Bulletin 208 June, 1915

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

A STUDY OF COLORADO WHEAT

By W. P. HEADDEN

PART I

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1915

The Agricultural Experiment Station

FORT COLLINS, COLORADO

THE STATE BOARD OF AGRICULTURE.

		Term Expires
HON. J. S. CALKINS	Westminster,	1917
HON. J. C. BELL	Montrose,	1917
HON. CHAS. PEARSON	Durango,	1919
HON. R. W. CORWIN	Pueblo,	1919
MRS. J. B. BELFORD	Denver,	1921
HON. A. A. EDWARDS	Fort Collins,	1921
MRS. AGNES L. RIDDLE	Denver,	1923
HON. H. D. PARKER	Greeley,	1923

GOVERNOR G. A. CARLSON, } *Ex-Officio*
PRESIDENT CHAS. A. LORY, }

L. M. TAYLOR, Secretary — G. A. WEBB, Treasurer

EXECUTIVE COMMITTEE

A. A. EDWARDS, *Chairman*

J. S. CALKINS — G. A. CARLSON

STATION STAFF

C. P. GILLETTE, M.S., *Director*	ENTOMOLOGIST
W. P. HEADDEN, A.M., Ph.D	CHEMIST
G. H. GLOVER, M.S., D.V.M	VETERINARIAN
W. G. SACKETT, B.S	BACTERIOLOGIST
ALVIN KEZER, A.M	AGRONOMIST
E. P. SANDSTEN, M.S., Ph.D	HORTICULTURIST
B. O. LONGYEAR, B.S	CONSULTING BOTANIST
G. E. MORTON, B.S.A., M.S	ANIMAL HUSBANDMAN
E. B. HOUSE, B.S. (E.E.), M.S	IRRIGATION ENGINEER
V M. CONE, B.S	IRRIGATION INVESTIGATIONS
W. P. LITTLE, B.S., *U S. Expert-in-charge*	HORSE BREEDING
R. E. TRIMBLE, B.S	ASSISTANT IRRIGATION INVESTIGATIONS
P. K. BLINN, B.S., ROCKY FORD	ALFALFA INVESTIGATIONS
EARL DOUGLASS, M.S	ASSISTANT CHEMIST
S. ARTHUR JOHNSON, M.S	ASSISTANT ENTOMOLOGIST
L. C. BRAGG	ASSISTANT IN ENTOMOLOGY
J. W. ADAMS, B.S., CHEYENNE WELLS	AGRONOMY ASSISTANT, DRY FARMING
J. W. TOBISKA, B.S., M.A	ASSISTANT CHEMIST
W. W. ROBBINS, M.A	BOTANIST
RALPH L. PARSHALL, B.S	ASSISTANT IRRIGATION INVESTIGATIONS
I. E. NEWSOM, B.S., D.V.S	VETERINARY PATHOLOGIST
MIRIAM A. PALMER, M.A	DELINEATOR
R. A. McGINTY, B.S	ASSISTANT IN HORTICULTURE
CHAS. R. JONES, B.S	ASSISTANT IN ENTOMOLOGY
GEO. M. LIST, B.S	ASSISTANT IN ENTOMOLOGY
JAS. D. BELL, B.S	ASSISTANT IRRIGATION INVESTIGATIONS
CARL ROHWER, B.S., C.E	ASSISTANT IRRIGATION INVESTIGATIONS
BREEZE BOYACK, B.A., M.S	ASSISTANT IN AGRONOMY

OFFICERS

CHAS. A. LORY, M.S., LL.D	*President*
C. P. GILLETTE, M.S	*Director*
L. M. TAYLOR	*Secretary*
MABEL LEWIS	*Executive Clerk*

A STUDY OF COLORADO WHEAT

By W. P. HEADDEN

PART I

It is generally conceded that the flour made from Colorado wheat is inferior to that made from Kansas hard wheat or the better grades of Minnesota flour. Such is the opinion of the bakers and of the public. I have made inquiry regarding the difference in the bread-yield between Kansas and Colorado flours on the supposition that they were equally well milled. As nearly as I can learn, there is a difference of from 30 to 40 loaves per barrel.

Having established the fact that soil conditions are, in the main, responsible for the characteristic properties of our sugar beets, it seemed advisable to study our wheat crop to find out if possible, the factors that determine the quality of our Colorado wheats. In beginning this work, we assume that the popular estimate of our wheat for the purpose of bread-making, i. e., that it is inferior to the best, is established.

In looking over the literature we find no published results of work done on Colorado wheats since the early eighties. Mr. Clifford Richardson published in the Report U. S. Department of Agriculture, 1883, forty-five analyses of Colorado Wheats. Protein (Nx6.25) ran from 11.0 to 15.94, average 13.27, and in the Report of 1884, sixty-one analyses. The protein ranged from 8.93 to 14.00, average 11.79 percent. The average of eleven Minnesota samples in 1883 Report is 12.4 percent, with one as high as 17.15 percent, and for fourteen Minnesota samples in the Report of 1884 the protein is 15.14 percent. The Colorado samples recorded seem to have been furnished by Prof. Blount, at that time Professor of Agriculture in this institution. In the Report of the U. S. Department of Agriculture for 1885 there is reference made to the low protein content shown in the results published in 1884. The statement is made that the low protein content was due to a storm which knocked down the plants and prevented the assimilation of nitrogen. It seems that the average nitrogen content of the sixty-one samples analyzed was 1.8864 percent which, so far as the amount is concerned, by no means calls for any apology and it matters little whether the reason assigned for its being lower than for the previous year, 2.00 percent, is correct or not. While Mr. Richardson's analyses are now upwards of thirty years old, they are probably as serviceable as they ever were, still we have deemed it advisable to make analyses of our own wheats, grown under conditions which we have varied to suit the purposes that we have had in view.

This bulletin will deal largely with the composition of our Colorado wheats, but more particularly with those factors which establish its quality or characteristics. It is evident from the analyses published that the Colorado wheats are, as a rule, as rich in nitrogen as other wheats. They compare favorably with the Minnesota wheats in nitrogen content and in other analytical respects, but the flour does not make as much bread as the Minnesota flour, at least this is the claim of our bakers. Whether it is justified or not, it is customary to consider the crude protein as an index of the quality of the wheat. There are many statements made which cast doubt upon the correctness of this practice. Still it is almost universal, and a high-protein wheat is considered a good wheat. Our wheats are rich enough in protein, but they are considered soft or weak wheats. The object of our study is to discover if possible the factor or factors in our conditions on which this inferiority depends. Our primary assumption is that our climatic conditions are favorable, the vegetative period of the wheat is usually short, our summers are warm and the sunshine practically constant. We do not have excessive quantities of rain, and irrigation is necessary, except occasionally, when the winter wheat may make a good crop without irrigation.

The amount of winter wheat grown in the irrigated sections of the State forms only a small portion of the total, so the wheat of chief importance is the spring wheat.

The climatic conditions are such that we should expect wheat of high quality; the temperature is sufficiently high and uniform, the nights are cool, the rainfall small, the water supply largely under our control, while the sunshine is practically constant and fogs are so good as unknown.

Our soils are easily cultivated, at least for the greater part. They are also well supplied with plant food and yield excellent crops. I have no statistics at hand whereby to establish the average crop on our irrigated lands, but from such information as I have obtained, I think that the average of spring wheat on such lands will not fall so low as 30 bushels, and in many years it will be better than 35 bushels. The kernels are usually plump, but sometimes shrunken; they are apt to lack in flintiness; in this respect, however, they vary. Some land produces very mealy wheat while other lands under the same climatic conditions produce flinty wheat. By far, the greater portion of our wheat that I have seen is mixed, that is, contains both characters of berries. This condition is not peculiar to Colorado. It is present in almost every sample of wheat, spring or winter, that I have seen, and in many of them it is very prevalent. I have treated of this condition, designated as Yellow-berry, in Bulletin 205 of this Station.

Yellow-berry wheat is considered as in some way deteriorated wheat. I do not think that this opinion has been shown to be based upon any established facts. The only justification that I know of for it, is the fact that such wheats, or rather kernels, are lower in nitrogen than flinty kernels when grown on the same plot of ground. It may be true that the flinty berries, richer in nitrogen, actually make a better flour than the yellow-berry kernels but, up to the present time, I think that this is inferred rather than proved. While writers, with almost no exception, assume that a high protein content in wheat indicates a strong wheat, the most of them at the same time insist that the quality of the gluten and not its quantity is determinative of the value of the flour for bread-making purposes. Colorado wheats are not deficient in nitrogen according to the information at present obtainable; even those samples affected with yellow-berry, while lower in nitrogen than samples containing only flinty berries, are not so deficient as to indicate inferiority in the essential quality of break-making. The inference, so far as I have been able to ascertain, has not even been based upon the lower nitrogen content, but is a general assertion based upon the assumption that the yellow-berry is an abnormality.

The Californian wheats are generally spoken of as soft, weak wheats, but are commended for their color and flavor. We find the nitrogen content given for Club, 2.064; White Australian, 1.936; and Propo, 1.918 percent.* These figures are as high as we find given for the hard wheats.

In comparing data concerning protein present it is to be remembered that all of the older data is based on the factor 6.25, while much of the more recent data is based on the factor 5.7. The former makes the protein 1.1 times as much as the latter.

Notwithstanding the fair percentage of nitrogen present in our Colorado wheats, the general experience is that it is not of high bread-making qualities. The second task that we set ourselves in this bulletin is to determine the properties and characteristics of our wheats as they are produced for the markets. We shall first consider our soil conditions and the effects of the individual elements, nitrogen, phosphorus and potassium.

We shall use the term "weak wheat" to designate one which yields a flour of low bread-making quality without regard to whether it is soft or hard and we shall use the term "soft" to indicate a wheat whose kernels crush easily without regard to its bread-making quality—so we shall have the two pairs of characters, weak and

---

*California Bulletin 212, p. 366.

strong, soft and hard. These may be synononomous terms, but not necessarily so, though we find them so used.

The plan of our work includes field experiments in which we cannot control all of the conditions, and later a series of experiments in which we can control all of the conditions. By means of the field experiments we hope to ascertain what the normal characteristics of our wheat really are, both in regard to composition and to the bread-making qualities of the flour produced. We found at the very beginning that this phase of our work required much more extended experimentation than we really desired to undertake, but it was unavoidable. Besides, this seemed to be the only way to analyze the effects of the individual fertilizers usually applied in agriculture, i. e., nitrogen, phosphorus and potassium, and in our case a fourth element, largely under our control, water. Concerning the effects of these elements upon the character, composition and properties of wheat, little seems to have been done. The effects upon the yield have been studied. Some observations have also been made upon the part that the time of application plays in the yield and properties of the grain, this is especially true of the nitrogen; but these observations have been incidental to the experiments rather than a main object. We have been unable to study these points as we wished to; this is especially true in regard to the effects of the water applied. We have been exceedingly fortunate, however, in obtaining samples of wheat grown under controlled conditions so far as the application of water is concerned which answer our purposes just as well as though we had made the experiments ourselves.

We have applied the three fertilizers, nitrogen, phosphorus and potassium, in different quantities. The latter two were added at one time, but the nitrogen was not. The nitrogen work consisted of three series of experiments, in which the minimum quantity of nitrogen used was applied to all of the plots at the same time. Two of the series subsequently received another application, so that one series received a minimum amount, one series received twice and one three times the minimum amount.

So far as the relative amounts are concerned, these ratios are true for the phosphorus and potassium, but the total amount was applied at the time of planting.

The cultivation of the soil was another point necessary to consider. The land used is not virgin soil, but has been under cultivation probably as long as most of our lands, an estimate of between 35 and 40 years would probably be correct. Deep cultivation of our prairie soils is not usually practiced. This is a result of experience on the part of the early settlers, who found that they obtained the best results by shallow plowing. The result of this in our case was that the land, to any depth greater than an average of six inches, was as firm as it had ever been with a slight plow sole at about six inches. My aim was to plow this land to the greatest feasible depth and subsoil it to a depth of eighteen inches in the fall of 1912, allow it to mellow and settle during the ensuing winter and plant it in the spring. I was not able to get this done, so I was compelled to plow and subsoil in the spring. As the season was quite wet, this made my planting late. Of the three sections of land on which I am making my experiments, I turned two of them to a depth of twelve inches and subsoiled four inches deeper, sixteen inches in all. The other section was turned to a depth of nine inches but was not subsoiled. All the advantages of fall plowing were lost, but I saw no disadvantages in the mechanical condition of the seed bed arising from the spring working of the soil. I did not do this spring plowing because I wished to, but because I had to begin some time to get the land in the condition that I desired.

This plowing turned up some six inches of subsoil and put it on top. Ordinarily this would be very disadvantageous, but in our case the subsoil is capable of making just as kind a soil as the surface portions, as there is no very great difference between the soil and subsoil from a chemical standpoint, but from a biological standpoint there is a very great difference in favor of the surface soil. So far as this feature was concerned, my deep turning of the soil was decidedly disadvantageous, but in another respect it was very much to my advantage. This land had been planted to oats and barley the preceding season; both crops had grown luxuriantly, lodged badly, were harvested late and there was a very heavy loss of grain. Even with my deep plowing there were many spots where the oats and barley crowded out the wheat. Had it not been for the deep plowing the oats and barley would have been very much worse. This land is a somewhat clayey loam with visible deposition of calcium carbonate and sulfate below the depth to which it previously had been plowed. On irrigating, it takes water readily, and on drying cracks badly. This last factor cannot fail to be of considerable importance, for these cracks often gape open as much as one-half or even three-quarters of an inch and extend into the ground for several inches. Many of them are as much as four inches deep. I cannot state that I saw any decidedly injurious effects from this cracking, but the segments of soil formed or separated from one another by these cracks dry out rapidly.

We made no study of the bacteriology of the soil but we know that the surface soil that we turned under possessed a decided ability to fix nitrogen and convert it into nitrates. From this standpoint the deep plowing was a decided disadvantage, if we may judge from the bacterial counts made on samples of this soil compared with those made on samples of soil from the same field which had not been plowed so deep.

The only object which I had in breaking up this land was to put it into what I considered good condition. The other and principal immediate objects have been mentioned, one of them was advantageous and the other probably not. The former was the suppression of the barley and oats and the other the diminution of the bacterial flora of a beneficient character. While we have reason to believe that the occupation of the land by cultivated crops influences the bacterial activity in the soil, both by the removal of the products formed, and perhaps also by being directly inimical to their development, still such activity continues with greater or less intensity. In this particular soil we have found nitric nitrogen corresponding to 160 pounds of sodic nitrate in the surface two inches of the soil and 342 pounds in the first foot of soil. This was in fallow spots occurring in a stand of beets. Perhaps the results obtained with land after cropping, compared with land cultivated fallow, may be more acceptable. The cropped land had been planted to wheat which was harvested in early August. Immediately after harvest the stubble was irrigated and disked and allowed to rest till October, when it was plowed and harrowed. The samples were taken from both sections 4 December. A part of the cropped land had received a dressing of phosphorus as superphosphate, and another of potassium as muriate. These facts make a very marked difference. The section cultivated fallow throughout the season contained nitric nitrogen equivalent to 518 pounds of sodic nitrate in the surface foot. The cropped land, which had received a dressing of phosphorus, contained 257 pounds of sodic nitrate taken to the same depth while that which had received the potassium contained 184 pounds. There is no question but that this is the result of fixation and nitrification in this soil and the differences show the effect of cropping on the one hand, though modified by the cultivation received after the removal of the crop, and cultivation fallow during the whole season on the other hand. The results also indicate the favorable effect of the application of phosphorus upon the bacterial activity of the soil. The application of 518 pounds of sodic nitrate per acre to wheat, immediately after sowing, would almost certainly lodge it and give small-grained, shrunken wheat, even if all other conditions were ideal. The consideration of these facts is important in our agriculture. I do not think that this question is as important to all other sections of this country as it is to us, but I believe it to be of very considerable importance to almost all sections of the State. While there is a question in regard to the application of observations made in one locality to the whole of so large a state as Colorado, to say nothing of other states, I still hold that they will, with little modification, be applicable to a very large portion of the west.

I learned much more by turning the land to a depth of twelve inches than I expected to and while I would not advise so radical a procedure as I adopted, the deep cultivation has not shown any disadvantage but on the contrary justifies itself in several ways.

This presents a general though incomplete outline of our field work and the special objects which we hoped to accomplish, *i. e.*, to produce wheat under field conditions on a sufficiently large scale to make the results thoroughly representative, and, through the study of these products to ascertain the properties and character of Colorado wheats. We further hope to control the cultural conditions in such manner that we may be able to establish the effects of nitrogen, phosphorus, potassium and irrigation upon the composition and quality of the wheat produced, and see if in any of these we find an explanation for the fact that our wheats do not produce as desirable a flour as Minnesota or Kansas wheats.

We have already shown in Bulletin 205, "Yellow-berry in Wheat; Its Cause and Prevention," that it is in our power to increase the yellow-berry or to suppress it and that the ratio between the available potassium and available nitrogen is the factor that determines the appearance of this characteristic. I studiously avoided making any assertion pertaining to the composition or quality of yellow-berry wheat in Bulletin 205 for the same reason that I now use the terms "weak wheats" and "soft wheats" with a more definite meaning than is usually done, and further for the very good reason that I did not know whether the yellow-berry, soft, starchy, mealy wheat is really inferior to the flinty, corneous or hard wheat or not. We left this question for discussion in the present bulletin. I adhered closely to the specific problem of the cause of yellow-berry and its prevention. This, however, is closely related to an important phase of my principal problems.

I stated that the growers could control the yellow-berry by increasing the nitrogen in the soil, as the cause is an undue proportion of available potassium compared with the available nitrogen. I also stated that one method of adding available nitrogen was to cultivate the land fallow; this statement applies to our conditions and I judge that it will apply very generally, but hesitate to make too broad a statement. The explanation that I offer is in the development of so large a quantity of nitrates in the soil that, though much may be washed beyond the reach of the plants or destroyed by reduction, there will still remain enough to counterbalance, for the one crop, the influence of the available potassium. This feature of the yellow-berry problem will be discussed further in this bulletin, and the composition and properties of such wheat will be treated of fully.

The experiments planned, consisted of three series with each of three varieties of wheat. Each series of experiments had four members including a check. The size of the plots was one-tenth of an acre. We made other experiments concurrently with these in which we used smaller plots. Casual reference may be made to these but they form no part of the series presented in this bulletin.

The soil chosen for these experiments varies some in character, but it is as nearly uniform as can ordinarily be obtained. The land is quite level and is easily irrigated. We have analyzed this soil, represented by samples taken from different portions of the field at various times. There are some differences, but whether they are great enough, compared with the total amount of the substances present, to justify one in giving them further consideration or not is a question. Absolute uniformity in areas of the size of the aggregate here used, about six acres, is not to be obtained. The mechanical and chemical analyses, including mass analyses of both the soil and subsoil, are given below.

There is but little use in discussing the amount of plant food present as indicated by the analyses, still it gives us a certain indefinite idea of abundance or lack of this food which, in a general way, may be of service. The amounts given are calculated for 8,000,000 pounds of soil, because the soil and subsoil together were taken to a depth of two feet. The total amount of potassic oxid present in this land taken to this depth is approximately 203,280 pounds, or 101.6 tons; of phosphoric acid, 16,080 pounds, 8 tons; of nitrogen, 8,240 pounds, 4¼ tons.

MECHANICAL ANALYSES OF THE SOIL AND SUBSOIL.

Size of Particles.	Soil Percent	Subsoil Percent
Over 1 mm	0.092	0.112
From 1 to 0.5 mm	0.865	0.456
From 0.5 to 0.25 mm	1.810	1.122
From 0.25 to 0.05 mm	45.790	49.883
From 0.05 to 0.01 mm	28.742	25.514
From 0.01 to Clay	10.062	9.617
Clay by difference	2.749	3.707
Moisture and organic matter	9.890	9.589
	100.000	100.000

AGRICULTURAL ANALYSES OF SOILS AND SUBSOILS.

	Soil Percent	Subsoil Percent	Soil* Percent	Subsoil Percent
Insoluble	54.653	57.068	63.485	63.547
Silicic acid	19.805	12.754	9.865	8.558
Sulfuric acid	0.047	0.049	0.094	0.069
Phosphoric acid	0.120	0.127	0.175	0.160
Carbonic acid	3.048	6.312	2.976	4.942
Chlorin	0.032	0.059	0.025	0.035
Potassic oxid	0.872	0.742	0.715	0.573
Sodic oxid	0.290	0.432	0.408	0.316
Calcic oxid	6.100	8.465	4.725	7.310
Magnesic oxid	1.355	1.448	1.258	1.376
Ferric oxid	5.601	3.499	5.663	5.337
Aluminic oxid	3.738	5.397	3.563	2.738
Manganic oxid (M_3O_4)	0.118	0.026	0.175	0.160
Water at 100° C.	......	......	2.816	2.111
Ignition	5.072	3.887	3.918	2.143
Sum	100.851	100.265	99.861	99.375
Oxygen equivalent to chlorin	0.007	0.013	0.005	0.007
Total	100.844	100.252	99.856	99.368
Total nitrogen	0.147	0.069	0.143	0.063
Humus	0.462	......	0.675	0.262
Humus nitrogen	......	......	0.060	0.023
Humus ash	......	......	0.537	0.387
Water soluble	......	......	0.388	0.345
Potassic oxid sol. in citric acid	......	......	0.031	0.018
Phosphoric acid sol. in citric acid	......	......	0.021	0.015
Potassic oxid sol. in N-5 nitric acid	......	......	0.057	0.020
Phosphoric acid sol. in N-5 nitric acid	......	......	0.066	0.073

*This and its corresponding subsoil are composite samples.

MASS ANALYSIS OF SOIL AND SUBSOIL.

	Soil Percent	Subsoil Percent
Silicic acid	63.500	61.350
Sulfuric acid	0.446	0.178
Phosphoric acid	0.217	0.185
Carbonic acid	2.976	4.942
Chlorin	0.025	0.035
Potassic oxid	2.475	2.607
Sodic oxid	1.305	1.444
Calcic oxid	5.250	8.170
Magnesic oxid	1.680	1.796
Ferric oxid	6.263	5.805
Aluminic oxid	9.200	8.760
Manganic oxid (Mn_3O_4)	0.210	0.190
Water at 100° C.	2.816	2.111
Ignition	3.918	2.143
Sum	100.281	99.716
Oxygen equivalent to chlorin	0.005	0.007
Total	100.276	99.709

We will assume that the plants take up all of their nitrogen in the form of nitrates so that the total amount of nitrogen is not so much the question as the rate of nitrification or the rate at which the nitrogen present may become available as plant food. Experiments made with this soil indicate a high power in this direction. The nitric nitrogen was determined at the time of planting and at intervals throughout the season of 1913, i. e., during the growth of the crop. We found at the time of planting very varying results, so much so that any statement relative to the amount of nitrates present not be correct for any other than the particular area taken. With this understanding it may be stated that the approximate amount of nitric nitrogen present at the time of planting was, for the two feet for which the phosphoric acid and potash has been calculated, about 35.16 pounds, corresponding to 211 pounds of sodic nitrate per acre. This amount of nitrogen was at that time available and capable of being appropriated by the young plants.

We used the three conventional solvents in our endeavor to obtain some data pertaining to the availability of the phosphoric acid and potash: hydric chlorid, 1.115 specific gravity; citric acid, 1 percent solution; and one-fifth normal nitric acid. These solvents, in the order given, indicated the presence of the following quantities of these two substances in the first two feet of the soil.

	Potash Pounds	Phosphoric acid—Pounds
Hydrochloric acid	51,520	9,880
Citric acid	1,960	1,440
N-5 Nitric acid	3,080	5,560

These quantities indicate a sufficiency of available plant foods to grow a large number of maximum crops, and explain the fact that the addition of phosphoric acid and potash, even in very liberal quantities, did not produce any observable effects upon the growing plants and only very small effects upon the yield of grain. These are so small that it is only by adhering to a very literal interpretation of the results that we can justify ourselves in claiming any advantage in crop from their use. There is no big, decisive and easily interpreted result produced by their application.

These analytical data are the basis of all of our experiments. They are as satisfactory as any others that we would be likely to obtain, for the mineralogical character of our soil makes it practically impossible to obtain any better or more concordant results, or others which might be more easily interpreted. This soil is exceedingly rich in felspathic sand. The felspar present is for the most part an orthoclase with some microcline. These minerals are readily attacked by decomposing agents, the action of water and carbon dioxide being easily demonstrated. Finely powdered felspar will yield potash to growing plants, as I have proved, using the oat plant.

We have not only grown oats in powdered felspar to maturity, with the production of seed, but we have taken our ordinary felspar and treated it just as we do soil samples with citric acid solution and with water to see how much phosphoric acid and potash it will yield to these solvents. Our results indicate that quite as much of these substances may be dissolved out of pure undecomposed felspar as out of our soils by a similar treatment. Felspar crushed to pass through a 60-mesh sieve yielded to a one-percent citric acid solution from 0.015 to 0.030 percent of phosphoric acid and from 0.018 to 0.051 percent of potassic oxid. The action of pure water, distilled water, on pulverized felspar is sufficient to become a factor in our soil problems.

The results in the preceding experiments led us to test the solubility of finely ground apatite in like manner. Apatite ground to pass a 100-mesh sieve yielded to one-percent citric acid 2.25 percent of phosphoric acid and to water 0.042 percent. A blank test made with the citric acid solution showed only an exceedingly minute trace of either phosphoric acid or of potash.

The mineral basis of our soils, according to these results, may play an unusually important part in our questions. Both the coarser and finer portions of this soil are composed largely of particles of felspar in a comparatively fresh condition, but according to the above results, they may serve as a source from which phosphoric acid and potash may be continuously supplied. It will be noticed that the mass analyses of the soil and subsoil give higher results than the analyses with hydric chlorid, specific gravity 1.115. This is probably due to the fact that the coarser portions of the felspar are large enough to protect the apatite contained in them from the action of the acid.

The moisture as well as the nitric nitrogen in the soil varies greatly. Both of these were determined from time to time throughout the season of 1913, and we intended to follow them throughout the season of 1914, but our working force was not large enough to do this and some of the field work done in 1913 could not be done in 1914. I would have preferred to have carried out the same schedule of investigation through the whole period of our field experiments, but we could not and I am not sure that we would have gained anything by doing so; concerning this, however, there may be room for difference of opinion.

NITRIC NITROGEN AND ITS DISTRIBUTION.

The caption states exactly what we intend to present in this section of our work as best we can. While the greater part of the samples were taken in the small alleys left between the plots, the results obtained have been checked by samples taken from the ground occupied by the plants. While we realized the objections against taking the samples in this manner, it seemed best to do this, as we desired the crop quite as much as these data. In taking the number of samples that we deemed necessary, the injury to the crop, had they all been taken from the cultivated area, would have destroyed the results.

The width of each section is 132 feet, and no sample was taken within 20 feet of either end. The samples are composite, consisting of three subsamples. The borings were approximately 30 feet apart in a line across the section. These borings were made four feet deep. Other borings, not in the midst of the plants, were made to a depth of twelve feet, unless for some reason we could not accomplish it, which sometimes was the case, due to striking coarse gravel. The selection of the depth of four feet for the shallower borings was determined by the consideration that the wheat roots would probably not go to a materially greater depth. The twelve-foot borings were made to determine that the depth of the water plane was at least this deep, and to learn something of the distribution of the water, also of the nitric nitrogen and its total amount.

The following samples were collected in the spaces between the sections 29 April, 1913; this was three days after the grain was planted. This land is of course always fallow.

MOISTURE AND NITRIC NITROGEN IN SOIL AT TIME OF PLANTING.

Depth	Sample 1		Sample 2	
	Moisture Percent	Nitric Nitrogen Parts per Million	Moisture Percent	Nitric Nitrogen Parts per Million
0 to 6 inches	13.37	10.47	13.00	6.66
7 to 12 inches	17.08	7.75	17.05	5.85
13 to 24 inches	16.20	23.80	16.47	4.22
25 to 36 inches	13.89	33.86	14.65	2.86
37 to 48 inches	12.47	12.92	14.32	5.58
49 to 60 inches	12.69	7.75	16.21	8.57
61 to 72 inches	14.22	5.85	17.96	9.93
73 to 84 inches	15.90	5.58	17.44	11.29
85 to 96 inches	15.57	4.76	17.00	11.02
97 to 108 inches	15.78	4.22	14.87	10.47
109 to 120 inches	16.78	2.58	14.30	7.75
121 to 132 inches	14.00	2.58	15.20	4.22

These two sections of soil were taken less than 150 feet apart. but there is a great variation in the quantities of nitric nitrogen present and its distribution is almost reversed; the maximum quantities being found in the second, third and fourth foot in the first case and in the seventh, eighth and ninth foot in the second case. The supply of nitric nitrogen within reach of any cultivated plant was very much greater in the first than in the second sample. While we do not know with certainty, it is very probable that the difference in distribution of the nitric nitrogen is due to a difference in the time of development, the supply of water and the permeability of the soil; the two latter factors facilitating the downward movement of the nitrates.

A second set of three samples was taken in the same manner as those already given on 27 June, twelve to fourteen days after we irrigated the field. The total nitrogen was also determined in this set of samples.

SAMPLE No. 1—27 JUNE, 1913.

Depth.	Moisture Percent	Nitric Nitrogen Parts per Million	Total Nitrogen Percent
0 to 12 inches	16.88	4.49	0.1292
13 to 24 inches	16.70	0.95	0.0653
25 to 36 inches	15.97	0.54	0.0340
37 to 48 inches	18.11	0.54	0.0258
49 to 60 inches	19.87	0.39	0.0177
61 to 72 inches	19.86	0.27	0.0218
73 to 84 inches	18.05	0.68	0.0218
85 to 96 inches	21.40	0.38	0.0218
97 to 108 inches	18.84	0.00	0.0218
109 to 120 inches	18.63	0.00	0.0218
121 to 132 inches	17.96	0.00	0.0218

SAMPLE No. 2.—27 June, 1913.

Depth.	Moisture Percent	Nitric Nitrogen Parts per Million	Total Nitrogen Percent
0 to 12 inches	15.96	2.04	0.1142
13 to 24 inches	16.49	0.95	0.0571
25 to 36 inches	16.41	0.68	0.0313
37 to 48 inches	17.07	0.39	0.0204
49 to 60 inches	18.78	0.39	0.0204
61 to 72 inches	20.15	0.39	0.0204
73 to 84 inches	20.04	0.68	0.0231
85 to 96 inches	20.23	1.22	0.0299
97 to 108 inches	14.78	0.68	0.0177
109 to 120 inches	18.14	0.68	0.0150
121 to 132 inches	19.75	0.68	0.0218

SAMPLE No. 3—27 JUNE, 1913.

Depth.	Moisture Percent	Nitric Nitrogen Parts per Million	Total Nitrogen Percent
0 to 12 inches	14.39	3.13	0.1115
13 to 24 inches	15.54	1.22	0.0530
25 to 36 inches	15.61	0.95	0.0326
37 to 48 inches	16.09	0.68	0.0231
49 to 60 inches	17.60	0.54	0.0204
61 to 72 inches	19.06	0.54	0.0163
73 to 84 inches	18.41	0.39	0.0177
85 to 96 inches	19.23	0.68	0.0258
97 to 108 inches	19.84	0.95	0.0109

This section was taken to a depth of nine feet because at this point we struck coarse gravel and it was impossible to get the auger any deeper.

We cannot infer that the water applied has washed out an amount of nitrates equivalent to the difference between the amounts shown by the first two and the last three samples, at least I do not consider it safe to make such a supposition, but four-foot samples taken subsequently will make it evident that large amounts of nitrates have actually been washed out of the soil. The amount of water used in this irrigation was one acre-foot, and the condition of the soil was such that this amount of water was necessary to permit the water, with the head that we had, to just flow over the soil. In other words, the ground took in this much water. The extent to which the irrigation had increased the water supply is fairly indicated by the differences in the percentages of moisture on 29 April, when the first samples were taken and those found on 27 June, 12 to 14 days after one acre-foot of water had been applied.

The nitric nitrogen in any foot of the last three samples is comparatively small; even the surface foot contains only a small amount, though it is considerably more than we find in any subsequent foot. There was no nitric nitrogen in the last three feet of the first sample taken on 27 June, though this sample contained the largest amount in the surface foot at that time.

The preceding samples were all taken in fallow strips, for we left spaces between each set of four plots. We did this so that we could take such samples without tramping down an unnecessarily large amount of our wheat. The loss of area due to taking of samples was too large as it was, for we also took samples in the wheat plots proper and cut many samples of plants. We, therefore, have two more series of samples to show the moisture, nitric nitrogen and total nitrogen in the soil throughout the season. These two series were taken to a depth of four feet; one series was taken in the strips left between the plots and the other series in the plots themselves. Each of these series is divided into subseries corresponding with the three sections of land which we used for these field experiments. These sections of land are designated as 1700, 1800 and 1900 and contain about two acres each. There were two sets of samples taken in each section on the dates given. These samples were not taken from one spot, but were composite. Each sample analyzed was composed of three samples which were well mixed before the final sample was taken out. These precautions were necessary in order to obtain a representative sample. I believe that the samples hereafter given are quite representative and dependable. The first set of nitric-nitrogen determinations was made by the phenolsulphuric acid method, all the others were made by reduction with a zinc-copper couple. With these soils the latter usually gives a shade higher results.

SAMPLES TAKEN 29 APRIL, 1913.

Depth	Section 1700 Moisture Percent	Section 1700 Nitric Nitrogen Parts per Million	Section 1800 Moisture Percent	Section 1800 Nitric Nitrogen Parts per Million	Section 1900 Moisture Percent	Section 1900 Nitric Nitrogen Parts per Million
0 to 6 inches....	13.60	7.00	14.50	4.00	13.97	4.00
7 to 12 inches....	14.11	6.00	16.91	5.00	17.62	3.00
13 to 24 inches....	15.20	4.50	16.09	3.00	15.78	1.00
25 to 36 inches....	14.69	2.50	14.78	1.50	15.10	1.00
37 to 48 inches....	13.12	2.50	13.52	1.50	13.06	0.15
0 to 6 inches....	14.68	8.00	14.22	8.00	14.58	3.00
7 to 12 inches....	15.79	7.00	17.02	5.00	17.67	4.50
13 to 24 inches....	14.54	4.50	16.52	2.50	16.45	1.50
25 to 36 inches....	14.69	2.50	14.78	1.50	15.10	1.00
37 to 48 inches....	14.81	1.50	14.50	Trace	14.32	0.05

SAMPLES TAKEN 12 MAY, 1913.

Depth	Section 1700 Moisture Percent	Section 1700 Nitric Nitrogen Parts per Million	Section 1800 Moisture Percent	Section 1800 Nitric Nitrogen Parts per Million	Section 1900 Moisture Percent	Section 1900 Nitric Nitrogen Parts per Million
0 to 6 inches....	16.74	5.58	16.90	11.02	17.18	6.39
7 to 12 inches....	19.18	6.94	18.57	10.20	18.48	6.12
13 to 24 inches....	17.51	2.58	17.08	5.30	15.94	2.04
25 to 36 inches....	15.10	1.22	15.37	2.04	14.59	1.22
37 to 48 inches....	12.93	0.95	14.47	1.22	13.23	0.68
0 to 6 inches....	15.71	6.63	16.36	5.31	16.52	7.21
7 to 12 inches....	19.36	7.48	18.68	10.20	18.53	8.02
13 to 24 inches....	16.90	2.31	16.77	3.67	16.68	2.58
25 to 36 inches....	15.43	0.95	15.12	1.22	15.18	0.68
37 to 48 inches....	14.97	0.68	14.54	0.82	14.63	0.54

From the evening of May 8 to the morning of May 10 we had a rainfall of 1.05 inches.

SAMPLES TAKEN 26 MAY, 1913.

Depth	Section 1700 Moisture Percent	Section 1700 Nitric Nitrogen Parts per Million	Section 1800 Moisture Percent	Section 1800 Nitric Nitrogen Parts per Million	Section 1900 Moisture Percent	Section 1900 Nitric Nitrogen Parts per Million
0 to 6 inches....	15.37	8.02	15.05	7.62	13.66	6.80
7 to 12 inches....	16.74	9.38	17.83	9.11	16.98	6.66
13 to 24 inches....	15.71	3.67	16.86	3.13	16.19	2.86
25 to 36 inches....	15.02	1.63	15.60	1.90	14.92	0.95
37 to 48 inches....	13.78	0.95	14.14	0.82	14.14	0.54
0 to 6 inches....	15.39	7.21	14.01	6.94	13.42	6.39
7 to 12 inches....	17.74	11.29	17.30	9.38	17.04	5.44
13 to 24 inches....	16.26	3.40	16.16	4.08	16.03	1.63
25 to 36 inches....	15.25	1.63	15.13	2.31	15.26	1.22
37 to 48 inches....	14.72	0.95	15.05	1.77	14.96	0.54

SAMPLES TAKEN 7 JUNE, 1913.

Depth	Section 1700 Moisture Percent	Section 1700 Nitric Nitrogen Parts per Million	Section 1800 Moisture Percent	Section 1800 Nitric Nitrogen Parts per Million	Section 1900 Moisture Percent	Section 1900 Nitric Nitrogen Parts per Million
0 to 6 inches....	12.51	8.30	10.77	9.93	11.06	9.66
7 to 12 inches....	16.17	6.94	16.01	9.93	16.08	7.48
13 to 24 inches....	15.36	3.13	15.36	....	15.59	2.86
25 to 36 inches....	14.01	1.22	14.96	1.77	15.25	1.22
37 to 48 inches....	13.96	0.68	14.82	0.95	13.74	0.68
0 to 6 inches....	11.33	7.48	10.36	8.30	10.97	8.30
7 to 12 inches....	16.87	8.84	15.98	9.11	15.81	5.58
13 to 24 inches....	15.99	3.40	15.42	4.49	15.53	1.77
25 to 36 inches....	15.03	1.22	15.28	1.50	14.49	0.95
37 to 48 inches....	15.67	1.22	14.50	0.95	14.52	0.95

We began irrigating five days after the above samples were taken. The water was applied at this time, not because the plants showed any need of it, but because they were for the most part in boot and we deemed this an opportune time to apply it.

SAMPLES TAKEN 24 JUNE, 1913.

Depth	Section 1700 Moisture Percent	Section 1700 Nitric Nitrogen Parts per Million	Section 1800 Moisture Percent	Section 1800 Nitric Nitrogen Parts per Million	Section 1900 Moisture Percent	Section 1900 Nitric Nitrogen Parts per Million
0 to 6 inches....	11.27	4.49	11.33	7.07	11.84	2.86
7 to 12 inches....	14.44	2.31	15.71	4.90	15.14	1.77
13 to 24 inches....	14.89	0.82	15.08	3.54	15.25	0.68
25 to 36 inches....	15.08	0.00	15.20	2.86	15.57	0.68
37 to 48 inches....	14.92	0.68	15.24	1.16	16.04	0.54
0 to 6 inches....	14.07	7.48	13.90	6.26	12.42	2.72
7 to 12 inches....	16.73	3.67	16.92	4.35	15.49	1.50
13 to 24 inches....	15.90	1.77	16.53	2.18	15.90	0.68
25 to 36 inches....	15.99	1.22	15.59	2.18	16.03	0.68
37 to 48 inches....	17.63	1.50	16.55	1.16	16.92	0.54

SAMPLES TAKEN 14 JULY, 1913.

Depth	Section 1700 Moisture Percent	Section 1700 Nitric Nitrogen Parts per Million	Section 1800 Moisture Percent	Section 1800 Nitric Nitrogen Parts per Million	Section 1900 Moisture Percent	Section 1900 Nitric Nitrogen Parts per Million
0 to 6 inches....	7.30	6.12	8.16	5.98	8.29	11.15
7 to 12 inches....	13.80	3.13	14.05	3.26	13.71	4.90
13 to 24 inches....	14.17	1.50	14.57	2.72	14.79	....
25 to 36 inches....	15.57	0.95	14.85	2.18	14.87	1.90
37 to 48 inches....	14.06	0.95	14.49	1.16	14.46	1.63
0 to 6 inches....	9.49	8.30	10.87	10.34	7.14	5.44
7 to 12 inches....	15.05	3.67	15.81	8.43	12.69	1.90
13 to 24 inches....	14.67	1.77	15.24	2.18	13.99	1.16
25 to 36 inches....	14.62	1.50	15.46	1.90	11.07	1.16
37 to 48 inches....	15.57	1.22	15.68	1.90	14.80	0.82

The total nitrogen in these sections of land was all redetermined on 1 July, 1913.

TOTAL NITROGEN IN SAMPLES TAKEN.

Depth.	Section 1700 Total Nitrogen Percent	Section 1800 Total Nitrogen Percent	Section 1900 Total Nitrogen Percent
0 to 6 inches	0.1224	0.1278	0.1238
7 to 12 inches	0.1142	0.1047	0.0843
13 to 24 inches	0.0517	0.0680	0.0558
25 to 36 inches	0.0340	0.0435	0.0394
37 to 48 inches	0.0272	0.0258	0.0258
0 to 6 inches	0.1278	0.1074	0.1278
7 to 12 inches	0.0898	0.0898	0.0952
13 to 24 inches	0.0558	0.0585	0.0517
25 to 36 inches	0.0354	0.0367	0.0367
37 to 48 inches	0.0231	0.0218	0.0231

All of the preceding samples were taken within the fallow strip left between the sets of four plots.

The nitric nitrogen found in the samples taken 7 June, five days before the irrigation, and in those taken 24 June, ten to twelve days after irrigation, gives a measure of the effect of the irrigation upon the nitrates in the soil to the depth to which the samples were taken, four feet. We have six samples, each composed by uniting three subsamples, eighteen subsamples in all, representing six inches or the foot, respectively, given in the tables. We will consider only the surface six inches. The average amount of nitric nitrogen per million for this section of soil before irrigation was 8.66 p.p.m. On 24 June, ten or twelve days after irrigation, it was 5.18 p.p.m., a difference of 3.48 p.p.m. An examination of the tables also shows that these nitrates had been moved either into the lower portion of this section or still deeper. An examination of the next series of samples given, that for 14 July, 1913, gives a very fair idea of the rate at which these nitrates were being replaced, for the surface six inches of these same plots now contains an average of 8.8 p.p.m. a little higher average than was found five days before irrigation. The whole section of soil sampled shows the same fact, but not always to so marked a degree. This accumulation of nitric nitrogen in the surface portions of this soil is not due to immigration of the nitrates from greater depths aided by capillarity. Direct experiment, Colorado Bulletin 186, p. 29, shows that capillary attraction will not move nitrates, under ordinary atmospheric conditions, more than 25 inches in thirty days and their distribution through the soil is the reverse of that which we find in our plots. The increased nitric nitrogen in the soil is due to nitrification. It was shown in Colorado Bulletin 178, p. 86, *et seq.*, also in Colorado Bulletin 179, pp. 14, 26 and 29, by W. G. Sackett, that this soil possesses such high fixing and nitrifying powers that these phenomena are, beyond question, important factors in the production of the nitric nitrogen found.

The amount of nitric nitrogen found in soil cultivated fallow, compared with the foregoing results on the one hand, and with the nitric nitrogen found in cropped soil on the other hand, is of interest in this connection.

The cropped land referred to in the following tables is the same land for which the nitric nitrogen is subsequently given as sampled 1 August, 1913, Defiance, Check, Section 1700. The wheat was harvested off of the land 6 August. The land was irrigated 28 August and disked a few days later. The land was plowed about 20 October, and the samples were taken 4 December, 1914. These facts are stated in order that the part played by the cultural conditions may be taken into proper consideration.

Six series of samples were taken from the adjoining section of land, three on 14 November and three on 4 December, 1914. This section had been cultivated fallow during the season preparatory for use in wheat breeding experiments. The area of these sections is two acres each.

NITRIC NITROGEN IN FALLOWED LAND.
SAMPLES TAKEN 14 NOVEMBER, 1914.

Depth.	Nitric Nitrogen Parts per Million Sample I.	Sample II.	Sample III.
0 to 3 inches	6.36	8.52	7.37
4 to 7 inches	20.71	28.63	22.03
8 to 13 inches	9.24	18.73	14.74
14 to 19 inches	5.63	3.89	3.88

SAMPLES TAKEN 4 DECEMBER, 1914.

Depth.	Sample I.	Sample II.	Sample III.
0 to 3 inches	11.12	7.44	14.32
4 to 7 inches	31.13	18.42	25.71
8 to 13 inches	17.11	15.67	18.73
14 to 19 inches	6.57	4.79	6.43

TOTAL NITROGEN IN FALLOWED LAND.
SAMPLES TAKEN 4 DECEMBER, 1914.

Depth.	Percent	Percent	Percent
0 to 3 inches	0.1293	0.1244	0.1230
4 to 7 inches	0.1319	0.1265	0.1225
8 to 13 inches	0.0974	0.1091	0.0987
14 to 19 inches	0.0709	0.0705	0.0677

NITRIC NITROGEN IN LAND CROPPED TO WHEAT.
SAMPLES TAKEN 4 DECEMBER, 1914.

Depth.	Nitric Nitrogen Parts per Million. Sample I	Sample II
0 to 3 inches	6.39	5.42
4 to 7 inches	11.74	7.92
8 to 13 inches	11.82	8.93
14 to 19 inches	6.69	3.44

TOTAL NITROGEN IN LAND CROPPED TO WHEAT.
SAMPLES TAKEN 4 DECEMBER, 1914.

Depth.	Percent	Percent
0 to 3 inches	0.1258	0.1150
4 to 7 inches	0.1223	0.1205
8 to 13 inches	0.1203	0.1101
14 to 19 inches	0.0820	0.0764

Each of the samples in these series was made up of three sub-samples. The accumulation of nitric nitrogen during the period of fallow is very evident. The facts stated in Colorado Bulletin 205, pp. 36 and 37, regarding the effect of fallowing upon the prevalence of yellow-berry in wheat, taken in connection with the demonstrated effects of nitrates are very suggestive and interesting. The following samples were taken in the same manner as the preceding ones, but in a line running lengthwise through the middle of the plots.

SAMPLES TAKEN WITHIN THE PLOTS 1 JULY, 1913.

Depth	Section 1700 Moisture Percent	Section 1700 Nitric Nitrogen Parts per Million	Section 1800 Moisture Percent	Section 1800 Nitric Nitrogen Parts per Million	Section 1900 Moisture Percent	Section 1900 Nitric Nitrogen Parts per Million
0 to 6 inches....	14.03	2.72	12.79	2.99	12.51	3.13
7 to 12 inches....	14.36	1.22	14.63	2.58	14.49	1.90
13 to 24 inches....	14.95	0.68	15.16	0.68	15.22	0.54
25 to 36 inches....	14.95	0.39	15.29	0.39	16.07	0.27
37 to 48 inches....	15.67	0.27	15.84	0.27	15.75	0.27
0 to 6 inches....	12.57	4.76	12.24	....	15.06	3.40
7 to 12 inches....	14.43	2.04	14.34	2.18	16.47	1.22
13 to 24 inches....	14.39	0.95	14.63	1.16	15.76	0.68
25 to 36 inches....	14.87	0.95	14.75	1.09	15.85	0.54
37 to 48 inches....	17.77	0.68	16.27	....	16.33	0.54

SAMPLES TAKEN WITHIN THE PLOTS 14 JULY, 1913.

Depth	Section 1700 Moisture Percent	Section 1700 Nitric Nitrogen Parts per Million	Section 1800 Moisture Percent	Section 1800 Nitric Nitrogen Parts per Million	Section 1900 Moisture Percent	Section 1900 Nitric Nitrogen Parts per Million
0 to 6 inches....	9.16	1.02	9.51	3.26	8.30	2.72
7 to 12 inches....	10.47	0.00	10.69	1.09	9.75	1.09
13 to 24 inches....	11.62	0.00	10.38	1.09	10.17	1.16
25 to 36 inches....	12.76	0.00	11.72	1.09	10.92	1.63
37 to 48 inches....	13.31	0.00	13.05	0.82	12.22	0.82
0 to 6 inches....	7.99	2.31	8.73	3.94	8.83	3.54
7 to 12 inches....	9.66	1.02	10.28	1.63	10.26	3.81
13 to 24 inches....	10.20	1.09	9.90	1.63	9.70	1.16
25 to 36 inches....	11.93	0.95	11.88	1.09	11.18	1.09
37 to 48 inches....	14.22	0.54	13.10	0.39	13.37	0.68

SAMPLES TAKEN WITHIN THE PLOTS 1 AUGUST, 1913.

Depth	Section 1700 Moisture Percent	Section 1700 Nitric Nitrogen Parts per Million	Section 1800 Moisture Percent	Section 1800 Nitric Nitrogen Parts per Million	Section 1900 Moisture Percent	Section 1900 Nitric Nitrogen Parts per Million
0 to 6 inches....	13.76	4.35	14.07	2.99	14.59	2.99
7 to 12 inches....	14.40	2.99	16.07	2.99	16.14	2.18
13 to 24 inches....	11.23	1.09	16.02	0.95	16.28	0.82
25 to 36 inches....	12.46	0.82	15.98	0.54	16.33	0.82
37 to 48 inches....	12.50	0.54	16.15	0.27	15.52	0.27
0 to 6 inches....	13.76	4.49	12.82	5.17	13.51	2.45
7 to 12 inches....	14.59	3.26	16.16	2.72	16.86	1.63
13 to 24 inches....	11.90	1.16	16.83	1.09	16.20	0.54
25 to 36 inches....	11.06	1.09	16.13	0.82	15.70	0.27
37 to 48 inches....	13.14	0.54	16.04	0.54	16.53	0.54

The land was not well leveled before planting and when we came to irrigate it there were a few spots on which it was impossible to force the water. These spots were comparatively small and I thought that the lateral movement of the water beneath the surface would effect a subirrigation, but in this I was wrong. The wheat on these spots matured as good wheat as the irrigated portion but the growth of the straw was very inferior to the rest of the plots in which they occurred. Because of the evident deficiency of water as indicated by the growth and color of the plants, I took a set of samples from one of these spots on 2 August, just a few days before harvest, and had the moisture and nitric nitrogen determined in them. The spot chosen was in Section 1700, Fife-Check plot. I have just given, in the last table, the moisture and nitric nitrogen for the regular samples taken the previous day, 1 August.

SAMPLE FROM UNIRRIGATED SPOT TAKEN 2 AUGUST, 1913.

Depth.	Section 1700 Moisture Percent	Nitric Nitrogen Parts per million
0 to 6 inches	12.17	8.70
7 to 12 inches	12.00	8.43
13 to 24 inches	8.56	2.99
25 to 36 inches	7.78	2.18
37 to 48 inches	11.32	1.09

It will be noticed that all of the samples taken 1 August were higher in moisture than those taken 14 July. This is not only true of all the shallower samples, but also of all of the samples; even in the fourth foot the moisture shows a very decided increase. I know of no cause for this except it be found in the fact that between 22 and 27 July we had a total rainfall of one and forty-three hundredths inches. Assuming that we had a rainfall of one and one-half inches, it would give us about 341,000 pounds of water per acre, provided it had all reached the ground, been absorbed and none had been evaporated, all of which is more or less contrary to the facts, for it did not all reach the ground, but lodged on the plants and was evaporated from their surfaces and some of that which did reach the ground had been lost by evaporation or by the activity of the plants and yet on 1 August there is an excess of moisture in the soil taken to a depth of four feet, over that present on 14 July, by over twice the amount that had fallen as rain and we are neglecting the activity of the plants for the whole of the intervening period. This slight rainfall is undoubtedly the cause of the moisture in the first foot of the unirrigated spot.

The nitric nitrogen is also very much higher in this dry spot than in the regular samples, almost as high at the surface as the fallow ground, and decidedly higher in the lower portions of the boring. This may be due to the fact that the wheat plants were not very vigorous and did not occupy the ground with their roots, a fact which may have favored nitrification. There was certainly no nitrates washed out of any portion of this soil by irrigating water; on the other hand the lateral movement of the irrigating water does not seem to have been sufficient to account for any accumulation by lateral secretion. If this actually took place to any extent at all, it would have been at the margins of the space, which we avoided, and took the sample as near the center of the dry area as possible.

MOISTURE AND TOTAL NITROGEN IN SAMPLES TAKEN WITHIN THE PLOTS 1 JULY, 1913.

	Section 1700		Section 1800		Section 1900	
Depth	Moisture Percent	Total Nitrogen Percent	Moisture Percent	Total Nitrogen Percent	Moisture Percent	Total Nitrogen Percent
0 to 6 inches..........	14.03	0.1278	12.79	0.1115	12.51	0.1251
7 to 12 inches..........	14.36	0.1156	14.63	0.1115	14.49	0.1088
13 to 24 inches..........	14.95	0.0721	15.16	0.0626	15.22	0.0490
25 to 36 inches..........	14.95	0.0340	15.29	0.0313	16.07	0.0231
37 to 48 inches..........	15.67	0.0258	15.84	0.0286	15.75	0.0161
0 to 6 inches..........	12.57	0.1292	12.24	0.1265	15.06	0.1251
7 to 12 inches..........	14.43	0.1047	14.34	0.1006	16.47	0.1006
13 to 24 inches..........	14.39	0.0598	14.63	0.0598	15.76	0.0544
25 to 36 inches..........	14.87	0.0313	14.75	0.0380	15.85	0.0218
37 to 48 inches..........	17.77	0.0286	16.27	0.0286	16.33	0.0190

If we consider the water contained in the soil on 29 April and 27 June, about fourteen days after irrigation, we observe that the irrigated land contains the greater percentages of moisture at all depths down to the twelfth foot. These percentages are comparable as both sets of samples were taken from fallow ground. But if we can compare the amounts of nitric nitrogen present, we observe great irregularities in distribution and scarcely any comparison at all in the quantities present. There is one thing very apparent and that is the extent to which the application of one acre-foot of water has removed the nitrates. The moisture present in the April samples was due to a series of light rains insufficient to effect leaching of the ground, whereas an acre-foot of water applied under our conditions affected a very perceptible amount of leaching. I do not know the rate of percolation, but when this amount of water is applied, the surface portions of our soil become very soft, so soft that one will sink into it half-leg deep. There is no doubt but this mass of water passes downward rapidly, as the amount present exceeds the capacity of the soil that it successively occupies to retain it. We can compare the results in another way; we can compare the percentages of water found for the four-foot samples taken 7 June, five days before irrigation, and the top four feet of the samples taken 27 June, about fourteen days after the irrigating had been finished. The differences are much smaller than we would expect and will aggregate approximately one percent in favor of the samples taken after irrigation. Some of the water had been removed by evaporation, but the greater portion of it sank rapidly to such a depth that evaporation took place slowly and from the ground surface only. An acre-foot of water is sufficient to increase the moisture in eleven acre-feet of soil by about six and one-quarter percent. We have no such increase. In the fourteen days elapsing since its application it has either evaporated from the surface or percolated through the soil to a greater depth than eleven feet, and this water moving through the soil has taken with it the greater part of the nitrates. In the samples taken 29 April, we find in the third foot 33.86 parts per million, and in the same foot of another sample taken at the same time we find 2.86 parts per million, but in the seventh, eighth and ninth foot we find this reversed. the smaller quantities being in the first sample. The nitrates have been washed further down in the latter than in the former sample.

The effect of the crop upon both the moisture and nitric nitrogen in the soil is evident from the samples taken 14 July, within the plots and in the spaces between the plots. Evidently the shading of the ground causes the top six inches to show a slight excess over the surface of the unprotected ground, but the next six inches and the remaining three feet show differences in moisture up to five percent or rather more. The samples taken within the plots are low in nitric nitrogen, the maximum being 3.94 parts per million, while the corresponding sample from the space between the plots contained 10.34 parts per million. In regard to the lower water content of the soil within the plot, no one will question its being due to the action of the plants and the difference represents principally the water taken up by the plants and given up to the air. Concerning the nitric nitrogen, two things may have happened. The occupancy of the ground by the plants may have prevented the formation of the nitrates and there may never have been as large a quantity in the soil within the wheat plots as in the unoccupied space between the plots, or the plants may have used up the difference that we find between the nitric nitrogen content of the samples. We are sure that the latter process took place, but we do not know certainly that the former supposition is not true. It is maintained that it is true.

The differences in the total nitrogen present in the soil within the plots and in the spaces between the plots are so small, that we are inclined to attach no value to them, especially when we remember that it is exceedingly difficult to select two samples of soil that are really comparable in this respect, and the difficulty of making chemical determinations which are free from all errors. Very slight differences in percentages often have a significance, but our methods and operations are not so perfect that we are justified in attaching too much significance to differences that are, perhaps, no greater than our errors. The total nitrogen does not show sufficient differences to justify us in attaching much importance to them, but the percentages of moisture and the quantities of nitric nitrogen do justify such inferences as have been presented.

The question of how great variations may be found in a series of samples taken at very small distances apart has been considered. To put the question to a practical test, we selected an apparently uniform plot, 5 feet by 30 feet, and laid it off in 150 equal squares and took a sample to a depth of one foot from the center of each square. We have six blocks, each five feet square, which gives us twenty-five samples in a block. The total and nitric nitrogen was determined in each of these samples, which were taken 19 May, 1913. The results are shown in the table on the next page.

The smallest amount of total nitrogen found was 0.11016 percent, Sample 8, Block 6. One sample in Block 1 and two samples in Block 4 also contained this amount. The largest amount found was 0.14552 percent. This was in sample 13, Block 6, so that we have the minimum and maximum in adjacent areas one foot square. This difference amounts to 354.4 parts of nitrogen per million. The significance of this amount of nitrogen at a given time will depend upon the character of the compounds of which it forms a part. The amount of organic matter that it represents may be readily seen from the following: Nitrogen forms approximately one-sixth of proteid matter and an acre-foot of soil weighs about four million pounds. These factors give us for the nitrogenous organic matter corresponding to the difference found for the total nitrogen in these samples, four and one-quarter tons, or the equivalent of about seven tons of dried blood of average grade.

The difference for the average of the nitric nitrogen in twenty-four samples from Block 1, and twenty-five samples in Block 6, is 1.8 p.p.m. This may seem a small difference, but it is actually a larger amount than we sometimes find in cropped soils taken to the same depth.

The maximum variation in the nitric nitrogen found within this area, five feet by thirty feet, is from 5.44 to 14.18 p.p.m., a difference of 8.6 p.p.m., or a difference equivalent to 206 pounds of sodic nitrate per acre-foot of soil.

We also determined the variation in the amounts of phosphoric acid and potash within this area; but we reduced the number of samples to four from each five-foot square. The choice was arbitrary, but the same for each of the six blocks, in which the first,

VARIATION OF TOTAL AND NITRIC NITROGEN IN 150 SQUARE FEET OF SOIL.

	Block 1		Block 2		Block 3		Block 4		Block 5		Block 6	
Sample Number	Total Nitrogen Percent	Nitric Nitrogen p.p.m.	Total Nitrogen Percent	Nitric Nitrogen p.p.m.	Total Nitrogen Percent	Nitric Nitrogen p.p.m.	Total Nitrogen Percent	Nitric Nitrogen p.p.m.	Total Nitrogen Percent	Nitric Nitrogen p.p.m.	Total Nitrogen Percent	Nitric Nitrogen p.p.m.
1........	0.13056	7.34	0.12648	6.32	0.13056	9.35	0.11560	7.97	0.13464	11.27	0.12920	11.66
2........	0.11968	6.12	0.14144	9.18	0.13736	.....	0.11152	6.02	0.13328	9.86	0.13464	9.35
3........	0.11560	6.12	0.13056	6.99	0.12104	8.14	0.12920	7.14	0.13328	12.63	0.12376	7.82
4........	0.11696	6.97	0.12784	.....	0.12512	7.97	0.13464	8.35	0.13464	.....	0.12104	7.99
5........	0.13192	5.44	0.11968	6.02	0.12920	8.35	0.13464	7.38	0.11424	7.58	0.12376	9.69
6........	0.11832	8.33	0.12104	11.08	0.11560	8.55	0.13056	7.99	0.11560	7.32	0.13056	11.07
7........	0.11968	9.01	0.12240	11.08	0.11016	7.65	0.12240	10.88	0.13056	12.24	0.12920	7.97
8........	0.11832	9.33	0.11288	7.77	0.12104	9.33	0.12240	9.32	0.13736	10.20	0.11016	8.16
9........	0.13328	11.73	0.11832	9.13	0.13328	11.66	0.12920	8.16	0.13192	10.10	0.11016	7.97
10........	0.12104	9.69	0.12104	7.97	0.12376	9.29	0.12512	7.99	0.11152	7.97	0.13328	9.52
11........	0.12784	9.69	0.12648	6.41	0.13056	9.91	0.11152	8.16	0.12648	8.33	0.13464	10.10
12........	0.11016	6.41	0.11696	7.58	0.12784	8.84	0.11968	9.52	0.13600	10.88	0.13600	8.33
13........	0.11560	7.97	0.12784	7.65	0.12104	8.74	0.13056	11.56	0.12648	9.52	0.14552	14.18
14........	0.12784	8.35	0.13192	9.52	0.12512	9.32	0.13056	8.84	0.12920	7.93	0.14416	10.69
15........	0.13056	.....	0.12684	8.35	0.11968	7.97	0.11560	8.16	0.12376	9.29	0.12784	7.97
16........	0.12240	10.20	0.14280	9.01	0.11288	8.94	0.12784	8.43	0.11696	7.31	0.12512	12.41
17........	0.11832	10.20	0.12104	10.61	0.12648	8.55	0.12648	8.61	0.13872	8.94	0.13056	10.30
18........	0.12376	10.71	0.13056	9.52	0.12104	10.30	0.14008	9.18	0.13192	8.35	0.13056	12.41
19........	0.12512	8.67	0.12784	9.29	0.11696	7.97	0.13056	8.43	0.13464	10.30	0.11696	11.05
20........	0.13328	9.35	0.11696	9.69	0.13736	10.54	0.12648	10.30	0.12512	8.55	0.12784	9.29
21........	0.13600	11.46	0.12104	8.55	0.13192	13.41	0.13056	7.97	0.12104	9.52	0.13872	12.24
22........	0.12240	7.97	0.11696	7.65	0.12512	8.74	0.13192	9.13	0.13056	11.46	0.13600	10.30
23........	0.11696	7.97	0.12920	11.39	0.13736	.....	0.13328	7.97	0.13464	9.71	0.14144	9.52
24........	0.12376	10.03	0.12648	9.52	0.13056	9.91	0.12240	9.35	0.13464	9.18	0.13600	12.07
25........	0.13872	8.74	0.12784	9.33	0.13464	8.35	0.13056	11.73	0.12512	7.99	0.12784	9.52

eighth, eighteenth and twenty-fifth were chosen. The method of extraction was with hydric chlorid, specific gravity 1.115, for ten hours. Two samples out of each four were treated a second time, namely, samples 8 and 18 of each block. The second extraction takes up a further quantity of each of these substances, but particularly of the potash. We were aware of this fact before we made these analyses. The new portion of potash unquestionably comes from the progressive decomposition of the felspar. This fact puts every potash determination made in our soils by this method in more or less doubt. I do not believe, however, that it is a serious matter, for the amount of potash involved is so large that a considerable mistake will matter but little, besides, even fresh felspar yields potash to plants or even to water, so that a mistake of 10 to 15 percent of the total potash involved does not in this case seem to me a very serious matter. For the sake of clearness and brevity, I shall give only the twelve results obtained by the double extraction as sufficient to show the variation in the amounts of phosphoric acid and potash within small, consecutive areas to a depth of one foot. It has already been explained that each block is five feet square and contains twenty-five square feet, which are numbered from left to right, beginning at the upper left-hand corner.

VARIATION OF PHOSPHORIC ACID AND POTASH IN CONSECUTIVE AREAS

Block	Sample	Phosphoric Acid Percent	Potash Percent
1	8	0.140	0.775
1	18	0.140	0.736
2	8	0.143	0.745
2	18	0.143	0.785
3	8	0.132	0.751
3	18	0.157	0.713
4	8	0.134	0.722
4	18	0.145	0.787
5	8	0.147	0.743
5	18	0.145	0.745
6	8	0.131	0.698
6	18	0.153	0.739

The variation in these results for the phosphoric acid extracted from the soil by this method is 0.026 percent, and for the potash 0.089 percent. The absolute amounts of phosphoric acid and potash indicated by these percentages are sufficient to have, possibly, some influence, but we can scarcely think that we are justified in laying any stress upon them, because we know that their common source is the felspar and we cannot regulate the extent to which the solvent shall act upon it in a given time. The quantities actually involved are, for the phosphoric acid, 1040 and, for the potash, 3560 pounds for the acre-foot of soil sampled; whereas the total quantities soluble in the solvent used, are about 5600 pounds for the phosphoric acid and 30,000 pounds for the potash. With such quantities present the variations shown by our analytical results, even if these be absolutely correct, are too uncertain in their significance to justify us in seriously undertaking to interpret them. These samples show so little variation, even though quantities greatly in excess of those available to the plants may be involved, that there can be but little object in considering them further. Reference to the analyses of this soil given on a preceding page (11) will further justify us in assuming that, while there may be some variation in the supply of phosphoric acid and potash in small and adjacent pieces of this land, the range is too small to admit of definite assertions in regard to its effects, especially as our knowledge of results obtained with the application of these individual fertilizers to this land leads us to believe that there is an abundant available supply of them present. This is the testimony of the crops raised and not simply an opinion.

We have presented the last few paragraphs to exhibit, as far as we can depend upon our data, the variation in the amounts of nitrogen, nitric nitrogen, phosphoric acid and potash from foot to foot within a small area. We could not, because of lack of time, examine plants, especially the wheat grown on a similar plot, to learn whether the composition of the wheat varied in a corresponding manner. We find, however, in Bulletin No. 269 of the Bureau of Plant Industry, that Prof. E. G. Montgomery, in trying to determine the "Experimental Error in the Nursery and Variation in Nitrogen and Yield," has practicaly done this and finds, using the nitrogen content as his measure, that there is a decided variation from place to place within very small areas. Prof. Montgomery determined this difference in quadrangular areas and also in parallel rows. He adopted as his standards of classification all plants yielding grain below 2.2 percent—from 2.2 to 2.8; from 2.8 to 3; and all plants above 3 per cent. While these standards seem high they served his purpose well. The general result obtained was that the "highs" and "lows" tend to segregate, that is, there would be an area in which they would obtain, as a rule, high results, again an area in which they obtained low results. Concerning these variations he says: "Just why these wide fluctuations occur when every precaution is taken to grow plants under uniform conditions is not very apparent." Again he says: "It is difficult to explain why such great variations exist when there seems to be little or no tendency to transmit them. It seems apparent that the variations must be due to differences in environment. Since the ordinary factors of environment, as sunlight, warmth, moisture and apparent fertility of the soil, are constant for all plants under our nursery conditions, we must conclude that there are factors profoundly influencing the growth of plants beyond the ordinary range of observation." Later Professor Montgomery adds, "A number of interesting problems are suggested. Why should one plant, growing under practically the same environment as another, collect from the soil two or three times as much nitrogen." Again, "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 quality." Professor Montgomery does not ascribe this difference to the soil, and the quotations are not made for the purpose of intimating that he does, but simply to show that variations in the composition of individual plants, growing, as is here asserted, within two feet of one another, may be very great, and that the difference in their nitrogen content cannot be attributed to heredity. The inference that I draw from the facts given is that there was a relation between the soil and these variations, but we shall find occasion to come back to this subject at another time.

SOME SURFACE SAMPLES OF SOIL AND THEIR BACTERIAL CONTENT.

It was proposed to study the relation between the moisture, the number of bacteria, the total nitrogen and the nitric nitrogen present from time to time. Our plan proved to be more generous in scope than our ability to perform. In addition to this Professor Sackett did not encourage me with the promise of any easily interpreted results, as the bacterial counts do not include all of the bacteria, one or more important classes being eliminated by the character of the culture medium used.

In this connection it may be well to note one of the effects of turning the land to such a depth as I did, twelve inches in two cases and nine inches in one case, whereby I put several inches of the subsoil on the surface, at least two inches by the shallower and five or six inches by the deeper plowing. This plowing was done in the spring immediately before seeding. I appreciated the disadvantages of the procedure, but as previously explained, I had, owing to circumstances over which I had no control, no choice if I wished to give the land a deep plowing. The result was that the surface of my plots represented unweathered subsoil with a comparatively meager bacterial population. We united twenty samples of this subsoil to form a composite one taking care that the samples should not be inoculated by admixture of surface soil or by other means. Professor Sackett kindly made the bacterial count which he reported to us as—bacteria 911,875, moulds 97,975 per gram of soil. These samples represented six inches of this subsoil. Later we took a few samples from different sections to the depth of three inches and determined the moisture, the total nitrogen and the nitric nitrogen and Professor Sackett made bacterial counts in a few of them. Whether the depth of three inches was well chosen is a question, but this would depend largely upon the immediately preceding weather conditions. The samples were all taken on the same date and we considered them comparable. The results were as follows:

MOISTURE, BACTERIA, ETC., IN SURFACE THREE INCHES OF SOIL.

Section	Moisture Percent	Total Nitrogen Percent	Nitric Nitrogen Parts per Million	Bacterial Count
Corn	7.880	0.12444	9.11	
Corn	8.859	0.12988	7.48	
Corn	7.102	0.12716	10.47	
Sorghum	7.206	0.12444	6.53	
Winter wheat	4.986	0.11968	2.58	
Winter rye	4.180	0.12172	2.72	834,000
Spring wheat check	4.825	0.13328	3.81	1,440,000
Spring wheat P_2O_5 applied	6.510	0.14552	3.67	2,483,000
Spring wheat KCl applied	5.614	0.13872	5.71	
Soil taken eight inches deep	....	......	...	1,560,000
Subsoil 9 to 14 inches	....	....	....	476,000

These samples were taken 20 June, a time when 4,000,000 bacteria per gram may be taken as a fair average for an ordinary loamy soil. These soils are very much poorer in bacterial life than the average; this is true even in the case of the plot to which we had added phosphoric acid which seems to have favored their development very greatly. The subsoil is very much poorer than the entire sample given above—in fact, it contains practically only one-half as many bacteria which developed on the culture medium employed. It will be noticed that the soils of our spring wheat plots, while richer in total nitrogen, were decidedly poorer in nitric nitrogen than the corn and sorghum plots.

We have not been able, up to this time, to pursue the study of the relation between the moisture, crop, nitrogen supply, etc., to any greater extent than is indicated by the statements given, which are not sufficient to justify any conclusions but they suffice for the purpose for which they are introduced, which is to show that the turning of five or six inches of subsoil to the surface and planting in this immediately after turning, gave us, in all respects, unusual conditions for which, if we only knew how, allowances should be made.

This subject is not permanently dismissed for I am satisfied that this is one of the most important factors in our problem, and if strength and opportunity be granted me, I shall prosecute it *further, for herein lies, I am fully persuaded, the explanation for the variations in the total, as well as in the nitric nitrogen present in the soil from foot to foot, and also one of the causes of variation in the composition and quality of the wheat produced.*

These statements are made with a full knowledge and appreciation of the important influence attributed to "climatic conditions." While there can be no question about the importance of the factors, designated by this term, uniformity of climatic conditions does not mean uniformity in characteristic properties of the same variety of wheat. On the contrary, given uniformity of climatic conditions, we can influence both the physical properties and chemical composition of the wheat kernel by varying the relative amounts of the individual substances necessary for plant growth. We can, by supplying nitrogen, cause the kernel to be small, maybe shrunken, flinty, high in nitrogen and difficult to crush; or by increasing the potassium in the soil, we can cause it to be large, plump, high in starch, correspondingly low in nitrogen and easy to crush. These properties constitute those groups which, so far as I can gather, are characteristic of the two classes of wheat usually designated as "hard" and "soft" wheats. In making these statements at this time I disclaim the expression of any opinion concerning strong and weak flours; this is a matter for future consideration.

NITROGENOUS COMPOUNDS IN THE DEVELOPING PLANTS.

In our study of the sugar beet* we found it comparatively easy to follow the development and disappearance of the various forms of nitrogen in the blades of the leaves, the petioles and in the root. We made the attempt to follow the development of the nitrogenous compounds in the wheat plant from the time of blooming till the plant was mature. The same methods were used in this as in the former case except that we made no attempt to determine the animo-group and we used only the stems, leaves and heads of the plants. The sheaths for the most part were taken with the stems. The plants came into bloom about 7 July, a few anthers appeared 6 July and they had practically all disappeared by 10 July, so I take it that the period of full bloom was from 6 to 8 July.

RATIOS OF LEAVES, STEMS AND HEADS.

The effects of the individual fertilizers applied to the different plots were not discernible in the growth or color of the various plots of wheat except in the case of those to which sodic nitrate had been applied. These plots were decidedly greener, leafier and a little taller than the others. We could not detect any difference between the other plots. We took three sets of samples from two

*Bulletin 183, Colo. Exp. Sta.

sections and two sets from the third section in order to determine the green weight of the stems, leaves and heads. We confined these observations to the Red Fife. We chose the Fife because we judged it to be more nearly representative than the other varieties and because it was somewhat more advanced in development. The portion designated as leaves was obtained by stripping the stems by drawing them through the hand. In this manner we got the blade and part of the sheath, but this portion consisted mostly of blades. The first samples were taken 7 July, 1913, and the latest samples 5 August, but the wheat was so nearly ripe on this last date that the leaves formed only about 4.0 percent of the plant and are included with the stems. The percentages given in the following tables are for green weights.

RATIO OF STEMS, LEAVES AND HEADS FOR RED FIFE.

Date	Fertilizer per acre	Stems Percent	Leaves Percent	Heads Percent
Sections 1700				
7 July, 1913	Nitrogen, 120 pounds	65.40	18.47	16.13
	Phosphorus, 60 pounds	66.57	14.26	19.17
	Potassium, 200 pounds	65.24	12.99	21.77
	None	70.84	14.58	14.58
21 July, 1913	Nitrogen, 120 pounds	56.64	12.65	30.71
	Phosphorus, 60 pounds	54.48	8.50	37.02
	Potassium, 200 pounds	54.73	9.40	36.47
	None	54.60	9.91	35.48
4 August, 1913	Nitrogen, 120 pounds	56.27	.....	43.73
	Phosphorus, 60 pounds	54.00	.....	46.00
	Potassium, 200 pounds	57.35	.....	42.65
	None	53.80	.....	46.20
Section 1800				
7 July, 1913	Nitrogen, 80 pounds	60.22	15.59	24.19
	Phosphorus, 40 pounds	69.05	13.49	17.46
	Potassium, 150 pounds	66.60	14.99	18.41
	None	69.39	13.49	17.21
25 July, 1913	Nitrogen, 80 pounds	59.88	8.56	31.56
	Phosphorus, 40 pounds	56.25	7.23	36.52
	Potassium, 150 pounds	54.66	6.43	38.91
	None	55.92	9.86	34.22
5 August, 1913	Nitrogen, 80 pounds	58.76	.....	41.24
	Phosphorus, 40 pounds	57.41	.....	42.59
	Potassium, 150 pounds	58.67	.....	41.33
	None	56.97	.....	43.03
Section 1900				
13 July, 1913	Nitrogen, 40 pounds	63.01	12.52	24.47
	Phosphorus, 20 pounds	62.07	10.09	27.84
	Potassium, 100 pounds	61.57	10.13	28.30
	None	62.77	9.70	27.53
30 July, 1913	Nitrogen, 40 pounds	56.70	7.10	31.16
	Phosphorus, 20 pounds	55.68	6.64	37.68
	Potassium, 100 pounds	53.47	5.15	41.38
	None	54.74	7.05	38.21

We could only make an approximate determination of the total green matter per acre by cutting the plants on a given small area and weighing the same. We did this as accurately as we could and obtained the following figures on 15 July, 1913, for Section 1700: Nitrogen applied, 120 pounds per acre, 10.1 tons; phosphorus applied, 60 pounds per acre, 8.3 tons; potassium applied, 200 pounds per acre, 7.4 tons; check, which received no fertilizer, 7.0 tons. The tables given above, together with these approximate figures, serve to give an idea of the effects produced upon the production of green matter by the fertilizers applied and some idea of the relative development of stems and heads.

THE DRY MATTER IN THE PLANTS.

The dry matter in the plants was also determined, but we had to use other samples. The earliest sample taken for this purpose was cut 7 July, 1913, at the time of blooming. The results are given in the following table for the whole plant till 28 July, but on this and subsequent dates the stems and heads were weighed separately.

DRY MATTER IN WHEAT PLANTS GROWN WITH DIFFERENT FERTILIZERS.

Date	Section	Variety	Fertilizer per acre	Air-dry matter Percent
7 July, 1913	1700	Defiance	120 pounds nitrogen	27.02
7 July, 1913	1700	Defiance	60 pounds phosphorus	30.78
7 July, 1913	1700	Defiance	200 pounds potassium	31.71
7 July, 1913	1700	Defiance	None	30.00
9 July, 1913	1700	Red Fife	120 pounds nitrogen	29.47
9 July, 1913	1700	Red Fife	60 pounds phosphorus	34.22
9 July, 1913	1700	Red Fife	200 pounds potassium	34.06
9 July, 1913	1700	Red Fife	None	34.29
9 July, 1913	1700	Kubanka	120 pounds nitrogen	32.66
9 July, 1913	1700	Kubanka	60 pounds phosphorus	33.60
9 July, 1913	1700	Kubanka	200 pounds potassium	32.42
9 July, 1913	1700	Kubanka	None	32.66
10 July, 1913	1900	Defiance	40 pounds nitrogen	29.38
10 July, 1913	1900	Defiance	20 pounds phosphorus	33.60
10 July, 1913	1900	Defiance	100 pounds potassium	32.34
10 July, 1913	1900	Defiance	None	32.34
10 July, 1913	1900	Red Fife	40 pounds nitrogen	30.55
10 July, 1913	1900	Red Fife	20 pounds phosphorus	36.25
10 July, 1913	1900	Red Fife	100 pounds potassium	33.83
10 July, 1913	1900	Red Fife	None	33.75
10 July, 1913	1900	Kubanka	40 pounds nitrogen	31.34
10 July, 1913	1900	Kubanka	20 pounds phosphorus	32.11
10 July, 1913	1900	Kubanka	100 pounds potassium	33.05
10 July, 1913	1900	Kubanka	None	30.86

DRY MATTER IN WHEAT PLANTS, STEMS AND HEADS SEPARATE.

Date 1913	Section	Variety	Fertilizer per acre	Dry matter stems	Dry matter heads	Ratio of green stems to heads
28 July	1700	Defiance	120 pounds nitrogen	42.30	46.54	1.5
28 July	1700	Defiance	60 pounds phosphorus	48.03	52.30	1.2
28 July	1700	Defiance	200 pounds potassium	45.97	49.80	1.3
28 July	1700	Defiance	None	43.65	48.40	1.3
31 July	1700	Red Fife	120 pounds nitrogen	44.77	54.74	1.3
31 July	1700	Red Fife	60 pounds phosphorus	49.98	56.80	1.2
31 July	1700	Red Fife	200 pounds potassium	43.84	60.06	1.2
31 July	1700	Red Fife	None	45.45	55.88	1.3
29 July	1800	Defiance	80 pounds nitrogen	42.05	44.87	1.9
29 July	1800	Defiance	40 pounds phosphorus	53.97	52.52	1.3
29 July	1800	Defiance	150 pounds potassium	47.40	49.11	1.5
29 July	1800	Defiance	None	43.89	47.78	1.5
29 July	1800	Kubanka	80 pounds nitrogen	51.81	53.37	1.3
29 July	1800	Kubanka	40 pounds phosphorus	47.28	54.80	1.2
29 July	1800	Kubanka	150 pounds potassium	57.96	56.77	1.3
29 July	1800	Kubanka	None	51.69	58.12	1.2
30 July	1900	Defiance	40 pounds nitrogen	49.45	47.42	1.7
30 July	1900	Defiance	20 pounds phosphorus	53.53	50.83	1.3
30 July	1900	Defiance	100 pounds potassium	47.26	47.92	1.4
30 July	1900	Defiance	None	51.93	49.58	1.3
30 July	1900	Red Fife	40 pounds nitrogen	51.99	54.52	1.8
30 July	1900	Red Fife	20 pounds phosphorus	51.76	54.80	1.6
30 July	1900	Red Fife	100 pounds potassium	48.23	56.90	
30 July	1900	Red Fife	None	49.47	55.51	

There is no question but that the tendency of the nitrate is to lessen the percentage of dry-matter in the plant. This is quite evident in the earlier samples and it is still true in the later ones though less pronounced and regular.

The samples of Defiance given in this table all seem to be remarkably low in dry matter. These are, however, the results obtained and I have no explanation to offer unless it be due to immaturity of the variety which requires about ten days longer for its normal development than the Red Fife. The preceding samples were dried in a large steam drier and then permitted to stand exposed to the atmosphere till they had absorbed as much moisture as they would under our atmospheric conditions before being weighed.

A few samples taken at random were used to ascertain how much moisture such samples contained. The average for seven samples used was 7.482 percent (Max. 8.652, Min. 5.566 percent). The samples grown with the application of nitrate contained higher percentages of moisture than the others, but the few samples tested do not justify the extension of this observation to all samples as a general rule.

THE EFFECTS OF FERTILIZERS AS INDICATED BY THE NITROGEN CONTENT OF THE PLANT.

The data previously given lead to the questions suggested by this caption. The most important questions that present themselves in our work during a given year pertain to the part played in the nutrition and development of the plant by the inorganic constituents available in the soil. Perhaps we should consider the absolute supply and the ratio of the respective substances.

The climatic influences for any given year are eliminated by the fact that they are the same for all series of experiments made during that year and our varying results in the different individual experiments cannot be attributed to the differences in this respect. All will agree that nitrogen is the inorganic constituent of the soil most easily traced during the development of the plant and at the same time the most important one both directly as a plant food and indirectly by its influence upon the appropriation of other ash constituents, and also upon the subsequent processes within the plant, depending upon the relative quantities of these present. In order to follow these processes we adopted the nitrogen content and its various forms, the amino group excepted, as the criteria whereby to judge of the influence of the nitrogen applied in the soil. It is our intention to try to follow these throughout the development of the plant from the time of bloom till the wheat is ripe and even into the flour. In order to accomplish this purpose we shall give the total nitrogen, the proteid nitrogen, the nitrogen present as ammonia and as amid.

We omit the amino-group in our analysis of the plant because we judge it, from our experience with the beet plant, to be of little significance and its determination as involving such large errors as to be of doubtful value.

The forms of nitrogen determined are given in the tables that follow. The variety studied was the Red Fife. We were compelled to confine our efforts to the one variety for the simple reason that we could not do any more samples while they were fresh and before there could be any question of material changes. In all cases in which the green samples had to stand, even for a few hours, we chloroformed them heavily.

A number of determinations were made, using the whole plant, but we found it quite impossible to obtain good agreement in the results because of variation in the samples as weighed out.

TOTAL AND PROTEID NITROGEN IN GROWING WHEAT PLANT.

Crop 1913	Fertilizer per acre	Total Nitrogen Percent Stems	Total Nitrogen Percent Leaves	Total Nitrogen Percent Heads	Proteid Nitrogen Percent Stems	Proteid Nitrogen Percent Leaves	Proteid Nitrogen Percent Heads
7 July	120 lbs. nitrogen	0.4304	0.9302	0.7670	0.2579	0.6767	0.4972
7 July	60 lbs. phosphorus	0.3420	0.8214	0.6990	0.2007	0.5788	0.4320
7 July	200 lbs. potassium	0.3182	0.8282	0.7194	0.1926	0.5462	0.4537
7 July	None	0.3318	0.8146	0.7058	0.2062	0.5843	0.4483
7 July	80 lbs. nitrogen	0.3896	1.3110	0.7534	0.2742	0.9114	0.5299
7 July	40 lbs. phosphorus	0.3250	0.9942	0.6990	0.2361	0.7583	0.4755
7 July	150 lbs. potassium	0.2866	0.8078	0.6922	0.2035	0.5788	0.4320
7 July	None	0.3386	1.0186	0.6922	0.2388	0.6441	0.4863
13 July	40 lbs. nitrogen	0.3699	0.7725	0.9153	0.2633	0.4972	......
13 July	20 lbs. phosphorus	0.3019	0.5957	0.8405	0.1599	0.3939	0.6060
13 July	100 lbs. potassium	0.2666	0.5005	0.6773	0.1708	0.3231	0.5788
13 July	None	0.2910	0.5141	0.8473	0.1953	0.3830	0.5897
21 July	120 lbs. nitrogen	0.3645	0.6909	0.9289	0.2415	0.4814	0.6387
21 July	60 lbs. phosphorus	0.2366	0.6093	0.8065	0.1436	0.4101	0.5679
21 July	200 lbs. potassium	0.2149	0.4529	0.8541	0.1505	0.3993	0.5843
21 July	None	0.2856	0.5821	0.8065	0.2171	0.3830	0.5679
25 July	80 lbs. nitrogen	0.4733	1.2893	1.0037	0.4762	......	0.7311
25 July	40 lbs. phosphorus	0.2965	0.8337	0.8540	0.2307	0.6332	0.6550
25 July	150 lbs. potassium	0.2666	0.8269	0.8813	0.1926	0.6115	0.6931
25 July	None	0.2421	0.5685*	0.8133	0.1768	0.4265	0.6985
29 July	40 lbs. nitrogen	0.3237	0.9357	1.0105	0.2307	0.2222	0.7420
29 July	20 lbs. phosphorus	0.2312	0.6773	0.9629	......	......	0.7475
29 July	100 lbs. potassium	0.1986	0.5889	0.9289	0.1382	0.4918	0.6659
29 July	None	0.2421	0.7929	0.8825	0.1550	0.7094	0.6767
4 Aug.	120 lbs. nitrogen	0.2611	1.5953	1.5001	0.1718	......	1.1446
4 Aug.	60 lbs. phosphorus	0.2366		1.3023	0.1355		1.0358
4 Aug.	200 lbs. potassium	0.1700		1.3382	0.0947		0.8508
4 Aug.	None	0.2149		1.4389	......		1.0739
5 Aug.	80 lbs. nitrogen	0.3155		1.2961	0.2035		1.0140
5 Aug.	40 lbs. phosphorus	0.1809		1.2621	0.1055		1.0031
5 Aug.	100 lbs. potassium	0.1958		1.3573	0.1164		1.0847
5 Aug.	None	0.2339		1.1193	0.1327		0.8889

*This determination was repeated with closely agreeing results.

The ratio of the green parts and also the dry matter in the stems and heads have been given in previous tables. No attempt has been made in these data to find the relative amount of kernels and their composition, as the dry weight of the wheat as threshed and the weight of the grain, while belonging to another step in the investigation, was considered sufficient for our purposes. Had our time permitted it, there is no question but that it would have been of interest to establish the relative weights of chaff and grain in at least, the last two samples, for these plants were fully matured. The leaves had dried to such an extent that it was not longer feasible to make a separate portion of them. In addition to lack of time it would have been almost impossible to separate the grain from the chaff without drying which would have changed, at least, the statement of our data. For these reasons these data are probabaly more serviceable in their present form than they would have been had I changed this form for part of them.

AMMONIC AND AMID NITROGEN IN GROWING WHEAT PLANTS.

Crop	Fertilizer	Ammonic Nitrogen Percent			Amid Nitrogen Percent		
1913	per acre	Stems	Leaves	Heads	Stems	Leaves	Heads
7 July	120 lbs. nitrogen	0.0052	0.0122	0.0133	0.0054	0.0090	0.0144
7 July	60 lbs. phosphorus	0.0065	0.0101	0.0139	0.0003	0.0052	0.0112
7 July	200 lbs. potassium	0.0046	0.0122	0.0152	0.0041	0.0125	0.0117
7 July	None	0.0060	0.0112	0.0144	0.0000	0.0108	0.0115
7 July	80 lbs. nitrogen	0.0054	0.0117	0.0125	0.0030	0.0082	0.0114
7 July	40 lbs. phosphorus	0.0043	0.0125	0.0128	0.0033	0.0060	0.0098
7 July	150 lbs. potassium	0.0035	0.0112	0.0128	0.0041	0.0095	0.0122
7 July	None	0.0046	0.0097	0.0117	0.0035	0.0071	0.0095
13 July	40 lbs. nitrogen	0.0071	0.0242	0.0193	0.0060	0.0095	0.0199
13 July	20 lbs. phosphorus	0.0052	0.0131	0.0158	0.0043	0.0065	0.0169
13 July	100 lbs. potassium	0.0043	0.0101	0.0212	0.0133	......	0.0120
13 July	None	0.0054	0.0112	0.0177	0.0049	0.0097	0.0182
21 July	120 lbs. nitrogen	0.0049	0.0144	0.0224	0.0046	0.0114	0.0166
21 July	60 lbs. phosphorus	0.0048	0.0122	0.0158	0.0075	0.0080	......
21 July	200 lbs. potassium	0.0048	0.0154	0.0190	0.0043	0.0093	0.0146
21 July	None	0.0046	0.0136	0.0181	0.0038	0.0069	0.0133
25 July	80 lbs. nitrogen	0.0054	0.0205	0.0185	0.0063	0.0101	0.0207
25 July	40 lbs. phosphorus	0.0027	0.0098	0.0140	0.0030	......	0.0122
25 July	150 lbs. potassium	0.0033	0.0090	0.0178	0.0028	0.0076	0.0150
25 July	None	0.0027	0.0041	0.0116	0.0024	0.0098	0.0116
30 July	40 lbs. nitrogen	0.0038	0.0131	0.0147	0.0022	0.0061	0.0095
30 July	20 lbs. phosphorus	0.0027	0.0090	0.0128	0.0053	0.0071	0.0079
30 July	100 lbs. potassium	0.0027	0.0030	0.0116	0.0035	......	0.0098
30 July	None	0.0018	0.0063	0.0122	0.0019	0.0079	0.0103
4 Aug.	120 lbs. nitrogen	0.0071	0.0270	0.0245	0.0067	0.0110	0.0185
4 Aug.	60 lbs. phosphorus		0.0065	0.0180		0.0043	0.0154
4 Aug.	200 lbs. potassium		0.0048	0.0146		......	0.0140
4 Aug.	None		0.0056	0.0174		0.0031	0.0139
5 Aug.	80 lbs. nitrogen		0.0057	0.0131		0.0050	0.0116
5 Aug.	40 lbs. phosphorus		0.0045	0.0161		0.0034	0.0160
5 Aug.	150 lbs. potassium		0.0050	0.0146		0.0041	0.0160
5 Aug.	None		0.0039	0.0095		0.0030	0.0122

The plants gathered on 5 August were mature, so mature that the crop was harvested on the 6th August. An inspection of the table shows that the time during which these samples were taken can be divided into two periods corresponding with the universally recognized divisions of development, the growing and ripening periods. The earliest samples were taken at the period of full bloom, 7 July; the latest samples were taken at the period of full maturity.

Our object in this feature of our work had two phases, one to follow the changes in the plant during the two periods just mentioned, and the other, the principal one, which we had in view, to determine the effects of the individual fertilizers upon the development of the plant and its composition. This is the reason why we used, in these experiments, no combinations of fertilizers. The object of this investigation as first proposed is to determine, if possible, what factors or factor in our conditions it may be that determines the character and quality of our wheat. It may prove to be the case that we have no justification in fact for assuming that Colorado wheat has any general character so fixed and invariable as to entitle it to recognition, either in a favorable or an unfavorable sense. This is still, to me, though the concensus of millers and bakers is to the contrary, an open question. It seems to me not only possible, but very probable that the variation in the composition and properties of samples of wheat grown on different lands in the same section may be as different as other samples from widely separated sections of the state or even from different states. In other words I doubt whether there is any standard which we can assert is characteristic of Colorado wheat. I must, however, acknowledge that the testimony of all the bakers that I have consulted is that the flour made from our wheats is an undesirable bread-making flour, falling from thirty to forty or more loaves per barrel behind flours which are first-class for this purpose. While these statements are somewhat anticipatory of subsequent work, the results of which are not yet known, they may not be wholly amiss in this place though we have presented no facts pertaining to the wheat, except those which it possibly may have in common with the plants, in respect to its nitrogen compounds.

We may consider the results obtained with the four sets of samples taken prior to the 25th July as representing the period of development of the plant, and those obtained with samples taken on the 25th July and subsequent dates up to 6th August, as representative of the changes during the ripening period.

According to the results obtained by Wilfarth, Roemer and Wimmer, it is probable that our earliest samples were taken at about the period when the crop contained the maximum amount of nitrogen, and from this period on, if their observations be correct, both the percentage of nitrogen in the plant and the total in the crop should diminish. Our results, taking stems, leaves and heads separately, agree with this statement. Of the sixty samples of leaves and stems given, there are only two instances in which we find any departure from this. These are found in the stems and leaves of one set of plants taken on 25th July in which, for some reason, we have high results. The heads as here given include the kernels and here we find an increase in the total nitrogen. When the period of ripening sets in we observe a rapid decrease in the amount of total nitrogen present in the stems and leaves, which is evidently not compensated by the increase in both the weight and the percentage of nitrogen in the heads. Wimmer, in the article already referred to, after pointing out the similarities and differences between the results obtained with barley and spring wheat says in regard to the total nitrogen in spring wheat at harvest time, "But here also, we find at the final harvest only 80.66 percent of the maximum amount of nitrogen previously appropriated."

What is true of the total nitrogen is also true of all the several forms of nitrogen. The one exceptional sample, already mentioned in connection with the total nitrogen, is consistent with itself throughout, i. e., all forms of nitrogen are relatively high. There is one sample that is somewhat lower than we would expect and this, too, is, in the main, consistently low throughout. These features, though interesting, did not constitute the question that we set out to determine. This question was—what effects, if any, do the individual fertilizers produce upon the composition of the plant and wheat.

Of late years, great stress has been laid upon the assumed fact that climatic conditions rather than the soil conditions constitute the principal factors in determining the composition and characteristics of the wheat grown. Our direct purpose is not to combat this idea, but to determine what the effects of nitrogen, phosphorus and potassium really are under our Colorado conditions.

It is too evident to need statement that there are fundamental conditions of climate and of soil fertility requisite to the growth of a crop of wheat and we cannot eliminate these. All that we can do is to change the relative supply of nitrogen, phosphorus or potassium under identical conditions of climate, using the same variety of wheat.

In making the preceding statement, I have the following consideration in mind: It is not just to compare samples of wheat taken on a given date unless they are of the same variety or it can be proven that they are in the same stage of development which would be exceedingly difficult to establish for different varieties. Our experience in 1914 with the two varieties, Defiance and Red

Fife, illustrates the importance of this point. We had a shower on the 28th July, which was of very short duration, but violent. The Fife and Defiance were planted on the same day and on contiguous plots of ground. The Fife matures about eight or ten days earlier than the Defiance. This shower did not appear to affect the Fife in the least, while it very severely injured the Defiance by inducing a strong development of rust, and inducing premature ripening. The difference in the results was apparently wholly due to the difference in the development of the respective varieties. The Defiance was still in a stage sensitive to this fungus, while the Fife probably escaped injury because of its advanced development. Perhaps some allowance should be made for the different powers of resistance to this fungus possessed by these different varieties. The principal cause of difference, however, is doubtlessly to be found in the different degrees of maturity at the time of the rain. The data relative to the nitrogen tabulated above will serve to show the same, especially in regard to the stage of development.

This study of the nitrogen in the plant from the time of bloom to maturity exhibits the answer to our main thesis, i. e., that the nitrogen content of the plant is materially affected by the fertilizers used.

The plan of experimentation was as follows: Three sections of land, lying side by side and uniform in quality, were divided into equal plots and four plots in each section were sown to one variety of wheat. In our nitrogen work on the plant we have used Red Fife only. The plots in one section received the maximum amount of the respective fertilizers, those of the next section received the medium amounts and those of the third section received the minimum amounts. Our results would have been more valuable had we been able to sample the whole twelve plots at the same time, but we could not do this and our results are faulty insofar as we cannot eliminate the changes which took place between the dates on which the different samples were taken. For instance, two members of a set were taken on 7 July and the third one was taken six days later, 13 July. These samples are not, strictly speaking, comparable. Still the effects of the fertilizers on the nitrogen content of the plant and the various forms of it determined are very clear.

Every fourth plot throughout the series was a check plot, and it is the products of these plots that constitute the bases of our comparisons. An examination of the results obtained with the stems and leaves shows:

First, that phosphorus exercised but little influence upon the amount of nitrogen in these parts of the plant. This is essentially true of all the forms of nitrogen determined.

Second, the application of nitrogen to the soil increased the nitrogen in the plant quite materially over that present in the plants grown on the check plots. This was true for each of the different applications made.

Third, the application of potassium depressed the amount of nitrogen present in the plants below that present in those grown on the check plots.

These facts hold, but not to the same extent, for the period of ripening of the grain. These statements are also applicable to the heads, though in this case we have a continuous increase in the amount of nitrogen present instead of a decrease as in the other parts of the plant. As the plants approach maturity, the differences in the amount of nitrogen present in the heads from the plants grown on the different plots becomes less certain. This is especially true of those from the plots which had received applications of phosphorus or potassium and of those from the check plots. The plants that were grown with the application of nitrates, remained richer in nitrogen in all parts throughout the period of investigation than the other plants, without any material exception.

THE ASH CONSTITUENTS OF PLANTS.

It is not proposed to follow the movement of the ash constituents in the plant, but simply to endeavor to determine in what sense and degree the amount of these constituents may be affected by the fertilizers used in our experiments. The observations given in this place do not include the kernels, only the plants. It is assumed that the amount of these constituents reaches a maximum at a certain stage in the development of the plant and from this time on decreases till the plant is mature. This is the case with the individual constituents in a very marked degree, except in the case of phosphorus, which recedes by only about one and one-half or two percent. That the ash constituents in the growing plant must be present in a soluble condition seems necessary in order that they should function, as we suppose them to do, and also that they should move out of the plant and return to the soil. We assume in this statement that these ash constituents return by the way of the plant itself and not by exudation or washing out by rain or by the dying and falling off of parts of the plants. With these questions we have nothing whatsoever to do, but simply to inquire in what sense and degree our fertilizers may affect them. For this purpose a number of samples were examined, but not all in the same manner. The first method used was to char the air-dried plant, extract with water and subsequently burn. This method gave the following results:

MOISTURE, SOLUBLE AND INSOLUBLE ASH IN AIR-DRIED PLANTS.

Crop 1913	Variety	Fertilizer Lbs. per Acre	Moisture Percent	Soluble Ash Percent	Insoluble Ash Percent	Total Ash Percent
8 July	Defiance	120 nitrogen	8.493	6.220	2.455	8.675
9 July	Red Fife	60 phosphorus	.....	4.206	2.678	6.889
9 July	Red Fife	None	5.566	4.007	2.193	6.200
9 July	Kubanka	200 potassium	6.759	4.436	3.514	7.950
10 July	Defiance	40 nitrogen	8.652	5.165	2.612	7.778
10 July	Red Fife	100 potassium	7.428	3.340	3.651	6.991
10 July	Kubanka	40 nitrogen	8.379	3.758	2.473	6.213
10 July	Kubanka	None	7.097	4.485	2.973	7.458

The table shows that from 50.0 to 75.0 per cent of the total ash is soluble in water. This amount is not only very high but also includes a large amount of silica which separates out on evaporation to dryness. For these reasons it seemed of some interest to determine the composition of this water-soluble ash; and at the same time to determine how its quantity and composition was affected by the addition of nitrogen compared with the water-soluble ash of plants grown without any fertilizer.

In the preparation of the preceding ashes, the ground plants were first charred and then extracted. The charring of the mass of organic matter containing so large an amount of silica and alkalis might have given rise to soluble silicates and for this reason alone the percentages of soluble and insoluble ash are not conclusive in regard to their solubility in the plant before ignition. We assume it as self evident that the mineral constituents, even the silica, are taken up as solutions and that they must continue to exist in the plant in this condition till they are either appropriated by the plant, *i. e.*, used in the formation of its various constituents, or, as in the case of the silica, are deposited in the cell walls in an insoluble form. But how long they continue to remain unchanged in regard to their solubility is not known. In order to determine whether the soluble ash obtained was formed by the ignition or existed in the plant as water-soluble salts, I extracted the ground plants with warm water. The water was not in contact with the plants for more than sixteen hours in all, so that fermentative changes probably did not bring the ash constituents into solution. The aqueous extract was evaporated to dryness, the dried mass ignited and treated as usual. The extracted plants were dried and the ash in them was determined, but not analyzed further than this, that it was treated with hydric chlorid and the amount of soluble and insoluble ash determined.

Two samples were treated in this manner. One was grown with the application of nitrates and the other without the application of any fertilizer, but both were of the same variety and taken on the same date, 8th July, 1913.

WATER-SOLUBLE ASH OF AIR-DRIED WHEAT PLANTS.

	Plants Grown with 120 lbs. of Nitrogen per Acre Percent	Plants Grown Without Any Fertilizer Percent
Ash constituents soluble in water	5.363	4.277
Ash constituents insoluble in water, but soluble in hydric chlorid	0.400	0.327
Insoluble ash (silica)	2.561	2.487
Total ash	8.324	7.091

ANALYSIS OF WATER-SOLUBLE ASH.

	Percent of Air-Dried Plant	Percent of Air-Dried Plant
Silicon	0.282	0.377
Iron	0.003	0.003
Manganese	0.002	0.001
Calcium	0.134	0.090
Magnesium	0.088	0.066
Phosphorus	0.204	0.225
Potassium	2.396	1.752
Sodium	0.035	0.028

No provision was made in the preparation of this ash to prevent loss of phosphorus and yet the water-soluble phosphorus is very high. Whether it existed in the plant as phosphoric acid or not does not appear, but it seems probable that the most of it did, and yet very considerable quantities of iron, calcium and magnesium were present in the aqueous solution, which scarcely would be the case under ordinary conditions. We know that the magnesium is a part of the chlorophyll molecule and is probably not precipitable by phosphoric acid while in this combination. Possibly a like explanation might be offered in the other cases. There is no question but that the plants grown with the application of nitrogen have larger leaves which are of a much deeper green color and yield an extract much more heavily charged with coloring matter than those grown without it. Consonant with this we find the magnesium and calcium both higher, in the plants grown with the application of nitrogen, by at least one-third.

It is a recognized fact that the application of sodic nitrate to wheat results in the production of a soft, weak straw and a tendency for the wheat to lodge. Whether this result is due to suppression of silica in the straw or to some other effect upon the growth of the plant, for instance the production of large, thin-walled cells, especially in the lower internodes of the plants, with very heavy leaves and heads is, to my knowledge, nowhere stated. The softness of the straw and its lack of harshness to the touch suggests that the silica in the straw is small in amount, whether this be the cause of the weakness or not. The following determinations of total silicon were made to ascertain whether and to what extent the silicon in the straw may be suppressed by an increased supply of nitrogen in the soil.

SUPPRESSION OF SILICON IN STRAW DUE TO NITROGEN.

Date of Harvest	Variety	Nitrogen Lbs. per Acre	Moisture Percent	Silicon Percent	Difference
28 July, 1913	Defiance	120	9.395	1.656	
28 July, 1913	Defiance	None	8.274	1.817	0.252
31 July, 1913	Red Fife	120	9.544	1.029	
31 July, 1913	Red Fife	None	7.564	1.236	0.207
29 July, 1913	Defiance	80	8.177	1.190	
29 July, 1913	Defiance	None	8.711	1.649	0.459
6 Aug., 1914	Defiance	120	9.802	1.192	
6 Aug., 1914	Defiance	None	9.533	1.708	0.516
6 Aug., 1914	Red Fife	120	9.724	1.134	
6 Aug., 1914	Red Fife	None	9.205	1.391	0.257
6 Aug., 1914	Kubanka	120	9.515	1.169	
6 Aug., 1914	Kubanka	None	9.550	1.557	0.388

While there is in each of these cases a depression of the silicon in the straw due to the nitrogen applied it seems too small, especially if we consider the large amount in the plant, to cause the softness and weakness noted. This statement considers only the question of the total amount of silicon present. It is possible that there may be a difference in the form in which the silicon may be present due to the action of the increased supply of nitrogen. Further, there might be a difference in its distribution in the different parts of the plant. Silicon for instance deposited in the glumes or in the blades of the leaves or in the upper portion of the stems would not tend to prevent lodging if the lower internodes were so deficient in silicon that they could not support the plants in an upright position. We assume in this statement that it is true that the stiffness of straw is due to the silicon in it.

There is a decided difference in the tendency of the different varieties to lodge. The Red Fife has scarcely lodged at all on our plots even with the maximum application of nitrogen. The Kubanka has lodged some but not badly while the Defiance has lodged badly with the minimum application of nitrogen. That this is due to the nitrogen applied there can be no doubt for in every case so far (about twenty of them), the limits of the application of the nitrogen were sharply marked in the case of the Defiance by the lodging. The amount of silicon in the whole straw, however, is fully as high as in the other varieties, so it would not seem to be a question of the total amount of silicon present.

The effect of fertilizers upon the amount of silicon contained in the first internode below the rachis indicates that the Red Fife is influenced less than the Kubanka which is in keeping with the observation that the Red Fife resists the action of nitrogen in producing lodging or weakness of the straw. I have figures for Red Fife and Kubanka, showing the effect of fertilizers upon the amount of silicon in the upper portion of the stem, but none for Defiance.

SILICON IN THE TOP INTERNODE OF THE STEM.

Date of Harvest	Fertilizer Lbs. per Acre	Red Fife Si Percent	Kubanka Si Percent
31 July, 1914	120 nitrogen	0.535	0.543
31 July, 1914	80 phosphorus	0.559	0.612
31 July, 1914	150 potassium	0.509	0.826
31 July, 1914	None	0.508	1.174

SILICON IN DIFFERENT PARTS OF STRAW.

Date of Harvest	Variety	Part of Plant	Fertilizer per Acre	Silicon Percent
6 Aug., 1914	Kubanka	Leaves	120 pounds nitrogen	2.846
6 Aug., 1914	Kubanka	Leaves	None	3.520
31 July, 1914	Kubanka	Top of stem	120 pounds nitrogen	0.543
31 July, 1914	Kubanka	Top of stem	None	1.174
6 Aug., 1914	Kubanka	Middle of stem	120 pounds nitrogen	0.381
6 Aug., 1914	Kubanka	Middle of stem	None	0.658
6 Aug., 1914	Kubanka	Bottom of stem	120 pounds nitrogen	0.402
6 Aug., 1914	Kubanka	Bottom of stem	None	0.684

This variety, Kubanka, was chosen for these determinations because it seemingly responds to the effects of nitrogen in regard to the silicon to a less degree than the Defiance and to a greater one than the Red Fife and we assume the results to be of more general application than those obtained with the other varieties. These results show that an increase in the supply of available nitrogen suppresses the amount of silicon contained in these different portions of the plant.

There is some difference shown in the relative amounts of soluble and insoluble silicon in plants grown with and without addition of nitrogen to the soil. It seems to be the fact that the application of sodic nitrate suppresses the amount of silicon soluble in water to a greater extent than it does the insoluble silicon. This, however, is only a tentative statement based on the work that has so far been done.

The distribution of the ash in the different parts of the plant, the extent and manner in which it is affected by the application of nitrates has been studied in part, but not thoroughly. The results obtained, however, agree with those already presented, indicating that the effect of the nitrogen upon the intake of inorganic constituents by the plant is very strongly modified.

SOLUBLE AND INSOLUBLE ASH IN PARTS OF WHEAT PLANT.

Variety	Date of Harvest	Fertilizer per Acre	Part of Plant	SiO_2 per cent	HCl. Sol. per cent	Total Ash per cent
Kubanka	6 Aug., 1914	None	Chaff	13.762	2.595	16.357
Kubanka	6 Aug., 1914	None	Leaves and sheaths	7.500	5.135	12.635
Kubanka	6 Aug., 1914	None	Top section of stem	1.986	3.892	5.878
Kubanka	6 Aug., 1914	None	Middle section of stem	1.401	3.915	5.361
Kubanka	6 Aug., 1914	None	Bottom section of stem	1,457	2,614	4,071
Kubanka	6 Aug., 1914	$NaNO_3$	Chaff	9.526	2.495	12.021
Kubanka	6 Aug., 1914	$NaNO_3$	Top section of stem	1.156	4.080	5.236

The effect of the sodic nitrate, corresponding in this case to 120 pounds of nitrogen per acre, is evidently in the same direction as indicated by our preceding data, *i. e.*, to a suppression of the silicon and a relative increase in the amount of soluble ash.

These results are the same for the later stages of growth and even for the ripe plant.

We notice that at an early stage in the development of the plant, the period of bloom, the phosphorus and silicon are higher in the plants that received no fertilizer and that the potassium is much higher in those which received an application of nitrogen.

That portion of the ash constituents insoluble in water, but soluble in hydric chlorid was not analyzed. It was, however, evaporated to dryness and again taken up with dilute acid to see if any silica had been dissolved by the hydric chlorid, which was insoluble in water. The result in both cases was negative, so it would seem that the silica existed in the plant at this time in two forms, one soluble in water and the other insoluble in concentrated acid. The soluble form is much less in the plants grown with the application of nitrogen than in those grown without it. The insoluble portion was already deposited in the cell-walls. This fact was easily observed in the microscopic examination of the properly prepared ash in which the stomata with their guard cells, the epidermal cells, the collenchymatous cells with their thickened angles, hairs and other parts were easily recognized. These various cells were apparently not so distinct, or heavily built up with silica, as in samples taken later.

It was not at first intended to extend the examination of the plants to include the mineral constituents, but the facts already stated made it advisable to include these determinations in our presentation of the effects of the fertilizers applied. The statement of the mineral constituents of the straws does not include the sulphur and chlorin, and is to this extent incomplete. These substances would have been included had we in the beginning supposed that we would have any good reason for considering this feature at all.

I have had some difficulty in finding data which show what the variations may be in the mineral constituents of wheat straw under ordinary conditions. The most of the data I have found has been taken from Wolff's "Aschenanalysen" without any explanations as to what the data represent. The figures given below to represent the general analysis of the ash of wheat straw, have been taken from Van Slyke's "Fertilizers and Crops."

The methods followed in the determination of the mineral constituents of the straw will be given at a future time. It may, however, be stated here that we found it impossible to determine the phosphorus by direct incineration in the presence of so much silica and carbon.

THE MINERAL CONSTITUENTS OF AIR-DRIED WHEAT STRAW.

	Ca Per cent	Mg Per cent	Fe Per cent	Mn Per cent	K Per cent	Na Per cent	P Per cent	Si Per cent
General Analysis.	0.21	0.08	0.02	.....	0.48	0.05	0.12	1.45
Defiance—								
31 July, 1913.								
Nitrogen	0.22	0.08	0.03	0.012	1.81	0.04	0.07	1.54
Phosphorus ...	0.11	0.03	0.01	0.002	0.99	0.02	0.06	2.08
Potassium	0.13	0.03	0.01	0.001	1.09	0.01	0.09	2.19
Check	0.16	0.05	0.02	0.009	1.20	Trace	0.08	1.94
Fife—								
31 July, 1913.								
Nitrogen	0.21	0.09	0.02	0.002	1.53	0.12	0.12	1.76
Phosphorus ...	0.14	0.05	0.01	0.002	1.00	0.02	0.06	2.09
Potassium	0.15	0.05	0.02	0.002	1.23	0.01	0.09	2.36
Check	0.19	0.08	0.02	0.009	1.05	0.02	0.12	1.97
Kubanka—								
6 August, 1914.								
Nitrogen	0.16	0.03	0.01	0.003	0.96	0.14	0.03	2.40
Phosphorus ...	0.11	0.02	0.01	0.002	0.72	0.05	0.02	2.70
Potassium	0.08	0.02	0.01	0.001	0.77	0.09	0.02	3.00
Check	0.18	0.07	0.01	Trace	1.05	0.09	0.03	2.60

The manganese determinations are given for the purpose of showing that this element is uniformly present but the percentages are not correct as they represent only that portion of the manganese that was carried down as an oxalate with the calcium oxalate. The portion of manganese thus carried down varies greatly even when only small quantities are present, as in these cases, but the results serve perfectly for the purpose for which they are given.

The amount of sulphur given by Van Slyke is five one-hundredths of one percent.

It appears from the results presented that the mineral constituents of the plant as represented by these straws are decidedly influenced by the relative food supply furnished by the soil. I am aware that this view was held for a long time as almost self-evident, but so much stress has been placed of late years upon the effects of "climatic conditions" as influencing the composition of the wheat kernels, which has been and will doubtlessly continue to be the chief object of study in connection with this plant, that the influence of the soil and its composition has been relegated to a comparatively subordinate position.

The application of sodic nitrate has increased the total amount of ash and produced, in addition to its effects upon the nitrogenous constituents, three effects upon the mineral constituents of the plants, which appear from data given in this connection. The three effects here alluded to are the depression of the silicon and the increase of the potassium and calcium. The increase of the latter two elements is very pronounced in two of the three varieties of wheat used in the experiments. Another result is that the sodium is uniformly increased by the application of sodic nitrate, but the total amount of sodium present in any case is so small and our ignorance of the part that sodium may play in the nutrition of the plant is so great that we are compelled to consider it an open question whether this is not to be considered an accidental constituent which has been increased by its association with the nitrogen applied. The application of the sodic nitrate has also, as a rule, increased the magnesium while its effect upon the amount of phosphorus in the plant seems to be nil.

The application of phosphorus and potassium to the soil seem uniformly to have lowered the amount of phosphorus in the plant which is, perhaps, a matter for some surprise.

The amount of potassium in the plant does not appear to have been influenced perceptibly by the application of either phosphorus or potassium. That the variety experimented with has some influence is suggested rather strongly by the results obtained with the Kubanka, though these samples were grown in 1914 and were entirely ripe when gathered.

We have now given the composition of our soil, the soil moisture, the total water received during the season of 1913, the nitric nitrogen in the soil for different dates throughout the season (1913) to two depths, namely, to the depth of four feet, represented by series of samples taken on ten different dates, and to the depth of twelve feet represented by five series of samples taken on two dates, also the total nitrogen in the soil at different dates. Concerning the ash of the plant, we have given the amount soluble in water, the total, the distribution of silicon in the plant and the relative quantities of the constituents.

The data so far given are almost wholly for the experiments of 1913 and the results represent the effects of our conditions of soil under identical climatic conditions.