Bulletin 217 March, 1916

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

A STUDY OF COLORADO WHEAT

BY W. P. HEADDEN

Part II

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1916

The Agricultural Experiment Station

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A STUDY OF COLORADO WHEAT

By W. P. HEADDEN

PART II

In Part I of this study (Bulletin 208) we gave the results obtained during the season of 1913 in a study to determine the moisture in the soil, the variations of the nitric nitrogen in the soil, the various nitrogen compounds in the plants from the time of bloom till the wheat was ripe, and also the ash constituents of the plants.

The nitric nitrogen in the plants was not given because we wished to repeat our work on this subject. Our results were not concordant, neither did they agree with such data on the subject as I was able to find. Jost, in his Lectures on Plant Physiology, makes the statement that the air-dried plant may contain from 1.8 to upwards of 2.0 percent of nitric nitrogen, but says nothing about its occurrence in the green plant. He does not say whether it always occurs or not; the impression made by his language is that it may or may not be present. The quantities given are so far in excess of anything that we found, that we deferred any consideration of the subject at that time.

The ash constituents of the plants were given for some samples taken in 1913 and of one series taken in 1914. This last series was taken when the plants were entirely ripe and were really straw; the other samples were much less mature. This difference in the development of the plants at the time that they were cut lessens, in some degree, the value of the results for the purposes of comparison, but does not detract from their value in showing the effects of the fertilizers applied to the different plots upon the mineral constituents of the ash.

The purpose of this preliminary work has been stated to be the finding out of the distinguishing character of Colorado wheat, if it has any, and to ascertain if possible those factors in our conditions which determine this character.

With this purpose in view, and to establish what the effects of the individual fertilizers are, we studied the composition of the plants from the time of blooming till they were mature. This was done to enable us to draw sume inferences, at least, in regard to the part played by the soil constituents as distinguished from the climatic conditions. We hoped by applying nitrogen, phosphorus and potassium separately and each in varied quantities, to so increase the characteristic effects of each, that it would enable us to recognize their specific effects, not merely upon the composition of the plant, but also upon the characteristics of the grain. This procedure was based upon the assumption that the land used in our experiments already contained these elements in sufficient amounts, and in such relative quantities, that it would produce wheat which would be entirely normal for our locality, and that by adding sufficiently large quantities of these individual substances in proper form, we would be enabled to recognize their respective influences upon the grain, and particularly upon the bread-making qualities of the flour. While the composition of the flour, especially in respect to what we may designate its minor details, may have less effect upon the quality of the flour than we think, it is certainly wise in this case to be as thorough as possible, even if our effort produces but few usable results. I have in mind that it is customary to consider the amount of nitrogen in a wheat as indicative of its merit for making flour, assuming at the same time that all other constituents are either present in sufficient quantities, or are of so much less importance that mention of them is not called for. It is not intended to state that the importance of phosphorus or other ash constituents are never considered, for this is not true, but that the importance atached to the amount of nitrogen contained in the wheat overshadows that of the other constituents. Our general judgment is that the higher the nitrogen, the better the flour that it will yield, that is, the greater will be the amount of gluten contained. In this general view, only the total amount of nitrogenous substances is considered; neither the quality of these substances, gluten, nor the presence of other substances which, in the end, may have a deciding influence upon the quality of the flour, is given any weight. There is a large mass of literature upon this subject, but there are not any fixed criteria which may be used in judging the value of flour, nor is there any agreement as to the causes of the differences found in flours or wheats grown in the same, or in different places.

The portion of this work already published (Bulletin 208) shows that the nitrogen supply in the form of nitrates in the soil affects the amount of the total and also that of the proteid nitrogen in the plant throughout the period between blossoming and maturity.

The ammonic and amid nitrogen found in the plants probably represent nitrogenous compounds in a transition stage, at least to a large extent; still it is true that we find these more abundant in plants grown with the application of nitrates than in others. We further found that the effect of phosphorus, and also that of potassium, upon the total nitrogen in the stems, leaves, and heads was very small, until the period of ripening approached, when these elements seemed to effect an increase of the total nitrogen in the heads, but the proteid nitrogen in the heads of wheat plants dressed with phosphates or potassium salts was not greater than in those of plants that had received no fertilizer.

The mineral constituents of the plant were also affected by the application of the nitrate, but not in a uniform manner, some constituents increased while others were depressed. Calcium, magnesium and potassium (sodium is included) were increased, silicon was decidedly depressed, but the phosphorus in the plant did not seem to be affected. This statement pertains only to the plant and is not to be applied to the grain, which will be discussed later.

The effect of the application of water at different times was not studied, except by the results obtained on one plot which received a total application of two feet of water, one applied 12 June and the other 12 July, 1913. Four plots were irrigated on these dates, but plants from only one of these were analyzed. The effect of this increased water supply upon the amount of total and proteid nitrogen in the stems, leaves and heads of the plants was not marked enough to justify, in any measure at all, a statement that any results had been produced. The same statement applies to the yield of both total dry-matter and of grain, for in none of the four experiments was there an increase in either respect. The application of one acre-foot of water on 12 June, when the wheat was in boot, was sufficient for the production of a maximum crop.

The soil moisture for the season of 1913 is given in detail in Part I (Bulletin 208 of this Station).

It will be recalled that in the plan of these experiments every fourth plot was a check. The above statements are all based upon a comparison of results obtained with plants from these check plots with those obtained with plants from the plots to which we applied fertilizers.

It was impossible for us, during the season of 1914, to carry out the plan pursued in 1913, so we were not able to repeat the observations of 1913 till the season of 1915.

OBSERVATIONS ON SOIL MOISTURE, COMPOSITION OF THE PLANT, AND NITRIC NITROGEN IN 1915

The weather conditions in 1913 were favorable for our experiments, but were scarcely more so than they usually are. We would say that it was a good year, perhaps a little more favorable than an average one, but not enough so to cause comment. This was not the case with the season of 1915, which the consensus of opinion would unhesitatingly designate as a bad year for wheat, a wholly abnormal year. Mr. Robert Trimble, in charge of our meteorological observations, has furnished me the data for the months of April, May, June, July and August of the respective years, which show the differences between the seasons in so far as may be done by figures. The total rainfall during these months in 1913 was 6.77 inches, and in 1915, 13.37 inches. In 1913 we had only four wholly cloudy days during these months, while in 1915 we had only 57 days free enough from clouds to justify the designation of clear. In the following statements of mean temperatures that for 1913 is given first, and then that for 1915. April, 46.1°, 50.05°; May, 54.8°, 50.35°; June, 63.2°, 59.62°; July, 66.8°, 64.74°; August, 69.8°, 62.77°. The rainfall in 1915 was not only unusual, but it was distributed through the season so that the plants were kept wet most of the time, the prevalent cloudiness preventing a thorough external drying, even when there was no actual rainfall.

This proved to be very prejudicial, not only to my crop, but locally to all of our spring wheat, especially to our popular variety, the Defiance, because of the severe attack of rust which was induced by these conditions.

In 1913 I applied to my plots one acre-foot of water on 12 June and to four of them a second acre-foot on 12 July. Thirty-two of the plots received, as irrigating water and rainfall, practically 19 inches of water during the growing season, 12 inches of which was applied at one time and in clear weather. Three and one-half inches of the 6.8 inches of rain fell in April and May, and 2.5 inches between 13 and 24 July. This last period of rainfall caused some rust to develop. The subsequent fourteen days were dry and bright, and the damage was not serious. In 1915 the plots received from 0.5 to 0.6 of an acre-foot of irrigation water, this being all that was required to flood the land. It will be noticed that the amount of water received during the two seasons was very nearly the same. In 1915 the amount of rainfall was not only greater, but its distribution was different and accompanied by a great deal of cloudiness. These conditions affected not only the rate of the development of the plants and of the rust, but modified our conditions of soil moisture, the distribution of the nitrates, and probably also affected their formation, as well as the amount of fixation that took place. These last two factors are, unfortunately, not definitely known nor are they easily ascertained.

The general conditions as here described may seem to be unfortunate. As matters stand they really are, but were it not for the introduction of the factor of rust, I would be inclined to consider it fortunate that our experiments were made during this season, for many facts, to be given subsequently, will tend to show, or perhaps prove, that the amount of water applied, be it as rainfall or irrigation, has comparatively little influence upon the composition of wheat.

It is very fortunate in this connection that we made three parallel series of experiments with three different varieties which differ in their susceptibility to injury by rust. If this had not been the case, if we had used only the Defiance in these experiments, we would not have been satisfied to abide by any results obtained. This variety was so badly shrunken that I could not sell it, except for chicken feed. The weight per bushel and the yield will indicate how badly it was injured, almost wholly, as I think, by the rust. The grain weighed from 47 to 53 pounds per bushel and the yield ranged from 10 to 23 bushels per acre. The other varieties were much better, both in weight per bushel and in yield per acre, though they also suffered from the effects of rust to some extent. The maximum yield, 41.5 bushels, weight per bushel 60 pounds, was obtained with Kubanka.

It may be well to state, in this connection, that the plants grown with the application of sodic nitrate seem more easily atacked by rust than those which are grown without it, and on this account tend to produce shrunken wheat. This, however, seems to be a specific effect of nitrates upon the wheat kernel as well as an effect of rust. This year the two acted together and produced, in the case of the Defiance, an almost total failure of the crop. This statement is made in this connection lest it should be thought that subsequent statements, pertaining to the effects of nitrates, did not make sufficient allowance for the effects of this parasite.

MOISTURE AND NITRIC NITROGEN IN THE SOIL, 1915

During this season, 1915, we took no samples to a greater depth than four feet, whereas in 1913 we took four series of samples to a depth of twelve feet. In 1913 we took 42 series in fallow and 18 series in cropped land to a depth of four feet. In 1915 we took 54 series in cropped and 6 series in fallow land to the depth of four feet. The moisture and nitric nitrogen were determined in all of these samples and the total nitrogen in twenty of the series. The dates on which our samples of 1915 were taken do not follow at regular intervals because of the frequent rains. We endeavored to allow a few days to elapse after a rain before we took the samples, but even with this precaution it is not probable that we have succeeded in making the samples altogether comparable with those of 1913.

The results obtained are given in the following tabular statements:

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 13 MAY, 1915

Depth	Section 1800, Fallow		Section 1700		Section 1800		Section 1900	
	Moisture Per cent	Nitric Nitrogen, Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million
Red Fife Plots—								
Top 3 inches	14.08	4.57	14.60	1.05	14.08	4.57	12.76	4.34
4 to 7 inches	17.74	4.30	17.50	0.93	17.74	4.30	16.49	4.41
8 to 12 inches	17.73	6.42	17.41	3.12	17.73	6.42	17.04	5.44
13 to 24 inches	17.00	5.86	16.78	6.01	17.00	5.86	16.97	10.04
25 to 36 inches	16.48	4.80	16.87	1.50	16.48	4.80	16.92	3.8[illegible]
37 to 48 inches	15.74	2.84	16.35	1.66	15.74	2.84	16.32	1.7[illegible]
Kubanka Plots—								
Top 3 inches			12.07	4.19	12.53	4.21	13.93	5.08
4 to 7 inches			16.81	4.01	17.17	4.44	17.38	5.30
8 to 12 inches			16.85	6.52	16.99	5.69	16.72	4.42
13 to 24 inches			15.85	9.66	16.67	7.34	16.91	7.77
25 to 36 inches			16.10	5.22	16.54	4.41	16.51	5.24
37 to 48 inches			16.77	2.75	17.07	2.76	16.28	2.32

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 18 JUNE, 1915

Depth	Section 1800, Fallow		Section 1700		Section 1800		Section 1900	
	Moisture Per cent	Nitric Nitrogen, Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million
Red Fife Plots—								
Top 3 inches	13.52	5.45	9.08	1.80	9.20	1.45	8.33	1.21
4 to 7 inches	17.44	4.46	12.82	1.27	12.76	1.19	12.52	0.79
8 to 12 inches	16.61	2.50	13.45	1.49	12.93	1.01	14.11	0.89
13 to 24 inches	16.7[illegible]	2.00	14.27	1.22	14.74	0.65	13.67	0.80
25 to 36 inches	16.57	4.24	14.32	0.97	14.59	1.47	13.99	0.80
37 to 48 inches	16.05	3.64	14.75	0.97	13.97	1.38	14.65	0.81
Kubanka Plots—								
Top 3 inches			10.45	2.56	10.20	1.39	10.59	1.55
4 to 7 inches			14.14	1.38	13.71	1.37	13.60	1.60
8 to 12 inches			13.63	1.21	13.52	1.45	13.97	1.61
13 to 24 inches			13.72	1.21	13.79	0.80	13.83	1.53
25 to 36 inches			14.52	3.66	14.03	1.46	13.70	3.54
37 to 48 inches			16.15	2.15	14.65	1.38	13.35	1.92

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 8 JULY, 1915

Depth	Section 1800, Fallow		Section 1700		Section 1800		Section 1900	
	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million
Red Fife Plots—								
Top 3 inches	12.93	6.86	14.13	1.54	14.60	1.05	14.51	1.30
4 to 7 inches	17.48	3.36	14.95	1.31	15.56	0.82	15.89	1.40
8 to 12 inches	17.48	3.36	15.40	1.76	15.82	1.40	15.81	1.65
13 to 24 inches	16.97	1.92	15.30	1.02	16.04	1.16	15.27	1.63
25 to 36 inches	16.64	2.25	15.27	0.82	15.74	0.90	14.33	0.98
37 to 48 inches	16.07	2.56	14.20	0.81	15.80	0.82	15.04	0.49
Kubanka Plots—								
Top 3 inches			13.23	1.20	15.46	0.74	14.61	0.77
4 to 7 inches			15.02	0.81	16.06	1.07	16.17	1.16
8 to 12 inches			14.48	1.22	16.01	0.91	16.55	1.33
13 to 24 inches			14.80	0.81	15.73	0.66	16.30	0.83
25 to 36 inches			15.44	0.41	15.96	0.33	15.96	0.66
37 to 48 inches			16.62	0.16	16.18	0.25	17.19	0.42

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 3 AUGUST, 1915

Depth	Section 1800, Fallow		Section 1700		Section 1800		Section 1900	
Red Fife Plots—								
Top 3 inches	11.37	8.66	12.47	1.58	12.31	0.71	12.09	1.25
4 to 7 inches	15.65	5.89	12.14	1.11	11.56	1.88	12.06	0.83
8 to 12 inches	16.06	4.72	11.11	1.29	11.21	1.02	11.18	0.86
13 to 24 inches	16.06	2.11	10.75	0.85	12.13	1.22	11.96	0.78
25 to 36 inches	15.38	1.72	12.32	0.95	12.75	0.79	12.72	0.56
37 to 48 inches	15.44	1.93	12.97	0.69	13.18	0.69	12.96	0.00
Kubanka Plots—								
Top 3 inches			11.83	0.98	12.59	0.79	12.83	0.64
4 to 7 inches			11.23	0.86	12.51	1.11	12.40	0.47
8 to 12 inches			10.28	0.85	11.45	0.55	11.87	0.47
13 to 24 inches			10.03	0.54	11.59	0.55	12.19	0.55
25 to 36 inches			11.44	0.31	12.46	0.39	12.98	0.40
37 to 48 inches			13.97	0.08	13.49	0.40	13.68	0.16

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 30 AUGUST, 1915

Depth	Section 1800, Fallow: Moisture Per cent	Section 1800, Fallow: Nitric Nitrogen Parts per Million	Section 1700: Moisture Per cent	Section 1700: Nitric Nitrogen Parts per Million	Section 1800: Moisture Per cent	Section 1800: Nitric Nitrogen Parts per Million	Section 1900: Moisture Per cent	Section 1900: Nitric Nitrogen Parts per Million
Red Fife Plots—								
Top 3 inches	9.14	2.15	12.30	2.22	11.98	2.44	12.74	2.87
4 to 7 inches	12.64	1.59	12.16	1.82	12.76	1.75	13.65	2.41
8 to 12 inches	12.68	1.91	10.85	1.25	10.72	1.40	11.05	1.41
13 to 24 inches	14.18	1.54	10.78	1.71	10.81	1.01	11.45	0.78
25 to 36 inches	13.95	0.73	12.36	0.48	12.16	0.87	12.24	0.23
37 to 48 inches	14.16	2.19	12.88	0.24	12.71	0.64	12.62	0.32
Kubanka Plots—								
Top 3 inches			10.62	2.18	10.22	2.09	12.21	2.45
4 to 7 inches			12.04	1.50	13.68	1.49	14.28	2.11
8 to 12 inches			10.18	1.47	10.91	1.17	11.58	1.57
13 to 24 inches			9.62	0.84	10.89	1.25	12.03	0.94
25 to 36 inches			11.29	0.86	11.71	0.78	13.06	0.96
37 to 48 inches			12.85	0.64	12.56	0.72	13.64	0.80

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 14 SEPTEMBER, 1915

Depth	Section 1800, Fallow: Moisture Per cent	Section 1800, Fallow: Nitric Nitrogen Parts per Million	Section 1700: Moisture Per cent	Section 1700: Nitric Nitrogen Parts per Million	Section 1800: Moisture Per cent	Section 1800: Nitric Nitrogen Parts per Million	Section 1900: Moisture Per cent	Section 1900: Nitric Nitrogen Parts per Million
Red Fife Plots—								
Top 3 inches	10.08	4.79	12.60	5.70	11.62	3.85	11.90	5.76
4 to 7 inches	12.54	2.62	13.22	3.11	12.75	3.02	13.56	3.45
8 to 12 inches	13.40	3.29	12.01	2.05	11.09	1.95	12.01	2.21
13 to 24 inches	13.99	2.02	11.26	1.17	11.25	1.41	12.08	1.50
25 to 36 inches	13.81	1.93	12.28	0.87	12.32	0.95	12.41	1.03
37 to 48 inches	13.63	1.85	12.93	0.87	12.30	0.87	15.75	0.82
Kubanka Plots—								
Top 3 inches			10.38	3.25	12.47	2.78	12.68	4.85
4 to 7 inches			12.93	1.59	14.18	2.02	15.10	2.53
8 to 12 inches			11.30	1.25	12.08	1.26	12.44	1.27
13 to 24 inches			10.81	0.70	11.09	0.47	11.98	1.10
25 to 36 inches			12.74	0.24	12.17	0.39	12.93	0.78
37 to 48 inches			14.38	0.00	13.43	0.16	13.31	0.40

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 28 SEPTEMBER, 1915

Depth	Section 1800, Fallow		Section 1700		Section 1800		Section 1900	
	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million
Red Fife Plots—								
Top 3 inches	16.86	2.50	17.91	2.96	17.90	2.54	17.75	3.38
4 to 7 inches	15.91	5.70	16.40	4.65	16.84	4.76	16.96	6.69
8 to 12 inches	13.37	1.60	12.93	1.75	12.39	1.98	11.62	1.73
13 to 24 inches	14.14	1.21	11.30	0.78	11.53	0.78	11.14	0.86
25 to 36 inches	14.08	1.13	12.50	0.56	12.29	0.47	11.20	0.39
37 to 48 inches	13.52	1.60	12.77	0.24	13.11	0.24	11.32	0.00
Kubanka Plots—								
Top 3 inches			15.98	3.80	16.91	3.25	17.17	3.44
4 to 7 inches			16.00	4.30	15.99	4.05	16.77	4.59
8 to 12 inches			11.38	1.80	13.36	1.92	14.45	1.95
13 to 24 inches			10.92	0.78	11.69	0.71	13.07	0.48
25 to 36 inches			12.88	0.40	12.56	0.40	13.53	0.48
37 to 48 inches			14.36	0.32	13.43	0.32	13.87	0.08

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 25 OCTOBER, 1915

Depth	Section 1800, Fallow		Section 1700		Section 1800		Section 1900	
Red Fife Plots—								
Top 3 inches	No separate samples taken, same as Section 1800		14.82	2.09	15.16	1.80	14.84	3.34
4 to 7 inches			17.05	2.26	17.43	1.93	17.08	5.03
8 to 12 inches			16.72	2.88	16.88	3.51	16.72	3.84
13 to 24 inches			16.05	1.90	16.25	2.16	16.51	2.99
25 to 36 inches			15.12	0.41	14.92	0.98	14.36	0.81
37 to 48 inches			13.78	0.32	13.56	0.56	13.19	0.64
Kubanka Plots—								
Top 3 inches			13.68	2.26	14.88	1.71	14.67	1.71
4 to 7 inches			16.98	3.01	17.37	1.85	17.16	1.51
8 to 12 inches			16.39	3.82	17.35	2.60	16.91	2.50
13 to 24 inches			15.72	1.73	16.38	2.08	16.66	1.92
25 to 36 inches			14.65	0.57	15.49	0.58	15.51	0.50
37 to 48 inches			15.06	0.49	14.48	0.57	14.64	0.25

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 22 NOVEMBER, 1915

Depth	Section 1800, Fallow		Section 1700		Section 1800		Section 1900	
	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million
Red Fife Plots—								
Top 3 inches	No samples taken		10.97	2.73	11.81	3.70	11.99	3.16
4 to 7 inches			15.29	2.05	14.96	3.43	15.37	3.95
8 to 12 inches			15.60	2.54	15.52	3.95	15.44	2.30
13 to 24 inches			15.50	2.14	15.40	2.54	15.65	1.81
25 to 36 inches			14.52	0.49	14.15	0.80	14.40	0.49
37 to 48 inches			13.58	0.16	13.90	0.57	12.94	0.32
Kubanka Plots—								
Top 3 inches	No samples taken		10.60	2.48	8.83	2.58	12.14	2.68
4 to 7 inches			14.70	3.26	15.34	2.45	15.36	4.59
8 to 12 inches			15.26	2.53	15.00	3.93	16.26	3.32
13 to 24 inches			14.69	1.95	15.19	2.21	15.58	2.63
25 to 36 inches			13.99	0.57	14.34	0.88	14.85	0.89
37 to 48 inches			15.17	0.66	13.89	0.24	14.43	0.88

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 13 DECEMBER, 1915

Depth	Section 1800, Fallow		Section 1700		Section 1800		Section 1900	
Red Fife Plots—								
Top 3 inches			11.21	4.31	8.78	4.35	10.46	5.90
4 to 7 inches			15.42	3.87	14.61	3.83	14.86	5.06
8 to 12 inches			15.78	4.46	15.94	4.63	15.62	4.69
13 to 24 inches			15.52	2.97	15.16	3.52	15.62	2.72
25 to 36 inches			14.15	2.03	14.18	2.19	11.38	1.42
37 to 48 inches			13.78	1.46	13.65	2.26	14.44	1.14
Kubanka Plots—								
Top 3 inches			10.51	4.51	10.78	4.37	10.91	4.76
4 to 7 inches			15.20	3.77	15.34	3.11	15.62	3.79
8 to 12 inches			15.36	3.78	15.93	3.56	16.05	4.31
13 to 24 inches			14.37	3.25	15.52	3.20	15.60	3.79
25 to 36 inches			13.37	1.77	14.74	2.21	14.57	1.91
37 to 48 inches			14.40	1.71	14.46	1.47	14.30	1.66

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 16 FEBRUARY, 1916

Depth	Section 1800 Moisture percent	Section 1800 Nitric Nitrogen Parts per Million	Depth	Section 1800 Moisture percent	Section 1800 Nitric Nitrogen Parts per Million
Red Fife Plots—			Kubanka Plots—		
Top 3 inches	16.108	4.63	Top 3 inches	15.083	5.57
4 to 7 inches	16.607	4.10	4 to 7 inches	16.450	4.71
8 to 12 inches	16.717	4.34	8 to 12 inches	16.944	5.50
13 to 24 inches	15.834	2.46	13 to 24 inches	15.210	1.73
25 to 36 inches	12.947	0.70	25 to 36 inches	13.589	0.80
37 to 48 inches	13.492	0.64	37 to 48 inches	14.075	0.64

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 22 MARCH, 1916

	Section 1700		Section 1800		Section 1900	
	Moisture Percent	Nitric Nitrogen Parts per Million	Moisture Percent	Nitric Nitrogen Parts per Million	Moisture Percent	Nitric Nitrogen Parts per Million
Red Fife Plots—						
Top 3 inches	9.774	4.59	8.931	5.35	9.145	6.12
4 to 7 inches	16.234	4.63	18.456	4.07	15.549	4.67
8 to 12 inches	14.488	3.70	15.056	3.12	15.010	3.51
13 to 24 inches	15.095	1.64	15.369	1.88	15.621	1.97
25 to 36 inches	13.764	0.88	13.853	0.88	14.515	0.65
37 to 48 inches	13.367	0.64	13.465	0.64	14.238	0.32
Kubanka Plots—						
Top 3 inches	12.611	6.02	9.608	7.19	9.429	5.35
4 to 7 inches	16.096	4.38	15.394	4.34	16.392	4.46
8 to 12 inches	15.357	3.61	15.850	3.61	16.260	3.14
13 to 24 inches	14.587	2.11	15.456	2.12	15.593	1.64
25 to 36 inches	13.588	1.21	13.929	0.88	14.649	0.65
37 to 48 inches	14.602	0.65	13.636	0.24	14.057	0.57

We took no samples for the determinations of moisture and nitric nitrogen in January because the weather was unfavorable and the ground frozen. We took only two series of samples in February, i.e. on the 16th of the month when we found the ground frozen to a depth of six inches. A comparison of the results obtained for the samples taken 13 December, 1915, with those obtained for the same section in February and again in March,1916, shows that the distribution of the nitric nitrogen had changed during the interval between 13 December, 1915 and 16 February, 1916, but had remained essentially the same from 16 February to 22 March, 1916. These differences in the distribution are most marked in the third and fourth foot. Concerning the total amount present in the soil, there is in every case less in the second, third and fourth foot, in the two last series of samples taken, than in those taken 13 December, 1915, but more than in those taken 22 November, 1915. The surface foot shows an increase but it is not sufficient to balance the loss in the bottom three feet.

CONCERNING THE DISTRIBUTION OF MOISTURE

The rainfall in 1913 was only 6.77 inches during the growing season and this fell during two periods, the first from 9 to 20 May and the second from 13 to 23 July, with almost no cloudy weather. In 1915 we had 13.47 inches rainfall distributed rather evenly throughout the corresponding period. In July, we had only 2.12 inches rainfall, but this was distributed over eleven days and a "trace" is recorded on five days. Only eleven days during the month are recorded as clear. In 1913, we had a greater rainfall during this month, but its distribution was different and the cloudiness was very much less; there was only one day designated as wholly cloudy. The moisture in the soil, as shown by our samples, was much more clearly alike during the two seasons than one would expect, taking the very different weather conditions into consideration. But it must be remembered that we allowed a few days to elapse after a rain before we took our soil samples. These samples, except those designated fallow, were taken from cropped land. Determinations of moisture in the surface samples immediately after a rain would have had no object whatever for our purposes. A comparison of the tables given for 1913, in Part I (Bulletin 208), with those given for 1915 in the preceding pages, will show no regularity in the differences, which are much less than we would expect, two percent being about the maximum.

I deem it almost useless to state that the time of the rainfall, the cloudiness and temperature are much more important than the amount of the rainfall. Every farmer in the extreme eastern states is aware of this, for a few warm, foggy days with no rainfall may ruin the most flattering prospects for a wheat crop. Warm, cloudy weather, with but little wind and enough rain to keep the plants wet for a few days at the critical period in the development of the wheat may ruin the crop. It is in this manner that moisture enters into our problem of producing a crop rather than as a soil problem, provided that there is not at any time a decided deficiency in the soil. The moisture in these experimental plots for the two years 1913 and 1915 varied from approximately 12 to 17 percent, except at periods of irrigation or rainfall.

An excessive amount of water in the soil might drown the plants or it might dilute the nutrients in the soil, or even wash them out to such an extent as to be detrimental. We have no proof in the data so far obtained that the latter is the case to such an extent that we should give it any consideration in this place.

The distribution of the nitrates in the soil, particularly in the top two feet, is very largely determined by the water received at the surface. We endeavored in 1913 to follow this effect to a depth of 12 feet.*

At the end of April, we found the distribution of the nitrates in the soil taken to 12 feet very varying, but the nitrates were quite abundant within this depth. The application of one foot of water at one time sufficed to move the most of the nitrates to a greater depth. The frequent light rains of 1915 effected a different distribution of the nitrates in the top two feet of the soil from that which we had in 1913. I do not think that this was any disadvantage to the 1915 crop. It may have, and probably did, change the point of most active feeding within this depth, but was probably without further effect. In 1913 the surface foot was markedly the richest area; in 1915 the nitrates were more evenly divided between the top two feet.

The total amount of the nitric nitrogen present in the four feet of soil sampled during the two seasons is much more nearly uniform than we would expect to find it. There are such variations as we know to prevail in different sections taken on the same date. These variations are often relatively large both for any given foot, and also for samples representing from four to twelve feet. We have a few samples taken to a depth of four feet which are comparable, as they were taken from the same plots. On 14 July, 1913, we found nitric nitrogen equivalent to 260.3 pounds of sodic nitrate, and in another sample, 277.3 pounds; on the same date 1915, we found 273.2 pounds per acre.

The effect of the growing crop upon the amount of nitric nitrogen in the soil is very clearly shown during both seasons. The following data are obtained from the same plot of ground fallow and occupied by wheat: On 14 July, 1913, nitric nitrogen in the top four feet of fallow ground was equal to 260.36 pounds sodic nitrate, and in the cropped land to 120.36 pounds; on 8 July, 1915, it

* Part I (Colorado Exp. Sta. Bulletin 208), pp. 14 and 15.

was equal to 263.2 and 91.6 pounds, respectively.

Lyon and Bizzell of Cornell University have shown that the nitrifying efficiency of soil occupied by wheat is depressed, and this may account for a part of the difference.* But the results, taken as they stand, show a very decided difference between the fallow ground and that occupied by the plants. An examination of the 160 series of samples taken shows this to be uniformly the case, but in varying degrees.

This suppression of the nitrates, be it due to the utilization of the nitric nitrogen or the suppression of the nitrifying efficiency of the soil or to both, is certainly only a temporary result, for as soon as the wheat has ripened, the production of nitrates goes on rapidly, as the following results summarized from the data previously given shows. The equivalent sodic nitrate is given for the four feet sampled:

TOTAL SODIC NITRATE, FOUR-FOOT SECTIONS OF SOIL†

		1913		1915	
		Section 1800	Section 1900	Section 1800	Section 1900
12 May	Fife	459.7	340.6	440.4	489.6
1 Aug.	Fife	114.0	107.8	91.9	51.7
30 Aug.	Fife	....	....	102.7	80.3
22 Nov.	Fife	....	....	179.0	136.3
13 May	Kubanka	333.2	213.3	465.8	485.0
1 Aug.	Kubanka	155.9	81.4	51.4	38.9
30 Aug.	Kubanka	....	....	102.2	112.1
22 Nov.	Kubanka	....	....	154.3	191.6

† The results have been calculated as sodic nitrate.

The plants had not developed enough by 12 May in either year to make much difference betwen these plots and fallow ground. The figures given for 1 August, however, are really not altogether comparable, because in 1913 the plants were practically ripe on this date, but were two weeks later in 1915, so that the data for 30 August, 1915, are much more nearly comparable with those of 1 August, 1913, than are those of 1 August, 1915. In either case we see that a very large amount of nitrogen has disappeared. The irrigation may have washed out a large percentage of it, as we found in 1913 that the application of one foot of water sufficed to remove the larger part of the nitrates to a greater depth than 12 feet. That the irrigation did not make the difference in 1915 is indicated by the results obtained on a fallow plot used as a check. (See the tables for 18 June and 8 July.) The land was irrigated 12 June, but owing to the already abundant supply of moisture in the soil, this plot received only 0.60 of an acre-foot, which did not suffice to do much if any leaching. We are forced. I think, to attribute the depression of the nitrates to the action of the plants, either by inhibiting the formation of the nitrates or by using them up. The wheat

* Journal of the Franklin Institute. Jan. and Feb. 1911, p. 220.

on the plots that did not receive an application of the sodic nitrate did not indicate an excessive supply of these salts, nor did it show any deficiency, so far as growth and color of the plant may be depended upon as criteria for our judgment. As soon as the crop was removed the accumulation of nitric nitrogen took place rapidly and the ground was comparable to fallow land, especially as I had it double disced and there was at all times an adequate supply of moisture. The cropped plots had very nearly overtaken the fallowed check by the end of September. The rate of increase in the nitric nitrogen or its equivalent amount of sodic nitrate is clearly shown in the table just given, from which we see that we have a maximum increase of about five-fold from 38.9 to 191.6 pounds of sodic nitrate between 1 August and 22 November.

In my preceding statements concerning the nitric nitrogen, I have assumed that a glance at the tables given would suffice to make this subject clear, but it may be well to present it in another manner. In the following table I have converted the nitric nitrogen into its equivalent amount of sodic nitrate, and given the amount found in the first foot and that in the succeeding three feet. We did not continue the taking of our samples later than 1 August in 1913, for we harvested a few days (4 to 6) later, but in 1915 we continued the taking of samples till 13 December.

DISTRIBUTION OF NITRATES IN THE FIRST FOOT AND THE SUCCEEDING THREE FEET OF SOIL IN 1913 AND 1915

Date	Variety of Wheat	Section	First Foot	Succeeding Three Feet
12 May 1913	Red Fife	1800	254.2	205.4
13 May 1915	Red Fife	1800	124.4	316.0
12 May 1913	Red Fife	1900	150.1	190.6
13 May 1915	Red Fife	1900	115.7	373.9
1 Aug. 1913	Red Fife	1800	71.8	42.3
3 Aug. 1915	Red Fife	1800	29.3	62.6
1 Aug. 1913	Red Fife	1900	62.0	45.8
3 Aug. 1915	Red Fife	1900	19.5	32.2
30 Aug. 1915	Red Fife	1800	42.2	60.5
30 Aug. 1915	Red Fife	1900	50.6	29.7
22 Nov. 1915	Red Fife	1800	89.1	89.1
22 Nov. 1915	Red Fife	1900	73.6	62.8
14 Dec. 1915	Red Fife	1800	103.1	191.3
14 Dec. 1915	Red Fife	1900	121.8	118.7
12 May 1913	Kubanka	1800	186.1	147.0
13 May 1915	Kubanka	1800	117.7	348.1
12 May 1915	Kubanka	1900	142.0	71.4
13 May 1915	Kubanka	1900	117.1	367.9
1 Aug. 1913	Kubanka	1800	94.7	61.2
3 Aug. 1915	Kubanka	1800	19.3	32.5
1 Aug. 1913	Kubanka	1900	49.0	32.4
3 Aug. 1915	Kubanka	1900	12.3	26.6
30 Aug. 1915	Kubanka	1800	36.2	66.0
30 Aug. 1915	Kubanka	1900	47.3	64.8
22 Nov. 1915	Kubanka	1800	74.4	80.0
22 Nov. 1915	Kubanka	1900	86.0	105.6
14 Dec. 1915	Kubanka	1800	86.7	164.8
14 Dec. 1915	Kubanka	1900	104.1	176.64

It will be noticed that in 1913 the first foot of soil usually contained more nitrates than the succeeding three feet, except on 12 May, whereas this is not true to the same extent in 1915. In other words, the frequent rains of 1915 caused the nitrates to pass below the first foot. This was not due to the difference in the amount of water received during the months considered, for that was approximately the same during the respective seasons, about 19 inches, nor was it due to differences in soil, for we used the same plots, nor to the wheat, for we used the same varieties, but to the distribution of the water applied to the surface throughout the season.

THE TOTAL NITROGEN

On 27 June, 1913, we sampled three sections of soil to a depth of eleven feet, making a separate sample of each foot of the section. These samples agreed in showing that the surface foot contained, roughly, twice as much nitrogen as the second, and the second twice as much as the third, but from the third downward, including the eleventh foot, the amount of the total nitrogen remained fairly constant, at about 0.02 percent. In such four-foot samples, we took during this season of 1913, six sets of them, the same fact was shown, i. e., that the total nitrogen in the fourth foot was about 0.02 percent, or between this and 0.03 percent. These samples were taken from fallow land, but six sets taken from the cropped land showed essentially the same thing. We cannot say that the samples as taken showed any regular differences in the nitrogen in the first, or any succeeding foot in favor of the fallow land which would justify any attempt to interpret them.

In 1915 we determined the total nitrogen in 19 series of samples taken to a depth of four feet. These agree in showing that the total nitrogen falls to an amount equal to from 0.02 to 0.03 percent in the fourth foot. The samples taken 13 May, before the plants had attained any considerable development, showed that the surface foot was perceptibly richer in total nitrogen than on the two subsequent dates, 1 September and 25 October, when these determinations were repeated. The same fact holds to even a greater extent for the nitric nitrogen, as the table last given shows for the corresponding nitrates. Of course, we have in this question the two serious difficulties which confront us in this work, i. e., the difficulty of obtaining samples which are comparable even when taken from as nearly the same spot as possible without seeking the identical spot where we made the preceding boring, and the further question in regard to the importance that we are justified in attaching to a few ten-thousandths or even thousandths of one percent. There can be no question but that differences as small as, or even smaller than, thousandths of one percent, not only may, but are, of significance in these problems. If any question be entertained on this point, we have only to consider the results produced by the addition of 40 pounds of nitrogen to the acre, an amount equal to 0.001 percent calculated on a foot of soil. The application of this amount at the time of seeding, and harrowed in to a depth of three inches, suffices to change the growth of the crop and the character of the wheat. In determining the total nitrogen we involve all of the nitric nitrogen that may be present and other unstable forms to such an extent that the differences obtained in our analyses are difficult, if not impossible, of interpretation with any degree of certainty. We have, for instance, on 13 May, 1915, in Section 1800, Fife, a total of 5,305 pounds of nitrogen in the surface acre-foot; on 1 September in the same land cropped to wheat, 4,350, and in a check plot kept fallow, 4,684 pounds. We have for this land a loss of 625 pounds of nitrogen for the surface acre-foot between 13 May and 1 September. This is without the crop, but with the crop of wheat we have a further loss of 334 pounds. Some of this may have been washed below the depth to which we took our samples and this may have been lost. There are too many undetermined factors at play in this question to permit us to interpret our results. There have been, without doubt, both gains and losses, some of the latter due to the crop, but just to what extent we do not know. It seems very improbable that the loss of 334 pounds of nitrogen, noted above, is due directly to the crop, which did not remove, as a mature crop, more than a sixth or, at most, a fifth of this amount. The crop of grain removed was 33 bushels per acre and the straw weighed 4,750 pounds, which, together, would not remove a fifth of this deficit, 334 pounds. The analytical results themselves are as good as can be gotten; this is not the trouble, but other difficulties inherent in the problem.

PERCENTAGE OF TOTAL NITROGEN IN SOIL OF WHEAT PLOTS—SEASON 1915

Date	Depth	Section 1700 Fife	Section 1800 Fife	Section 1900 Fife	Section 1700 Kubanka	Section 1800 Kubanka	Section 1900 Kubanka	Section 1800 Fallow
13 May	Top 3 inches	.1393	.1279	.1331	.1368	.1327	.1373	Not
	4 to 7 inches	.1441	.1403	.1382	.1421	.1385	.1439	sampled
	8 to 12 inches	.1322	.1293	.1316	.1212	.1315	.1328	Same as
	13 to 24 inches ...	.0718	.0645	.0737	.0669	.0700	.0711	Section
	25 to 36 inches ...	.0351	.0349	.0477	.0339	.0383	.0374	1800
	37 to 48 inches ...	.0332	.0277	.0295	.0289	.0273	.0287	Fife
1 Sept.	Top 3 inches	.1205	.1113	.1243	.1198	.1239	.1260	.1202
	4 to 7 inches	.1251	.1123	.1208	.1218	.1224	.1282	.1226
	8 to 12 inches	.1045	.1044	.0984	.1130	.0994	.1046	.1108
	13 to 24 inches ...	.0561	.0506	.0578	.0523	.0562	.0553	.0551
	25 to 36 inches ...	.0297	.0274	.0332	.0294	.0338	.0292	.0295
	37 to 48 inches ...	.0190	.0175	.0214	.0245	.0244	.0247	.0224
25 Oct.	Top 3 inches	.1274	.1196	.1241	.1224	.1193	.1255	
	4 to 7 inches	.1157	.1263	.1292	.1307	.1145	.1108	Not
	8 to 12 inches	.0985	.0979	.0901	.0915	.1102	.1004	sampled
	13 to 24 inches ...	.0530	.0506	.0549	.0494	.0441	.0517	
	25 to 36 inches ...	.0327	.0275	.0341	.0305	.0353	.0308	
	37 to 48 inches ...	.0240	.0223	.0253	.0227	.0233	.0226	

The results of 1915 agree very closely with those obtained in 1913 showing that the total nitrogen falls, practically, to a constant at a depth of three feet. This was not the case with the nitric nitrogen, as is shown by the samples taken 29 April, 1913, to a depth of 12 feet. The distribution of nitric nitrogen in these was very erratic. (See Part I (Colorado Bulletin 208) p. 20). It is quite common in our samples to find that the fourth foot contains less than one-tenth as much nitric nitrogen as the first foot, but it may contain as much or more, or again it may contain no nitric nitrogen.

It has been intimated that we have considered the difficulty in obtaining samples on different dates, that would have been the same, had the samples been taken on the same date. This difficulty is real and is well shown by the results obtained with 150 samples taken from as many contiguous square feet. These results are given in Part I (Colorado Bulletin 208) p. 26, where we find a difference of 354 pounds of nitrogen in the surface foot. This difference is even larger than that found for the plot sampled on 13 May and 1 September, 1915, before and after the crop had been grown. This difficulty is not to be avoided in the case of field experiments. Recourse must be had to other methods of experimentation which was contemplated from the beginning of this work.

We have now given the weather conditions, the moisture in the soil, the nitric and total nitrogen in the soil for 1915, and compared these factors with the results for 1913. The two seasons were wholly unlike; the principal differences were that the temperature in 1915 was lower, and there was about twice the amount of rainfall. Its distribution was much more general than in 1913, when over two-thirds of the total for the growing season, 6.77 inches, fell in May and July. In 1913 the rainfall for July was confined to a period of not more than 12 days, including several on which either no rain or only a very small amount fell. The total water, rainfall and irrigation, received during the two seasons, was essentially the same, about 19 inches. The moisture in the soil samples taken in 1915 was a little higher, the average being between one and two percent. The effects of these weather conditions on the amount of the nitrates in fallow land, taken to a depth of four feet, were small. The maximum difference was equivalent to 13 pounds of sodic nitrate in the top four feet. The more even distribution of the water received by the land in 1915 brought about a different distribution of the nitrates, but we have no proof that they were removed beyond the feeding area of the plants, which we assume may extend in this soil, to a depth of four feet. There is no indication that the dilution of the nitrates in the soil was such as to affect in any way the growth of the crop. This last statement does not include any reference to the composition of the crop.

The total nitrogen is slightly higher in 1915 than in 1913. While this is subject to variation, due to the difficulties of sampling, it is true of so many samples that we may perhaps give it some weight even though the differences are very small. The soil conditions vary less in the two seasons than the weather conditions led me to expect.

THE EFFECTS OF INDIVIDUAL FERTILIZERS UPON THE GROWTH OF THE PLANTS

In Part I (Bulletin 208), p. 31, et seq., we stated that we could not discern any differences in the growth and ripening of the plants on the various plots, except on those that had received a dressing of sodic nitrate. The smallest amount of this salt applied, equal to 40 pounds of nitrogen, sufficed to produce a very marked difference in the color, growth, and tendency of the plants to lodge. The tendency to lodge varied considerably in the different varieties of wheat used. The Defiance seemed most susceptible. We would not be justified in asserting that 40 pounds of nitrogen per acre produced as serious results as 120 pounds, still it was enough to cause the plants to show its effects just as sharply as the 120 pounds, and to cause the wheat to lodge very badly, the plants to rust, and to produce, even when not attacked by rust, shrunken wheat. The results in 1915 were of the same character as in 1913, but owing to the frequent, light rains and the very luxuriant growth of the plants, the lodging and rusting were worse than in 1913. The yield of the Defiance on the plots that were dressed with sodic nitrate ranged from 9 to 13 bushels of very badly shrunken wheat. The wheat of this variety, Defiance, was all badly shrunken in 1915, but the plots which had received an application of sodic nitrate produced much poorer grain than the others; it was so badly shrunken that it could scarcely be considered grain at all. There can be no question but that the sodic nitrate tends to produce shrunken wheat, but in both 1914 and 1915 the most important cause was rust on the plants.

The following data will enable the reader to judge of the effects of the various fertilizers upon the development of the plant as grown under our conditions. The following table gives a sort of correlation of these effects:

EFFECTS OF FERTILIZERS UPON THE DEVELOPMENT OF PLANTS* 1914

Fertilizer per acre	DEFIANCE Average height in inches	DEFIANCE Average length of heads in inches	DEFIANCE Average number of spikelets	DEFIANCE Average number of kernels per spikelet	RED FIFE Average height in inches	RED FIFE Average length of heads in inches	RED FIFE Average number of spikelets	RED FIFE Average number of kernels per spikelet	KUBANKA Average height in inches	KUBANKA Average length of heads in inches	KUBANKA Average number of spikelets	KUBANKA Average number of kernels per spikelet
Section 1700												
120 pounds Nitrogen	52.1	4.49	19.8	2.20	51.4	3.93	16.2	2.10	59.6	2.78	18.0	2.67
60 pounds Phosphorus	50.9	3.99	18.1	2.56	52.1	3.74	15.6	1.80	56.8	2.61	16.5	2.62
200 pounds Potassium	48.0	3.96	18.3	2.50	50.4	3.70	15.3	...	55.3	2.58	16.1	2.48
None	48.7	4.07	18.5	2.31	52.2	3.80	15.5	...	56.5	2.66	16.7	2.50
Section 1800												
80 pounds Nitrogen	51.5	4.34	19.5	2.26	54.1	3.90	16.4	2.21	59.8	2.68	18.0	2.62
40 pounds Phosphorus	52.1	4.09	18.9	2.44	50.6	3.60	15.1	1.80	61.6	2.50	16.7	2.98
150 pounds Potassium	50.4	3.90	18.0	2.44	48.3	3.60	15.1	1.90	53.9	2.50	16.2	2.42
None	52.2	4.06	18.7	2.32	49.6	3.60	14.8	...	57.0	2.54	16.6	2.73
Section 1900												
40 pounds Nitrogen	54.8	4.28	19.0	2.35	56.2	3.85	16.3	2.00	57.4	2.64	17.0	2.11
20 pounds Phosphorus	52.1	4.18	19.0	2.39	50.3	3.67	15.5	...	55.9	2.55	16.5	2.27
100 pounds Potassium	50.6	3.79	17.1	2.46	50.2	3.50	14.6	1.80	49.3	2.49	15.5	2.45
None	56.1	3.88	18.0	2.51	51.1	3.60	14.8	...	58.1	2.50	16.4	2.28

* Averages are based on 100 plants taken without selection

It appears from this table that the shortest plants, with the shortest heads, were produced on the plots receiving potassium. The lowest average kernels per spikelet is found for those plots to which nitrates had been applied, but we find here the highest average for the length of head. This last is the only feature that holds throughout the table and this is not very pronounced. This table shows that the effects of the fertilizers given are neither great nor uniform, even in the small effects produced. We might infer from the effect of the nitrates that an excessive food-supply lessens fecundity.

RATIO OF THE STEMS, LEAVES AND HEADS IN THE GREEN PLANTS

The following table, which gives the relative green weights of the stems, leaves and heads for the plants grown with the different fertilizers, shows a few differences in these ratios, but they are not constant. The figures are based upon 2,000-gram samples and the loss represents the waste in preparing and cutting them, including the evaporation that took place. This was often very considerable, especially if the plants were wet, due to external moisture, which was often the case and unavoidable, as we had to cut the samples in the morning in order to handle them the same day.

RATIO OF GREEN WEIGHTS OF STEMS, LEAVES AND HEADS OF RED FIFE, 1915

Date	Fertilizer	Stems	Leaves	Heads
13 July	Nitrogen, 120 pounds	67.38	19.50	12.03
13 July	Phosphorus, 60 pounds	68.45	16.25	12.80
13 July	Potassium, 200 pounds	67.46	14.34	13.96
13 July	None	69.86	15.90	12.41
23 July	Nitrogen, 120 pounds	70.00	9.25	20.15
23 July	Phosphorus, 60 pounds	66.85	7.40	24.00
23 July	Potassium, 200 pounds	65.75	6.75	26.50
23 July	None	68.85	8.85	21.40
6 Aug.	Nitrogen, 120 pounds	69.25	....	30.25
6 Aug.	Phosphorus, 60 pounds	62.10	....	36.85
6 Aug.	Potassium, 200 pounds	61.10	....	38.85
6 Aug.	None	63.00	....	35.35
16 July	Nitrogen, 80 pounds	64.81	20.06	13.04
16 July	Phosphorus, 40 pounds	67.11	17.11	13.05
16 July	Potassium, 150 pounds	64.97	15.43	17.43
16 July	None	68.55	14.34	14.83
27 July	Nitrogen, 80 pounds	60.00	17.00	19.85
27 July	Phosphorus, 40 pounds	58.00	15.10	25.00
27 July	Potassium, 150 pounds	56.20	13.85	28.00
27 July	None	59.40	14.90	24.65
9 Aug.	Nitrogen, 80 pounds	66.75	....	32.35
9 Aug.	Phosphorus, 40 pounds	62.35	....	36.25
9 Aug.	Potassium, 150 pounds	59.50	....	39.35
9 Aug.	None	58.75	....	39.95
20 July	Nitrogen, 40 pounds	64.00	13.00	17.00
20 July	Phosphorus, 20 pounds	64.50	15.60	18.50
20 July	Pottasium, 100 pounds	62.75	15.50	20.35
20 July	None	63.50	18.50	16.75
30 July	Nitrogen, 40 pounds	66.50	6.75	26.25
30 July	Phosphorus, 20 pounds	63.10	6.00	29.75
30 July	Potassium, 100 pounds	63.25	5.35	30.90
30 July	None	63.55	5.55	29.75
9 Aug.	Nitrogen, 40 pounds	66.25	....	32.35
9 Aug.	Phosphorus, 20 pounds	63.10	....	35.95
9 Aug.	Potassium, 100 pounds	63.10	....	35.70
9 Aug.	None	62.25	....	37.00

There is one exception to the statement that the nitrate plots yielded plants with heavier stems and leaves than the others, but this set of samples was taken quite early in the season, 16 July. It may be well to state, for the benefit of those who may compare the data given here with that given for 1913, that the plants at this time, 16 July, 1915, were several days (6 to 8) behind the plants on the same plots in 1913 in their development. It will be noticed that the weight of the heads, even up to 9 August, was as a rule less than from the other plots. This is entirely consonant with the results of the season as shown by the weight of the threshed grain. How much of this result is to be attributed to the effect of rust and how much to that of the nitrate itself, is not clear, besides, these two questions cannot be judged separately, for it was evident that the nitrate plots suffered more from rust than the other plots. This fact we attributed to the effect of the nitrate upon the condition of the plant, not simply because it was lodged, but also because the nitrate had rendered it a better plant for the rust to grow on. One effect of nitrate has been stated in a previous bulletin to be the bringing about of an abnormal ripening, even when the weather conditions are favorable to a normal ripening of the crop, and the quantity of nitrate is not sufficient to cause lodging.

THE DRY MATTER IN THE PLANTS OF 1915 CROP

The inference from the preceding discussion would be that the plants grown with nitrate were heavy in stems and leaves because they were bigger and not because they contained more water. This latter, however, was the case. The samples for 1913 showed this to be the case in every set of samples in comparison with plants grown with the application of phosphorus and potassium, which were either essentially equal to or less than those grown on the check plots. This excess of water tends to make the dry weight of the plants more nearly equal. The following table shows that the rule is that the plants grown on the plots which received potassium or phosphorus are the richest in dry matter, irrespective of variety, though the plants grown on the check plots are almost as rich. sometimes even richer in dry matter than those grown with phosphorus or potassium. The plants grown with the application of nitrates are, almost without exception, the poorest in dry matter, irrespective of the variety or the amount of nitrate applied. These observations are applicable to the samples of both seasons. 1913 and 1915, but the samples of the two seasons cannot be compared date by date, for the development of the plants in 1915 was retarded from 6 to 14 days, owing, I take it, to the weather conditions. This difference in the development of the plant increased with the season and the maximum difference was at the time of ripening. The ripening period was greatly influenced by the appearance of rust, which practically killed some of the Defiance.

DRY MATTER IN PLANTS GROWN WITH DIFFERENT FERTILIZERS—SEASON 1915

Date	Section	Fertilizer	Defiance	Red Fife	Kubanka
13 July	1700	Nitrogen, 120 pounds	21.30	25.25	25.00
13 July	1700	Phosphorus, 60 pounds	25.99	29.49	29.90
13 July	1700	Potassium, 200 pounds	25.20	30.87	30.59
13 July	1700	None	24.63	28.12	27.34
14 July	1800	Nitrogen, 80 pounds	19.75	25.15	26.29
14 July	1800	Phosphorus, 40 pounds	20.04	28.33	30.00
14 July	1800	Potassium, 150 pounds	25.46	30.31	31.87
14 July	1800	None	23.16	27.65	32.03
15 July	1900	Nitrogen, 40 pounds	28.63	30.62	29.53
15 July	1900	Phosphorus, 20 pounds	28.59	30.93	33.59
15 July	1900	Potassium, 100 pounds	29.63	32.97	33.59
15 July	1900	None	29.33	31.40	31.56
21 July	1700	Nitrogen, 120 pounds	25.31	27.50	33.28
21 July	1700	Phosphorus, 60 pounds	31.87	36.72	36.25
21 July	1700	Potassium, 200 pounds	31.25	35.62	36.25
21 July	1700	None	29.53	36.87	36.87
24 July	1800	Nitrogen, 80 pounds	28.43	33.75	33.90
24 July	1800	Phosphorus, 40 pounds	36.40	40.62	40.62
24 July	1800	Potassium, 150 pounds	35.62	38.90	38.75
24 July	1800	None	33.90	39.69	41.25
26 July	1900	Nitrogen, 40 pounds	35.46	37.65	38.94
26 July	1900	Phosphorus, 20 pounds	37.57	39.37	39.76
26 July	1900	Potassium, 100 pounds	37.50	40.00	40.47
26 July	1900	None	36.56	39.22	40.15
4 Aug.	1700	Nitrogen, 120 pounds	36.82	40.47	37.97
4 Aug.	1700	Phosphorus, 60 pounds	43.90	46.72	45.00
4 Aug.	1700	Potassium, 200 pounds	43.43	45.78	44.37
4 Aug.	1700	None	39.84	45.47	43.75
5 Aug.	1800	Nitrogen, 80 pounds	35.31	41.72	43.90
5 Aug.	1800	Phosphorus, 40 pounds	42.50	45.00	46.09
5 Aug.	1800	Potassium, 150 pounds	41.40	46.25	44.53
5 Aug.	1800	None	40.93	45.47	47.19
10 Aug.	1900	Nitrogen, 40 pounds	44.84	49.07	51.25
10 Aug.	1900	Phosphorus, 20 pounds	48.12	52.65	51.25
10 Aug.	1900	Potassium, 100 pounds	49.84	53.90	50.78
10 Aug.	1900	None	47.65	52.65	48.75

The dry matter given in the preceding table is the weight of the air-dried plants. In 1913 we found the air-dried material to contain from 5.566 to 8.652 percent of moisture; in 1915 we find the amount of moisture, in the few samples on which this determination has been made, much more uniform from 5.00 to 5.68 percent. It is but fair to state that all of the determinations made were on samples of Red Fife and may not hold strictly for the other varieties. The results, however, indicate that we are justified in assuming that the term air-dried means that the plants still contain an average of not more than 7.5 percent of moisture, which is the average found for 1913.

The series of samples taken in 1915 is much larger than that taken in 1913, but the samples representing the same period of development yield quite closely agreeing results, which indicates that the influence of the weather upon this factor was much less than one would expect and further, that these conditions in no way eliminated or greatly modify the influence of the individual fertilizers.

Apropos of the influence of the date upon the development of the plant it may be added that the individual fertilizers are not wholly without effect upon this. It was a noticeable feature of the fields at one period in 1914 and again in 1915 that the wheat on the plots to which potassium had been applied was taller and appeared to be more advanced than that in the other plots, but this difference was entirely obliterated in a few days and afterwards no difference between these and the other plots could be observed.

THE EFFECT OF FERTILIZERS UPON THE NITROGEN CONTENT OF THE PLANTS

We do not wish to change any of the statements made in Part I (Bulletin 208), p. 35, in regard to the reasons for presenting this subject, the scope of the work, or the variety chosen. All that we then said applies to our work still.

We will add, however, the subject of the nitric nitrogen in the plant. This subject was passed over in Part I (Bulletin 208) because we wished to repeat our observations and extend our analytical work, which we have been able to do during the present season, and the results will be given in their proper place.

TOTAL AND PROTEID NITROGEN IN GROWING WHEAT PLANTS, 1915

Date	Fertilizer	Total			Proteid		
		Stems	Leaves	Heads	Stems	Leaves	Heads
13 July	Nitrogen, 120 pounds	.2797	.8092	.6324	.1598	.5838	.4066
13 July	Phosphorus, 60 pounds ...	.2050	.6150	.5629	.1270	.3946	.3614
13 July	Potassium, 200 pounds ...	.2050	.5907	.5803	.1286	.4170	.3683
13 July	None	.1911	.5837	.5456	.1216	.3981	.3545
16 July	Nitrogen, 80 pounds	.2777	.6463	.6376	.1843	.5018	.4239
16 July	Phosphorus, 40 pounds ...	.2084	.4639	.5872	.1529	.3892	.4045
16 July	Potassium, 150 pounds ...	.2359	.4934	.6185	.1494	.3753	.4149
16 July	None	.2102	.5786	.5959	.1490	.4309	.3593
20 July	Nitrogen, 40 pounds	.261[illegible]	.4361	.5803	.1891	.3662	.4274
20 July	Phosphorus, 20 pounds ...	.2376	.4100	.5699	.1703	.3475	.3906
20 July	Potassium, 100 pounds ...	.1963	.3179	.5542	.1425	.2828	.3788
20 July	None	.2120	.3509	.5629	.1430	.2884	.3732
23 July	Nitrogen, 120 pounds	.3457	1.2561	.7644	.2220	.1077	.5386
23 July	Phosphorus, 60 pounds ...	.2357	.6915	.6376	.1668	.0312	.4392
23 July	Potassium, 200 pounds ...	.1998	.6880	.5924	.1390	.0660	.4378
23 July	None	.2324	.6915	.6116	.1613	.5052*	.4309
27 July	Nitrogen, 80 pounds	.2884	.4621	.6533	.1824	.3461	.6533
27 July	Phosphorus, 40 pounds ...	.1964	.2187	.5212	.1432	.1703	.5212
27 July	Potassium, 150 pounds ...	.2187	.2988	.5872	.1613	.2168	.5838
27 July	None	.1928	.2797	.5247	.1390	.2234	.5247
30 July	Nitrogen, 40 pounds	.2654	1.0260	.7297	.1842	.5699	.5734
30 July	Phosphorus, 20 pounds ...	.2204	.7679	.6585	.1703	.6116	.4934
30 July	Potassium, 100 pounds ...	.2015	.5942	.6550	.1369	.1890	.5365
30 July	None	.2102	.7401	.6324	.1543	.2954	.4830
6 Aug.	Nitrogen, 120 pounds		.4169	.9221		.2967	.7794
6 Aug.	Phosphorus, 60 pounds ...		.2289	.6759		.1598	Lost
6 Aug.	Potassium, 200 pounds ..		.2154	.7210		.1369	.5817
6 Aug.	None		.2671	.6533		.1855	Lost
9 Aug.	Nitrogen, 80 pounds		.4500	.9069		.2898	.7401
9 Aug.	Phosphorus, 40 pounds ...		.2498	.6741		.1876	.5595
9 Aug.	Potassium, 150 pounds ...		.2726	.7747		.2030	.6568
9 Aug.	None		.2550	.7019		.1890	.5699
12 Aug.	Nitrogen, 40 pounds		.3787	.8895		.2780	.8023
12 Aug.	Phosphorus, 20 pounds ...		.3110	.7158		.2255	.6950
12 Aug.	Potassium, 100 pounds ...		.2272	.8286		.1703	.7815
12 Aug.	None		.2726	.8040		.2050	.6915

* This result appears abnormal. The whole set was repeated with the same results.

The table, when compared with a similar statement obtained for the crop of 1913, indicates that the amounts of total and proteid nitrogen are smaller throughout the season of 1915 than in 1913; the same conclusion is indicated for the dry matter, but when one considers plants of the same development we find that the difference in dry matter is not very pronounced, while the percentage of nitrogen is decidedly lower and holds, in the main, for the whole season. In both seasons we see that the application of nitrogen increased these forms of nitrogen in the plant, and these differences are quite as pronounced in 1915 as in 1913, showing that, while the season influenced the whole problem, it did not obscure the effects of the nitrate. The most noted differences are shown by the samples of the heads as they approached ripeness. The total nitrogen in the heads of the last four samples, gathered 5 August, 1913, averaged 1.2587 percent, but in those on 9 August, 1915, from the same plot of ground and of the same variety of wheat, the average was only 0.7644 percent. A difference is shown by the earliest samples gathered in the respective years, but the difference is smaller, 0.1675 against 0.4943 percent. The differences between the total nitrogen in the heads of the plants for the respective years increased as the plants matured. This was probably not due to the total supply of nitrogen in the soil, for, if we compare the plants grown with the application of 120 pounds of nitrogen per acre, in the form of sodic nitrate, at the time of full bloom, we find that the heads in 1913 contained 0.7607 percent of nitrogen; in 1915, the same variety, grown on the same land, and also with the application of 120 pounds of nitrogen, contained 0.6324, showing a difference of 0.1283 percent, which is a little less than the average found for all of the plots in this section, i. e., 0.1675. This difference increased during the season. These results, especially those obtained with mature plants, all involve the question of the effects produced by the abundant appearance of rust.

I have no way of estimating how great the influence of this factor was, nor of conveying any definite idea of the severity of the attack, but it was very bad, even on Red Fife, the variety used for the nitrogen work, while it ruined the Defiance. The factors appearing in this year's work are the fertilizers applied, the weather conditions, and the effects of the rust. The same factors were operative in 1913 also, but they were very different, the rainfall, for instance, in 1913, between 18 May and 7 July, the date on which the first samples of plants were taken, was 0.36 inch, in 1915, for the same period, 18 May till 13 July, the date of taking the first sample, it was 5.94 inches. In the former year we applied, on 12 June, one foot of water, in the latter 0.6 of a foot, also on 12 June, so that the amount of water received by the plots was essentially the same, but, in 1913 the water was applied to the land in practically one application, while the plants, throughout the period considered, were scarcely wet at all and the weather was clear. The quantity of water received in 1915 was smaller by less than one inch, but its application and distribution were different, the plants themselves being kept almost continuously wet by frequent light rains, and cloudiness prevented their rapid drying. The mean temperature, too, was a little lower in 1915 than in 1913. As the differences existed early in the season, before the appearance of the rust, we cannot consider the latter as the cause of it at that time. All that we can say is that the rust intensified this effect and apparently produced a similar if not an identical result. If we compare the ratio of the total nitrogen to the proteid nitrogen in the heads for the last eight samples taken in 1913, and for the last ten samples taken in 1915, we find it higher in 1913 than in 1915, 1.18 against 1.03; that is, the total and proteid nitrogen in the heads at the end of the season were more nearly equal in 1915 than in 1913, though both were decidedly lower in 1915. There was not only less protein in the whole plant than in 1913, but a larger percentage of it remained in the leaves and stems (straw).

AMMONIC AND AMID NITROGEN IN WHEAT PLANTS IN 1915

		Ammonic Nitrogen Per cent			Amid Nitrogen Per cent		
Date	Fertilizer per Acre	Stems	Leaves	Heads	Stems	Leaves	Heads
13 July	Nitrogen, 120 pounds	.00265	.00638	.00638	.00597	.00270	.00665
13 July	Phosphorus, 60 pounds ...	.00529	.00162	.00652	.00299	.00358	.00802
13 July	Potassium, 200 pounds ...	.00162	.00475	.00692	.00270	.00489	.00162
13 July	None	.00189	.00393	.00610	.00243	.00407	.00816
16 July	Nitrogen, 80 pounds	.00299	.00707	.01768	.01224	.00625	.01034
16 July	Phosphorus, 40 pounds ...	.00216	.00434	.00789	.00380	.00380	Lost
16 July	Potassium, 150 pounds ...	.00216	.00652	.01088	.00366	.00434	.01224
16 July	None	.00216	.00734	.00925	.00270	.00489	.01101
20 July	Nitrogen, 40 pounds	.00216	.00339	.00789	.00270	.00299	.00979
20 July	Phosphorus, 20 pounds ...	.00243	.00366	.00879	.00284	.00420	.00965
20 July	Potassium, 150 pounds ...	.00189	.00366	.00897	.00270	.00256	.00665
20 July	None	.00216	.00353	.00843	.00216	.00284	.01101
23 July	Nitrogen, 120 pounds	.00610	.00992	.01468	.00556	.01170	.01427
23 July	Phosphorus, 60 pounds ...	.00189	.00610	.00816	.00299	.00570	.00652
23 July	Potassium, 200 pounds ...	.00189	.00652	.00610	.00216	.00434	.00393
23 July	None	.00216	.00516	.00816	.00216	.00489	.00679
27 July	Nitrogen, 80 pounds	.00189	.00763	.00817	.00353	.00583	.00592
27 July	Phosphorus, 40 pounds ...	.00162	.00326	.00707	.00202	.00284	.00434
27 July	Potassium, 150 pounds ...	.00189	.00353	.00925	.00353	.00216	.00457
27 July	None	.00162	.00339	.00843	.00175	.00216	.00652
30 July	Nitrogen, 40 pounds	.00202	.01183	.00707	.00339	.01387	.00870
30 July	Phosphorus, 20 pounds ...	.00162	.00570	.00843	.00216	.00707	.00610
30 July	Potassium, 100 pounds ...	.00162	.00366	.00789	Lost	.00543	.00447
30 July	None	.00148	.00420	.00856	Lost	Lost	Lost
6 Aug.	Nitrogen, 120 pounds	.00679		.00665	.00843		.00707
6 Aug.	Phosphorus, 60 pounds ...	.00284		.00679	Lost		.00380
6 Aug.	Potassium, 200 pounds ...	.00353		.00462	.00420		.00407
6 Aug.	None	.00284		.00638	None		.00162
9 Aug.	Nitrogen, 80 pounds	.00734		.00353	.00816		.00747
9 Aug.	Phosphorus, 40 pounds ...	.00270		.00543	.00407		.00515
9 Aug.	Potassium, 150 pounds ...	.00407		.00353	.00570		.00489
9 Aug.	None	.00261		.00652	.00366		.00720
12 Aug.	Nitrogen, 40 pounds	.00762		.00734	.00638		.00543
12 Aug.	Phosphorus, 20 pounds ...	.00489		.00462	.00434		.00502
12 Aug.	Potassium, 100 pounds ...	.00543		.00462	.00407		.00353
12 Aug.	None	.00434		.00407	.00489		.00665

NITRIC NITROGEN IN GREEN AND DRY WHEAT PLANTS 1915

		Green Plants			Dry plants, but Calculated Back to Green Plants		
Date	Fertilizer per Acre	Stems	Leaves	Heads	Stems	Leaves	Heads
13 July	Nitrogen, 120 pounds	.02269	.01341	None			
13 July	Phosphorus, 60 pounds ...	Trace	None	None			
13 July	Potassium, 200 pounds ...	.00054	None	None	No samples preserved		
13 July	None	None	None	None			
16 July	Nitrogen, 80 pounds	.01996	.01179	None			
16 July	Phosphorus, 40 pounds ...	None	None	None			
16 July	Potassium, 150 pounds ...	.00039	None	None			
16 July	None	Trace	None	None			
20 July	Nitrogen, 40 pounds	.00620	.00069	None	.02163	.00514	None
20 July	Phosphorus, 20 pounds ...	.00043	None	None	.00087	None	None
20 July	Potassium, 100 pounds ...	.00024	None	None	None	None	None
20 July	None	None	None	None	None	None	None
23 July	Nitrogen, 120 pounds	.02886	.01226	.00048	.01995	.01954	.00014
23 July	Phosphorus, 60 pounds ...	None	None	None	.00028	None	None
23 July	Potassium, 200 pounds ...	None	None	None	.00024	None	None
23 July	None	None	None	.00034	None	None	None
27 July	Nitrogen, 80 pounds	.03283	.00296	None	.00690	.00061	None
27 July	Phosphorus, 40 pounds ...	.00126	.00034	None	None	None	None
27 July	Potassium, 150 pounds ...	.00043	None	None	None	None	None
27 July	None	None	None	None	.00030	None	None
30 July	Nitrogen, 40 pounds	.00489	.00134	None	.00551		None
30 July	Phosphorus, 20 pounds ...	.00059		None	None		None
30 July	Potassium, 100 pounds ...	.00093		None	.00050		None
30 July	None	Lost		None	None		None
6 Aug.	Nitrogen, 120 pounds	.02986		None	.03498		.00038
6 Aug.	Phosphorus, 60 pounds ...	None		None	None		None
6 Aug.	Potassium, 200 pounds ...	Trace		None	.00018		None
6 Aug.	None	None		None	Trace		None
9 Aug.	Nitrogen, 80 pounds	.02961		Trace	None		None
9 Aug.	Phosphorus, 40 pounds ...	None		None	None		None
9 Aug.	Potassium, 150 pounds ...	None		None	None		None
9 Aug.	None	None		None	.00018		None
12 Aug.	Nitrogen, 40 pounds	.00451		None	None		None
12 Aug.	Phosphorus, 20 pounds ...	.00046		None	None		None
12 Aug.	Potassium, 100 pounds ...	None		None	None		None
12 Aug.	None	.00023		None	Trace		None

These tables, taken together with the one giving the ammonic and proteid nitrogen, present some instructive features. Assuming that the nitrogen used by the plants is furnished wholly by the soil in the form of nitrates, which in our case is probably true, and referring to the tables giving the nitric nitrogen for the respective years, we see that we have no reason to believe that there was a less supply in 1915 than in 1913. The table entitled "Distribution of the Nitrates in the First Foot and the Succeeding Three Feet of Soil in 1913 and 1915'' shows plainly that the total amount in the top four feet of soil was not less in 1915 than in 1913, but it also shows that the distribution was quite different in the two years. This, however, should make but little difference, for reference to the tables giving the nitric nitrogen in the soil samples taken throughout the season to a depth of four feet, show that the fourth foot does not usually, even in 1915, when our soil was kept moist by a succession of moderate rains, contain any large quantity of nitric nitrogen. We consider this depth the limit of the feeding area of the wheat plant. But if this should be too great a depth to take under our conditions, and if the plants do not feed to a greater depth than three feet, this would not alter the statement made relative to the total supply of nitric nitrogen in the two years. Further, any question concerning the relative supply of nitric nitrogen which might apply to the check plots in the respective years, could scarcely apply to the plots to which we applied 120 pounds of nitric nitrogen per acre in three applications, made at intervals of approximately four weeks, with the purpose of maintaining an excessive supply of this form of nitrogen in the soil. The first application of 40 pounds of nitrogen per acre was harrowed in to a depth of from two to three inches. We had to depend upon the rain and irrigating water for the distribution of the succeeding applications. We made no attempt to follow the distribution of these 120 pounds of nitrogen through the soil. It might have been interesting if we had been able to do so and further to have determined what portion of it was utilized by the plant and how much of it was lost in the soil. We have, in our observations of the effects produced upon the plants, a basis for a very rough estimate of the relative effects of the quantities, 40, 80 and 120 pounds, applied to the different plots. This rough judgment is that 80 pounds, applied in two portions of 40 pounds each, produces on our soil, almost, if not altogether, as great effects as 120 pounds applied in three portions of 40 pounds each. The effects of 40 pounds, applied at the time of planting, produce quite as deep a color in the growing plants, and the limits of the area to which it has been applied are quite as definitely marked as those of 80 or 120 pounds. This statement does not hold in other respects, for we shall see that the effects of the larger applications are quite regularly bigger than those of the smaller applications. It does not seem probable that either the quantity of nitric nitrogen present in the two years, or the distribution of the same in the soil, varied enough to produce the differences in the nitrogen content of the plants which we actually find. The stems constitute approximately 65 percent of the total plant, and while the amount of nitrogen present is smaller than in the leaves, and the part played by the latter in the economy of the plant may be greater than that of the stem, still the general effects of the fertilizers and of the seasons may be quite clearly seen in this portion of the plant, so we will consider the stems only, whereby we sacrifice nothing of the truth and gain much in brevity.

In the samples of the stems taken in 1913 we see that the total nitrogen is increased by the application of nitrates, and while this increase is not proportional to the amounts applied to the different sections of land, it is true that up to the end of July the stems of those plants grown with the largest application of nitrates contain the highest percentage of nitrogen. This relation was no longer evident when the plants have become so nearly ripe that it was no longer possible to separate the stems and leaves. It has elsewhere been stated that the sheaths are, for the most part, taken with the stems.

The amount of total nitrogen in the stems during the season of 1915 is much smaller than in 1913, but those grown with the application of nitrates are uniformly higher than those grown without it. The total nitrogen in the stems in 1915 is roughly equal to three-fourths of that present in 1913. This is true of the nitrogen in the stems up to the end of July only; from this time till harvest the stems, with whatever leaves were left, in 1915, contain more nitrogen than they did in 1913, while the heads contained very much less nitrogen than in 1913. In other words, the nitrogen was not transferred from the stems and leaves to the heads in 1915 to the same extent that it was in 1913. The ripening period did not produce the changes taking place during this period in the same thorough manner in the former as in the latter season.

These facts divide our considerations in two parts. The first part brings us to the beginning of the ripening period, and the second consists of this period. This is a natural and common division, which we observed in writing Part I (Bulletin 208), but for entirely different reasons than now.

The facts that we have presented show that the effects of the nitric nitrogen applied to the plots are of the same character and persistent throughout the two very dissimilar seasons. The same is true of the phosphorus and potassium, but in so far as the nitrogen content of the plant may be relied upon as an indication, the composition of the plants were quite unlike, all parts examined, stems, leaves and heads, were richer in total and proteid nitrogen in 1913 than in 1915, without regard to the amount of this element in the form of nitric nitrogen at the disposal of the plant.

The effects of phosphorus and potassium are, as in 1913, so indefinite and irregular that the small variations observed are not entitled to consideration. The plants from the three check plots show quite as great variations among themselves as we find between these and the phosphorus and potassium plots. It must be remembered, however, that there is no compelling reason why plants grown on three abutting check plots should be identical in composition, especially if our contention that differences in the supply of plant food produces differences in the composition of the plant, and we may anticipate a little by adding, if its seeds, too, be correct. We have shown by experiment what we all know, that soil varies in the amount of total and of nitric nitrogen from foot to foot. (See Part I (Bulletin 208) p. 26.) We have further given, in former publications on the subject of Fixation of Nitrogen In Our Colorado Soils, instances of very great variations of nitrates within a few feet, variations of hundreds or even thousands of parts per million. Identity of results cannot be expected, but larger and persistent differences, such as we find occurring in all of the series of plants presented in Part I, and in this one, are founded on something more than accident; they have some general and sufficient cause.

Further, while the effect of the nitric nitrogen is evident and persistent through the two seasons, the total nitrogen in the plants in 1915 is only about three-fourths of that present in 1913. In this statement we compare 32 samples in 1913 with 36 samples taken in 1915. As stated, the relative effects of the respective fertilizers are discernable throughout both series. The seasons were dissimilar and this difference would appear to be the direct cause of the differences in the nitrogen content up to the end of July, or during the vegetative period. The factor which caused this difference can not be the total amount of water supplied by way of the soil, for that applied by irrigation and rainfall during the two seasons was very nearly the same. This is on the assumption that all the rainfall reached the ground, which is not correct. But if the amount of water supplied by the soil had been different, other results would still compel us to eliminate this as the cause for the difference. It is fortunately the fact that some of our plots in 1913 received during the season 30 inches of water, whereas, in 1915, the total received was a little over 19 inches. The samples from these plots receiving 30 inches of water in 1913 contained as much nitrogen as the corresponding plots that received 19 inches, so that a difference of 11 inches of water applied to the soil made no difference in the amount of total nitrogen contained in the stems, which we have used as representative of the whole plant. The same is true of the proteid nitrogen, or, perhaps I should say, that the differences are so small and irregular that we cannot consider them in this work.

These facts are in harmony with others obtained with the wheat berry grown with different quantities of water.

We are justified by the latter facts in going further and asserting that the time of the application of water to the soil, provided there be at all times a sufficient amount of water present, does not make the differences which we are considering. This statement contemplates the application of water to the soil up to within fifteen days of the harvest. These statements are, however, in anticipation of the discussion of the work done with the berry and not with the plant.

There are three facts left in the problem, the prevailing temperature, the application of the water to the plant, not to the soil, and the sunshine. While it may be true that the temperature affected our problem, it seems difficult to believe that a difference of a few degrees should make such a radical difference in the amount of the total nitrogen in the plant, especially as the mean temperature for July was 64.74 and for August 62.77, which includes a period from before blooming till the maturity of the plant.

I am not conversant with any data on the minimum energy requirements of the wheat plant that serves to aid me in a solution of this question, but until I obtain further light upon the question, I shall consider the heat energy at the disposal of the plant as fully adequate. If this view be correct, we have left but two factors, the application of the water to the plants in frequent light rains and the prevalent cloudiness of the season. The determining factor seems to be either a combination of these two, or one or the other of them. It is a fact that the plants were wet a great deal of the time either from rain or dew. I do not think that we, at any time during the season, collected a sample of dry plants, except near or after midday, and the plants were often wet throughout the day. This fact impresses itself upon me as of great importance in our problem. Had we had wet plants, as we did have, and at the same time our usual amount of sunshine, I imagine that things would have stood much worse with us than they did at the end of July, for the plants would certainly have been scalded, if no worse trouble had ensued.

I do not intend in any way to indicate that continued cloudiness is not a factor in this question, but at the present time I believe that the frequent light rains and consequent heavy dews which kept our plants dripping wet for so large a portion of each day, often all day long, was the more important factor of the two. I do not recall having seen any data on this point and have made no experiments myself to study the effects of such conditions.

We have said nothing about the ripening period. The principal reason for this is, that in 1913 the transference of the nitrogen from the plant to the seed, or its elimination from the plant, went on till the total in the plant was reduced far below what it was during the vegetative period; this was not the case in 1915. The total nitrogen in the plant remained high and the amount in the head did not increase as it did in 1913. In 1913 the season was very favorable, in 1915 it was quite unfavorable for the maturing of a good crop. One result of the unfavorable crop season of 1915 was the development of rust on all three varieties of wheat grown, but it injured the Red Fife, whose composition we have given for two years, 1913 and 1915, perhaps the least of the three. The indications are that the normal processes in the wheat during the ripening period were seriously interfered with, and while the changes may have been normal in their general character, which admits of a doubt, they were at least incomplete. The severe attack of rust was a direct result of the weather conditions. It was fortunate for us that we had chosen the Red Fife for our study. Had we chosen Defiance we would have been unable to obtain any results that we would have felt willing to use, because the crop was ruined, especially on those plots to which sodic nitrate had been applied. That these plots were more susceptible than the others to attack by this fungus can scarcely admit of a doubt. We might express the reasons otherwise. The plants were large, succulent, badly lodged, almost continuously wet, and rusted. The other plots were very severely attacked, but they were not so severely, and the wheat yielded was better than that of the nitrate plots, though very far from good. The Red Fife is naturally several days earlier and probably more resistant to the effects of rust than the Defiance. It is from such considerations that we conclude that the course of the changes in the plant, including also the heads during the ripening period of 1915, was greatly interfered with by this fungus, and that this is the cause of the results obtained. The weather conditions, especially those features which kept the plants continuously wet, were accountable for the low nitrogen in the plants up to the end of July. But during the ripening period the immediate cause of abnormal development was the severely diseased condition of the plants, and the effects of the weather conditions proper are concealed by the effects of the rust.

The ammonic, amid and nitric nitrogen in the plants are considered of less importance in this question than the total and proteid nitrogen. The presence of nitric nitrogen in the wheat plant is probably altogether dependent upon an accidental excessive supply in the soil, while the ammonic and amid nitrogen are intermediate and transient forms in the plant. The proteid nitrogen, on the other hand, is presumably the end product of the transformations and while it may be transferred from one part of the plant to another by little-understood processes, it represents the most permanent form of nitrogen in the plant. It is, however, evident that the total nitrogen includes a very considerable amount of nitrogen in other forms; at the end of July only about 60 percent of the total nitrogen is present as proteid nitrogen, nitrogen precipitated by Stutzer's reagent, and at the end of the ripening period in a few cases as much as 70 percent. The latter figure was obtained in 1915, when both the total and proteid nitrogen in the plant were very high compared with the results obtained in 1913.

I have stated that the nitric nitrogen appearing in the wheat plant owes its presence to an excessive supply of this form of nitrogen in the soil, and is probably accidental. This statement is based upon the fact observed in all of the samples examined during the two years, i. e., that the plants grown with the application of sodic nitrate regularly contain some nitrogen in this form, while those grown without it contain either only a very small amount, or no nitric nitrogen at all. The table contains only the results of 1915 and none of those of 1913. At one time we thought that oxidation in the air-dried plant actually took place, but were unable to establish this, and now believe that any nitric nitrogen found, even in the dried plant, represents an unused excess originally derived from the soil. The method used in determining the nitric nitrogen in the plant may give us slightly low results, but it certainly does not give us high results, so I think that we can depend upon our results as corresponding to the facts, especially as we took 150 grams of the green plant, or an equivalent amount of the dried plant, for the determinations. We found no nitric nitrogen in the heads. The facts are, in the main, concordant with what is known regarding the occurrence of nitrates in wheat plants. Jost, in his Plant Physiology, p. 140, says "Tobacco, turnips, sunflowers, potatoes and wheat may be taken as examples of cultivated plants which contain large quantities of nitrates. In the last two the nitrate amounts to from 1.5 to 2.8 percent of the dry weight. * * * The maximum of nitrate is found in the root, less in the stem and leaf, none at all in the seed. The nitrate increases as the flowering period approaches and decreases when fruiting takes place. * * Such storing of nitrate, however, is by no means universal. Many plants absorb no more than they absolutely require." It will be noticed that the amounts that we have found in our samples, grown with the application of 120 pounds of nitric nitrogen per acre, are far below the quantity given by Jost. In summarizing the lecture from which the above quotation is taken, Jost says we have learned "that nitric acid is the chief source of nitrogen, and that that element in co-operation with carbohydrates goes to form proteid especially." (p. 145). To quote Jost again, Plant Physiology, p. 174: "Schultze assumed that the amino-acids first arising from the proteid substances, in addition to which perhaps also primarily asparagin and glutamin may arise, break down further into ammonia and form this, in presence of suitable carbohydrates—perhaps glucose—asparagin and glutamin are constructed. These amids would be thus, not the main products of decomposition, but rather the first stages in a higher synthesis and their formation from this point of view is not inconceivable. According to Hausteen's experiments the amino-acids appear—so far as they have been investigated—much less adapted to the formation of proteids than ammonia and the two amids above mentioned. * * * * This hypothesis of Schultze's which has been recently supported by Balicka-Iwanoska (1903), (and also by Prianischnikow, 1904 and earlier), appears to us to explain best the facts known to us at the present time in this difficult region of investigation. * * * *

'A new difficulty presents itself when we attempt to investigate how proteids arise from amino-acids and amids. It cannot be doubted that the process takes place in light and Pfeffer (1873) has further given proof that light acts indirectly in the process."

The nitrogenous material out of which the proteids are built is primarily nitric acid, the principal intermediate products are ammonia and the amids, and these may occur in our wheat samples in varying quantities according as their transformation into proteid is more or less complete. We observe that corresponding to this theory we find the nitric, ammonic, amid, proteid and also the total nitrogen highest in those samples grown with the application of nitrates, which we used in liberal quantities for the purpose of discovering if possible the specific effects of nitric nitrogen, especially upon the character of the kernels produced.

THE ASH CONSTITUENTS OF THE PLANTS

We have not repeated the work of 1913 on this subject except to determine the ash constituents in one set of samples of the whole plant taken 5 August, 1915. We gave one set of samples for Fife in Part I, taken 31 July. The plants at this date in 1913 were as mature, or perhaps rather more so, than plants of the same variety on 5 August, 1915. The results obtained with the 1913 samples present the effects of the fertilizers upon the ash constituents under favorable seasonal conditions. The results of 1915 will serve to show the same thing under unfavorable seasonal conditions, and in these particular cases also the character and extent of the changes that we may attribute to the weather conditions.

ASH CONSTITUENTS OF WHEAT PLANTS—CROP 1915

Red Fife Fertilizer per Acre	Ca. Perct.	Mg. Perct.	Fe. Perct.	Mn. Perct.	K. Perct.	Na. Perct.	P. Perct.	S. Perct.
Nitrogen, 80 pounds	0.156	0.107	0.022	0.004	1.376	0.026	0.084	1.469
Phosphorus, 40 pounds	.116	.094	.007	.004	.868	.035	.058	1.527
Potassium, 150 pounds	.087	.0106	.012	.004	.980	.031	.061	1.627
None	.105	.073	.014	.004	.972	.041	.091	1.828

The sulphur and chlorine were not determined. These determinations were omitted also in the 1913 series.

The above series, though consisting of fewer members than might be desirable, shows the same effects upon the relative amounts of the ash constituents as in 1913, when we analyzed 12 instead of 4 samples of straw as in 1915. The specific effects of the nitrate were to increase the calcium, potassium and magnesium and to depress the silicon; we see the same features in the above results. In 1913 it produced no appreciable effect upon the amount of phosphorus. The check plot was of course adopted as our standard. In the results of 1913, we observed that the application of phosphorus and also that of potassium tended to depress the phosphorus in the plant. We observe the same tendency in 1915. While the nitrate depressed the silicon, it increased the potassium, calcium and, in a less degree, the magnesium. The net result, however, was to increase the ash. The increase in 1915 is very slight, so slight that one can scarcely claim it to be satisfactorily decisive. If we compare the amount of these constituents for the two years, we will find it from 0.340 to 1.0 percent lower in each of the four samples than in 1913. On looking at the individual constituents we observe that the potassium suffers approximately one-third of this depression, though all of the ash constituents participate in it.

The weather conditions have already been given in some detail. It has been stated that the plants were kept wet a great portion of the time. Whether this is the cause of the lower ash constituent or not, it is a fact and seems to me the probable cause.

In considering the nitrogen compounds in the plants we had two series of effects, one of which we attributed to the fertilizers and which was consistent throughout the two seasons. The other we attributed to the weather conditions. In addition to these two series of results, which seemed to run parallel up to the end of July, we had a third series of results which was not consistent at all for the series of samples taken after 30 July in the respective years. These results I believe to have been effected by the action of the rust. The results obtained by the study of the ash constituents of the plants in the two years are in harmony with those obtained by that of the nitrogen compounds up to the end of July, the latest date to which our work on the ash constituents can be applied.

SUMMARY

The summary includes the facts presented in Part I, with which no summary was presented, because we intended to record the results of another season's work on the subject dealt with before we formulated our conclusions.

We believe that the fundamental condition in this work is the question of food supplied by the soil; the weather conditions are important, but accidental.

The land used for these experiments contains a liberal supply of total potash. We found in 1913 that in the top two feet of soil there was 101.6 tons of this substance per acre, of which approximately one ton was available at that time. If, however, we base our estimate on the hydrochloric acid-soluble potash, we find that there was over 25 tons available. The citric acid, soluble phosphoric acid was about 1,400 pounds, that soluble in hydrochloric acid, 9,800. The total nitrogen found in the same depth of soil was 8,240 pounds. The amount of plant food was considered ample. This estimate, however, was based not entirely upon analytical results, but the crops produced by the land were also considered.

The nitrogen, while sufficient, was not considered remarkably high. It was shown that a very considerable portion of this nitrogen actually existed in the soil in the form of nitric nitrogen at the time of planting. The top two feet contained nitric nitrogen equivalent to 211 pounds of sodic nitrate. The biological conditions of the soil are such that the conversion of the soil nitrogen into nitric nitrogen proceeds rapidly

The power of this soil to fix nitrogen has been discussed in previous publications (Headden, Bulletin 178, p. 89; Sackett, Bulletin 179, p. 29), in which it is shown that this factor is a very important one, being sufficient to add very considerable quantities of nitrogen to the soil annually, provided the conditions be reasonably favorable. I may emphasize this fact by giving the results of observations made on a sample of soil from this tract of land, but not from either of the three sections used for these wheat experiments. The sample was kept in a large bottle, loosely corked, at the temperature of the laboratory. There was no opportunity for the soil to absorb ammonia or nitric fumes. This sample was put into the bottle just as it was brought from the field, except that the clumps were broken up and the soil made reasonably fine. In 27 days this soil gained 4.82 milligrams of nitrogen for each 100 grams of soil, or 48 parts per million. This soil had nothing added to it, nor was it treated in any way to facilitate this bacterial activity, except that it was kept in a moderately warm room. This was the smallest gain observed by myself or Prof. Sackett in samples of this soil. The other samples, however, were incubated and the moisture was brought up to about the optimum quantity. Even at this minimum rate of fixation, the amount of nitrogen added to the soil in one month would be sufficient, if nitrified, to nourish several crops of wheat. So it is by no means necessary that even this minimum observed rate of fixation should be maintained throughout the year in order that this process should form a factor demanding our consideration. This amount of fixation means the addition of 192.8 pounds of nitrogen to an acre-foot of soil in one month, equivalent to the addition of about 1,100 pounds of sodic nitrate. We have nowhere intimated that we hold this nitrogen to be available in this form, but have taken, tacitly it may be, the extreme view that only nitric nitrogen is available to the wheat plant.

It is because of the importance and immediate connection of this latter form of nitrogen, with the growth, yield and, as I believed when I began this work, with the character of the wheat produced, that we have given in some detail the moisture and nitric nitrogen in the soil throughout the two seasons of 1913 and 1915. The moisture is not only necessary to the growth of the wheat plant, but also to the biological factors in the soil. We determined the moisture in the soil for the latter reason quite as much as for the former, and endeavored to determine the effects of irrigation upon the distribution of the nitrates. In 1913, we found a very great difference in the amount of, and also in the distribution of, the nitrates on the different dates, 29 April, before irrigation, and on 27 June, thirteen days after irrigation. These differences were so big that the usual considerations of variability due to differences in samples from place to place within limited areas, are wholly excluded. In the top four feet of one sample we found on 29 April, nitric nitrogen equivalent to 1,908 pounds of sodic nitrate; in another on the same date, for the same depth of soil, the equivalent of 471 pounds; but in this latter sample we find in the 7th, 8th and 9th foot, taken together, the equivalent of 721 pounds. On 27 June, after irrigation, we found for the top four feet of three different sections of soil, 162, 91 and 156 pounds, respectively, and below the depth of four feet, usually from six to eight pounds per acre-foot; but this amount varies somewhat; the maximum found below four feet in three borings taken to a depth of 12 feet was 30 pounds to the acre-foot, the minimum was nil. In the cropped land the nitric nitrogen, especially during the actively vegetative period of the plants, usually falls to less than an equivalent of 20 pounds of sodic nitrate per acre-foot of soil, except in the top three or perhaps six inches, where it is usually a little higher, provided the sample be not taken immediately after a rain. The surface portions of land cropped to wheat may occasionally show nitric nitrogen equivalent to as much as 200 pounds of sodic nitrate to the acre-foot, but in most cases we found from 30 to 40 pounds in such samples. In 1913, the second foot seldom showed as much nitric nitrogen as would be equivalent to 20 pounds of sodic nitrate per acre-foot. This was a season of high rainfall in general, and long periods without any. In 1915, with twice the total rainfall, which fell in a succession of light rains well distributed throughout the season, we have a very different distribution of the nitric nitrogen, for we find even the fourth foot containing, at the end of June, as high as the equivalent of 48 pounds of sodic nitrate; but by 3 August, the nitric nitrogen had been used up to such an extent, that the surface foot contained the equivalent of only about 20 pounds of sodic nitrate; the minimum found in the fourth foot at this time was nil. The nitric nitrogen had disappeared from all of the plots in the same manner and to about the same extent. The amount of nitric nitrogen in the top four feet of soil was at all times throughout the season larger in 1915 than in 1913. This fact was due, in all probability, to the different distribution of the moisture. The period of minimum nitrates in the soil was, in 1915, 3 August, or the beginning of the ripening of the grain. The effects of the crop upon the nitric nitrogen in the soil were checked by cutting out the wheat on a small section 20 by 20 feet, and keeping it fallow throughout the season. Samples were taken from this fallow ground, and also from that occupied by the wheat plants on 3 August, 1915, to a depth of four feet. The nitric nitrogen present in this fallow land to this depth was equivalent to 285.5 pounds of sodic nitrate; that present in the cropped land, to the same depth, was equivalent to 46.9 pounds of sodic nitrate. The crop, either by preventing the formation of the nitrates, or by using them up, had made a difference equal to 238.6 pounds of sodic nitrate in this depth of soil.

It was shown in Bulletin 178, p. 91, and again by Sackett in Bulletin 193, sample No. 75, pp. 24 and 39, that the nitrifying effiiciency of this soil is relatively high. In Part I (Bulletin 208), pp. 20 and 21, I showed the differences in the amount of nitric nitrogen in land cultivated fallow during the season, and in that cropped to spring wheat, for samples taken on 4 December, 1914. I also gave the amount of nitric nitrogen found in the cropped land on 1 August, 1913. The average given by three sets of samples, each composed of eighteen sub-samples, taken to a depth of nineteen inches, corresponds to 542.43 pounds of sodic nitrate per acre for the fallowed land. The nitric nitrogen found in one of our check plots of Defiance wheat on 1 August, 1913, taken to a depth of two feet, corresponded to 101.20 pounds sodic nitrate per acre. This same plot was cropped to wheat in 1914, the wheat was harvested 6 August, the land irrigated 28 August, plowed 14 November, and sampled on 4 December. We found as the average of two sets of composite samples taken to a depth of nineteen inches, the equivalent of 299.35 pounds sodic nitrate per acre. While the value of these figures is lessened by the fact that the sample representing the nitric nitrogen present just before harvest was taken in 1913, and the other two in 1914, they still serve to give us a very definite idea of the rate at which the nitric nitrogen is restored to this land after previous removal by a crop, for we can safely assume that the crop of 1914 reduced the nitric nitrogen present at harvest time, 1914, to approximately the same amount that the crop of 1913 had reduced it the previous year. The difference between the amounts of nitric nitrogen in the fallow land and the cropped land on 4 December, 1914, gives us the difference of nitric nitrogen in favor of the fallowed land. This difference is equal to 243 pounds of sodic nitrate. The difference between 299.35 and 101.20 gives us an approximation to the difference in the amount of nitric nitrogen in the top two feet of soil on 1 August and 4 December; this difference is equivalent to 198 pounds of sodic nitrate.

This question was followed more closely in 1915 than in 1913, with equally positive results. The cropped land again contained its minimum amount of nitric nitrogen about 1 August. On 3 August, Section 1800 Red Fife, Check Plot, contained in the surface foot the equivalent of 29.3 pounds of sodic nitrate, on 30 August 42.2, on 22 November 89.1, on 14 December 103 pounds; Section 1900, Red Fife, Check Plot, contained: On 3 August 19.5 pounds, 30 August 50.6, 22 November 73.6, 14 December 121.8. An extended statement of these results is given in tabulated form on a previous page, in which the amount of sodic nitrate corresponding to the nitric nitrogen found is given both for the surface foot and also for the succeeding three feet. This table also exhibits the rapid fall of the nitric nitrogen in the cropped land from the middle of May till the beginning of August, namely, during the growing period of the plant.

The total nitrogen was determined at various times during both seasons. The results for 1913 are given on pages 15, 19 and 23 of Part I, and for 1915 on page 18 of this bulletin. I think it very unsafe to attempt any interpretation of the results, owing principally to the difficulty of obtaining samples of soil which will vary by less than the amounts of nitrogen here concerned; for instance, an actual increase of ten parts per million in any month would mean a percentage difference of one one-thousandth, but this would mean, if converted into sodic nitrate or calculated as proteid matter, 240 pounds for each four million pounds of soil. We sampled 150 square feet of soil, taking a core from the center of each square foot to a depth of one foot, and it was rarely the case that contiguoue square feet of soil showed so small a difference in total nitrogen as 0.001 percent. On the other hand, this difference actually reached 0.0354 percent, or more than 35 times as much as would have a very considerable significance in the development of the crop if present in the form of nitric nitrogen. It is for this reason that I have preferred to state the fixing power of this soil as found by laboratory experiments.

We have not been able, up to the present, to follow the study of the bacteriology of this soil further than was given in Part I.

The study of the composition of the plant, and the effects of the fertilizers, have been presented, together with a general statement of the weather conditions for the two seasons.

One of the first, important questions in our study, especially under our conditions, is: What is the effect of different amounts of water applied to the soil? Others have studied this question in relation to the production of dry matter, but not, so far as I know, as touching the composition of the plant. This question is important in our study, but is incidental to it, for this reason we have prosecuted it only so far as seemed advisable to determine its influence in a general way. We found no differences in the amount of nitrogenous compounds in the plants that could be attributed to the varying amounts of water applied.

This statement is based on two series of samples which have received 31 inches of water in all, 24 inches irrigation and 6.77 inches rainfall, compared with 16 series grown with 19 inches of of water, 12 inches irrigation and 6.77 inches rainfall. I am speaking of the plant at this time, but I shall present the effect of different quantities of water applied to the soil on the composition of the kernels, at another time. This question was presented in another form in 1915, when a series of light rains, amounting to about 13 inches during the growing season, kept the plants wet a great portion of the time and further caused very heavy dews, so that the plants, not the soil, were thoroughly wet by application of water almost daily. The amount of water received by the crop in the two seasons was essentially the same, about 19 inches, but the effects which seem attributable to water, or more accurately stated, to the manner of its application in 1915, are very marked. For the present it may suffice to state that it caused the principal differences in the composition of the plants up to the end of July, at which period another factor, largely the result of this external moisture, began to play a still more important part. This factor was the abundant development of rust. These conditions were unfortunate so far as the size of the crop was concerned, but fortunate for the purpose of our study, though we did not desire to introduce these factors into our problem. The general effect was to suppress all forms of nitrogen present in the plant throughout its growing period, and the same was true of the ash constituents. It seems almost as though this externally applied water had actually caused a leaching out of the very substance of the plant. This does not seem so improbable, especially in regard to the ash constituents, when it is recalled that it is shown in Part I, p. 42, that 93 percent of the total soluble ash in the air-dried wheat plant can be extracted with water. The size of the plants and the percentage of dry matter in them was not materially different in the two seasons.

The part played by the greater cloudiness and a lower mean temperature in 1915 than in 1913 has not been made out. It is for this reason that I refer to effects that seem attributable to water, or its manner of application in 1915. At the present time, I entertain almost no doubt but that these effects are due to the external application of the water to the plants, or to their having been kept wet for so large a portion of their growing period. There are but two other things that I see, in addition to the cloudiness and mean temperature, that may militate against this view, and they are, the extent to which a living plant may differ from a dead one in the solubility of its constituents, and the possibility that transpiration was retarded to a sufficient extent to have reduced the intake of nitric acid and the non-volatile ash constituents.

The very different weather conditions which prevailed during the two seasons were in reality very fortunate for us, for they served to demonstrate the fact that the observed effects of the fertliizers applied in 1913 are independent of the weather. The weather conditions of 1915 made great differences in both the nitrogen compounds and ash constituents of the plants, but they did not obscure the effects of the nitrate applied upon the total or the proteid nitrogen or the silicon or the ash constituents in general. The same is true in regard to the effects of the phosphorus and the potassium.

The effects of the application of nitrogen was to increase the nitrogen in all parts of the plant; this was uniformly true in the stems, leaves and heads, for both the total and proteid nitrogen, and as positive in the wet season as in the dry one. It increased it in the stems and leaves and less regularly so in the heads. It lowered the percentage of dry matter; it lowered the percentage of silicon; it increased the percentage of potassium, calcium and magnesium as a rule, and increased the total ash, while it exerted no influence upon the amount of phosphorus in the plant. It increased the height of the plant, the length of the head, and the color of the plant, but it did not increase the kernels per spikelet.

Phosphorus seemed to be either indifferent to, or possibly tended to depress, the amount of nitrogen in the different parts of the plant. The same is true of potassium, with a stronger tendency to depress the nitrogen.

Both phosphorus and potassium depressed the phosphorus in the plant. This is true of these elements except in one case, in 1913, in which the plants grown with the application of potassium, contained more phosphorus than those grown on the check plot.

These effects upon the composition of the plant are not changed by the weather conditions. In Colorado Bulletin 205, I pointed out a marked effect produced upon the physical properties of the kernels by the application of nitrogen in the form of sodic nitrate, namely, that it produced flinty and often shrunken kernels. This effect was not changed in our wet season of 1915. Further, we cannot see that the yellow-berry question was materially affected by the weather conditions of 1915 compared with those of 1913.

The attack of rust seemed to materially affect the course of the chemical changes that took place after the early part of August, 1915, compared with those that took place during the ripening period of the plant in 1913.