus and potassium in all the samples to show their dependence upon and relation to the composition of the wheats. We have said nothing about the effects of phosphorus for the reason that in our soils, under our conditions, it has failed to produce such effects that we believe can be interpreted; in other words, its effects upon the growth of the plant, the ripening of the grain, and the character of the wheat produced have not been decided enough, that is, they have not been of sufficient magnitude, to justify us in entertaining even tentative judgments relative to them, in fact, we are compelled to doubt whether this element has exerted any influence at all. We have carefully avoided, and even disclaimed, any opinion relative to the milling and baking qualities of these wheats, though we have found it convenient to give the gluten for the purpose stated above, and have given the gliadin, glutenin, etc., for future reference. In regard to the hardness and softness of the varieties experimented with, we have given their crushing strength in considerable fullness. The statement of these results is possibly due the reader, but he must put his own value on them. I cannot see that any useful fact has been established by the data acquired.

We have shown in grams the difference in the crushing strength of the flinty and mealy berries as given by this method. This difference varies from 3,000 to 5,000 grams, but it is doubtful whether this corresponds to the differences in composition or quality of the wheat. The suggestive fact that I have in mind is this: The Kubanka, as grown on our land with irrigation, is a hard wheat, i.e., has a high crushing strength; the averages obtained vary from 17,000 to 19,000 grams. The Red Fife, for samples grown in the same season on adjacent plots, yields a crushing strength of 10,000 grams. The Kubanka was lower in its protein content than the Red Fife. This difference does correspond to a difference in the deportment of the two wheats in the mill, the Kubanka working very unsatisfactorily in a short reduction. This is due to the difference in the manner of breaking into gritty meal. The miller may know how to eliminate this difference by varying his tempering process. We have offered no explanation for the difference in the deportment of the Red Fife and Kubanka on drying at 100 degrees C. for seven hours, the crushing strength of the one being regularly increased, and that of the other decreased rather than increased, for the sufficient reason that I know of no reason to offer. The kernels are certainly effectively dried on being heated at 100 degrees C., under a pressure of not more than 75 mm. for seven hours.

SUMMARY

Our conclusions in the matter are as follows:

That the wheat plant is much more easily influenced in the character of its product, seed, by the soil fertility than we have been taught to believe.

That the individual elements of plant food exercise specific influences on the composition of the grain produced.

That nitrogen in the form of nitric-nitrogen in the soil affects the growth of the plant, increasing the nitrogen in both the plant and the seed.

That nitric-nitrogen influences both the composition and the character of the grain, producing in the latter respect the characteristic designated as "hard" wheat, i.e., small, flinty, translucent, dark-colored berries, relatively rich in nitrogen.

That these characteristics have a deeper significance in the plant metabolism than the production of an increase of a few tenths of one percent in the nitrogen content of the berry.

That the mineral constituents contained in the berry are influenced by the amount of nitric-nitrogen available to the plant.

That the mineral constituents of the plant are also influenced by the amount of nitric-nitrogen available to the plant, but to a different extent and not necessarily in the same direction as in the berry.

That the nitric-nitrogen produces a soft, weak straw, causing lodging, both by producing a heavy growth of leaves and an elongation of the upper portions of the plant, and by causing a weakness in the lower nodes of the plant.

That nitric-nitrogen greatly increases the susceptibility of the plants to the attack of the rust fungus, probably by furnishing a better nutrient and also because of the softness characteristic of such plants, which is probably due to the weakness of the cell walls themselves.

That organic nitrogen in farmyard manure does not produce these results, except in the measure that it is converted into nitric-nitrogen, the rate of which process depends upon the nitrifying efficiency of the individual soil.

That our results do not show that potassium has increased the starch; neither do they show that it has had any positive effect on the quantity of this substance formed.

That potassium has a tendency to suppress the nitrogen content of the berry.

That potassium suppresses the nitrogen in the plant throughout its growing period, particularly in the stems and leaves, but does not appear to suppress it in the head.

That potassium, under our conditions, produces an effect upon the development of the plant as shown by the larger size of the plants at a certain stage of development, but the plants on the other plots attain the same degree of development a few days later, eliminating this difference.

That potassium increases the condition designated as yellow-berry.

That phosphorus under our conditions has produced so little effect that no interpretation is possible.

That the phosphorus in the berry is depressed by nitric-nitrogen but is not affected by potassium.

That manganese is uniformly present.

That the amount of water applied as irrigating water may increase the crop, but has so good as no effect upon the composition of the crop produced.

That the leaching effect of irrigating water on the nitrates in the soil is not sufficient to affect the nitrogen content of our wheat, if first applied when the plants are two months old, or two months after the application of the nitrates.

That frequent light rains, when associated with heavy dews, produce different effects on the plant from those produced by irrigating water applied to the soil.

That the time of the rainfall and the weather conditions succeeding, are the most important factors in determining the effects of rain upon the wheat.

That the importance of these conditions is an indirect, rather than a direct one, depending upon the development of rust or its failure to develop.

That there is a period just before the maturing of the plant, when, under favorable conditions, the plant transfers its substance to the berries.

That the effect of rust is practically to inhibit this transfer.

That, for the production of the best wheat, there exists an optimum ratio between the nitric-nitrogen and available potassium in the soil.

That, if the potassium predominates, yellow-berry is produced.

That, if nitric-nitrogen predominates, soft, weak plants, small, flinty, and often shrunken berries result.

That, so far as the crushing strength is a proper criterion whereby to judge, our wheats range from semi-hard to hard.

That, so far as composition is concerned, our wheats, produced under normal conditions, i.e., when the plants are free from rust, stand well above the average.

That our soil varies in character to such an extent that there is no general average composition of the wheat produced that can be considered characteristic.

That our climatic conditions are so favorable that differences in composition are, for the most part, attributable to other immediate causes.

That rust causes a very marked depression in the protein content of the wheat, even if the crop is well advanced at the time that the rust attacks the plants.

That rust increases the percentage of crude fiber in the wheat by preventing the filling out of the berries.

That the effects of the fertilizer upon the composition of the wheat and the production of flinty berries, or the increase in the yellow-berry, are not eliminated or concealed by the unfavorable conditions that we had in 1915.

That, on the other hand, the effects of the nitric-nitrogen in increasing the protein content of the wheat was rather emphasized thereby.

That, in 1915, we have shown three classes of effects in the plants, those due to fertilizers or soil, those due to weather and those due to rust.

That of these, those due to rust were by far the most marked and were prejudicial in their character.

That the effect of rust on the grain is to prevent the transfer of the filling material to the berries.

That the shrunken berries due to this cause are not high in protein.

That small berries sifted out of normally developed crops average a little lower in protein than the large berries.

That fixation proceeds in our soil rapidly enough to furnish a sufficient amount of nitrogen to become an important factor in our problems.

That nitrification proceeds rapidly enough to more than quintuple in five months, the amount of this form of nitrogen in the soil at harvest time. The actual increase was from the equivalent of 43.2 to that of 232.7 pounds of sodic nitrate from August to December, 1915.

APPENDIX

The analytical methods followed in the work presented in this bulletin differ in some respects from those given in our manuals. This is true to such an extent that I feel it incumbent upon me to give my methods, in justice to myself, and in order that others may prove the work presented, if they wish to do so, by the same methods that I have used.

The preparation of the ash of either the wheat straw or wheat kernels, involves the loss of important elements, phosphorus, sulfur and chlorin, therefore it seemed desirable to avoid this tedious work and the losses.

I believe that Leavitt and LeClerc were the first to call attention to the material loss of phosphorus in incinerating wheat kernels *. My own experience has taught me that the loss of phosphorus due to volatilization renders it almost impossible to make duplicate phosphorus determinations by incineration that agree reasonably well no matter at how low a temperature one may char the wheat.

The loss of phosphorus during the burning of the straw is much more marked. It is impossible under the joint action of the silica and carbon to expel the phosphorus so completely that only traces of it, a few thousandths of one percent, remain. The determinations not given in the following notes were made by the usual conventional methods, and are therefore omitted.

THE DETERMINATIONS OF IRON, CALCIUM, MAGNESIUM AND THE ALKALIS

These determinations were effected as follows: One or more portions of 25 grams of wheat were treated with concentrated nitric acid in separate portions of 15 to 20 c.c. The mass foams strongly and, if too much nitric acid be added at one time, one is apt to lose the portion, unless an unduly large dish be used. I used a 4-inch silica dish. The whole was evaporated down to a gummy mass before the addition of the next portion of acid. When 50 c.c. had been added, the residue was heated for a while in a hot-air oven, though this is not necessary, and then charred over a free flame and finally put into the muffle. Most of the carbon was burned out. The mass, still containing carbon, was treated with *aqua regia*, the solution evaporated to dryness, the residue treated with hydrochloric acid and filtered. The filter containing the residual carbon and silica was returned to the dish and burned and the residue treated as before. The united filtrates contained all of the bases as phosphates. The silica, together with any crease-dirt, consisting of fine sand, remained on the filter. The total silica and crease-dirt was so small in quantity that no attempt was made to separate them. An examination, however, with an ordinary pocket lens, suffices to show the presence of sand grains.

* Journal Am. Chem. Soc. Vol. 30, pp. 391-394.

The only objection against the use of silica dishes was the fact that small flakes sometimes broke loose and were weighed as silica. The amount of silica this adds to that of the wheat is extremely small and is usually negligible.

The iron, calcium and magnesium were precipitated as phosphates. The iron was weighed as phosphate, the calcium as oxid and the magnesium as pyrophosphate.

The alkalis remained in the filtrate from the precipitate of the phosphates of iron, lime and magnesia. The filtrate was concentrated, and if still alkaline, was acidulated with hydrochloric acid. An excess of ferric chlorid was added and then ammonia in excess to throw down the ferric oxid and with it the phosphoric acid. The precipitate was filtered off, washed, dissolved in hydrochloric acid and reprecipitated. The united filtrates contain the alkalis as chlorids. The procedure from this on was as usual.

The calcic oxid obtained in the above manner is always slightly brown, due to the presence of manganese. It is very probable that the magnesia is also always contaminated in a slight degree.

The chlorin was determined in a separate portion of 10 grams or more.

The portion of wheat taken was dissolved in a mixture of nitric acid and argentic nitrate. When the wheat was completely dissolved and only a white flocculent precipitate remained, water was added, which materially increased the precipitate. This precipitate contained the whole of the chlorin as silver chlorid or otherwise. It was filtered off, washed in part (washing is not necessary when sucked sufficiently dry by the pump), the mass impregnated with a mixture of potassic nitrate and sodic carbonate, transfered while still moist to a nickel dish containing two or three grams of the deflagrating mixture on which the fully opened filter was placed, covered lightly with the mixture and the whole heated until the mass was completely fused. The amount of the deflagrating mixture used was from five to seven grams. The fused mass was dissolved in water and the usual method for the determination of chlorin followed. The fusion is so quickly made that chlorin, if present in the gas, can cause no appreciable error in the results.

The phosphorus was also determined in a separate ten-gram portion.

The wheat was dissolved in concentrated nitric acid and one and a half grams of magnesic oxid added. The whole was evaporated to a brown gummy mass and ignited. The amount of magnesia added is not sufficient to cause the complete combustion of the organic matter, but the mass burns without deflagration. The cooled and partly white mass was treated with dilute nitric acid, or wet with water, and concentrated acid added, evaporated again, and the combustion completed. The magnesic oxid containing the phosphate was dissolved in nitric acid and evaporated with sulfuric acid to separate silicic acid and the phosphoric acid precipitated as molybdate, and finally weighed as magnesic pyrophosphate.

The sulfur was determined in the same manner as the phosphorus, except that ordinary gas could not be used, either in evaporating or igniting. I used electricity for the former and gasolene for the latter purpose. The magnesic oxid was dissolved in hydrochloric acid. If the magnesic oxid be heated in the muffle, care must be exercised that it does not attain too high a temperature or a loss of sulfuric acid may occur.

The manganese was determined colorometrically. The wheat was destroyed by nitric acid as in the other instances. The combustion was completed in the muffle, the residue taken up with sulfuric acid and filtered. Any carbon that had escaped combustion was burned off and the residue dissolved in sulfuric acid and added to the first filtrate. The solution contained about 5.0 percent of sulfuric acid. A few milligrams of silver sulfate were added as a catalytic agent. A few grams of ammonic presulfate were then added and the solution heated in a boiling water bath so long as the color deepened.

THE ANALYSIS OF WHEAT PLANTS AND WHEAT STRAW

The analyses of these substances present some difficulties. To determine the ash, I took 10 grams of the ground straw or plant, charred thoroughly and extracted three times with boiling water, then burned out the carbon as completely as possible and extracted again with water as thoroughly as possible. The residue was ignited and weighed as insoluble ash. This portion is seldom white and an examination under the microscope shows the siliceous outlines of the cells inclosing particles of carbon. The water-soluble portion of the ash contains from 25 to 30 percent of its weight of silicic acid. The terms soluble and insoluble ash mean but little in this case. Their sum gives the total ash, less the phosphorus, which in this process may be so good as wholly lost by volatilization. Hydrochloric acid will extract from the insoluble ash obtained in this way about 0.1 percent of the weight of the straw.

For the analysis proper, I took 100 grams of the ground straw and proceeded as above, except that I extracted the charred mass with hydrochloric acid, as it extracts less coloring matter than water. The charred and extracted mass was pulverized, the carbon burned out as far as possible and the residue again extracted with hydrochloric acid. This residue was ignited and considered as pure silica, though it was not white. The hydrochloric acid extracts were evaporated to dryness to separate silicic acid that had gone into solution. The weight of this was added to the insoluble silica and their sum was considered as total silica. The hydrochloric acid solution was made up to 250 c.c. An aliquot part, from 60 to 100 c.c. according to the quantity of soluble ash found in the sample, was taken for further manipulation. A few cubic centimeters of a ten-percent solution of ammonic phosphate were added and the bases precipitated by the addition of ammonia, to which a little ammonic sulfid was added to carry down traces of manganese and, possibly, zinc. The manganese and zinc were present in such small amounts that no further attention was paid to them at this time.

The separation of the bases and the determination of the alkalis were effected just as in the case of the wheat.

Phosphorus

I took 25 grams of finely ground straw, disintegrated thoroughly with concentrated nitric acid, added 1½ to 2 grams magnesic oxid, evaporated down, and finally heated to introduce the combustion. The residue was not white, but contained much unburned organic matter. Nitric acid was added and the previous operation repeated. The residue, if still too dark, was burned white in the muffle. The thoroughly burned mass was dissolved in nitric acid, a few cubic centimeters of concentrated sulfuric acid added and evaporated, at last, on the sand-bath till the sulfuric acid fumes began to escape, the dish was then placed in a hot-air oven and kept at 160° or higher to separate the silicic acid. The phosphoric acid was separated from this solution with the usual precautions by ammonic molybdate and eventually weighed as magnesic pyrophosphate.

As the silicic acid may give some trouble, this may be removed by digesting the disintegrated straw with 10 to 15 c.c. of strong hydrofluoric acid before the addition of the magnesic oxid.

Sulfur was determined in essentially the same manner as the phosphorus, except that gas cannot be used unless free from sulfur, and the magnesic oxid, which must not be heated too strongly, was taken up with hydrochloric acid and evaporated to separate silicic acid.

The manganese in the straw was determined in ten-gram portions in the same manner as in the wheat, except that to the thoroughly disintegrated mass was added a few c.c., 5 or 6, of concentrated hydrofluoric acid to remove the silica; the mass was then heated for 10 minutes, when I added 5 c.c. concentrated sulfuric acid and continued the evaporation, heating at last over the free flame. The residual mass of carbon usually burned out readily in the muffle.

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