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EFFECTS OF NITRATES ON COMPOSITION OF THE POTATO

By WM. P. HEADDEN

COLORADO AGRICULTURAL COLLEGE
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*On leave, 1927-1928.

EFFECTS OF NITRATES ON COMPOSITION OF THE POTATO

BY WM. P. HEADDEN

This bulletin records the continuation of the work reported in Bulletin 291, which contains data pertaining to the soil, the composition of the general crop, and detailed data pertaining to the crop of 1920.

It may be well to restate briefly the object of the study. From about 1911 to 1914 serious troubles developed in the growing potato plant in the Greeley district and also in other portions of the state. These troubles were very serious, especially in the Greeley district. The Experiment Station, in conjunction with the United States Department of Agriculture, undertook the study of these troubles with the idea of ascertaining the causes and, if possible, finding remedies for them. The work was wholly under the direction of the U. S. Department of Agriculture.

The virulent outbreak of the diseases had been studied by the Colorado Experiment Station previous to the time that the Department of Agriculture undertook these investigations. The conclusions arrived at were duly published but more extended and systematic study seemed desirable and the Colorado Potato Experiment Station was established in 1914 and has addressed itself to the study of these problems since that time.

There are some features peculiar to our soils which should be taken into consideration in such a problem as this.

In 1920, by common consent, but without formal cooperative agreement, I associated myself with Dr. H. G. MacMillan, representative of the Bureau of Plant Diseases, as I was glad to avail myself of his knowledge of plants and plant diseases.

One of the conditions peculiar to our conditions and soils is the development and accumulation of notable, even excessive quantities of nitrates. These salts actually accumulate in the surface portions of some of our soils to the extent of several percent of the weight of the dry soil. Such accumulations are, of course, fatal to vegetation. I shall present two instances in which this has occurred in the case of potatoes. Such excessive quantities of nitrates do not occur everywhere but large quantities of nitrates are formed in very many of our soils, among them these Greeley soils as is set forth on page 17 of Bulletin 291 and discussed more fully on page 22 of the same bulletin under the caption of "How our check plots failed us."

It is very unfortunate that we have no data showing how much nitrate is required to produce in any measure a deleterious effect. Further, the deleterious effect is not defined; it may be direct or indirect. The direct effects are not always apparent and violent, as has been the case in many places, especially noticeable in apple and other trees, which were often killed quickly, i. e., in a few days. The first instance of this to which my attention was called was in an apple orchard in which a number of trees, previously vigorous and healthy, with fruit about one-third grown, died in a few days. The leaves and fruit were still on the tree. In imitation of this we killed a four-year-old tree in five days by the application of sodic nitrate, 25 pounds to the tree distributed in an area a little greater than the spread of the crown. This tree showed the same deportment as the orchard trees. Nitrates occurred abundantly in this orchard and the whole orchard finally perished. Such extreme results have been, and are still, frequently met with, but they are probably far from being the most important results produced.

Some of the effects of nitrates on the sugar beet are to increase the growth of the tops very greatly, to delay maturation, and to produce a beet of poor quality. It may be too much to assert that there is a correlation between the amount of nitrates present in the soil and the susceptibility of the beet plants to the leaf-spot and other diseases, but this idea has been entertained by some.

There are three distinct effects of the nitrates which are deleterious: The killing of the plants, rendering them susceptible to the attacks of diseases because of excessive growth and consequent physiological weakness, and changing the composition and characters of the crop produced.

The study of these phases of the effects, especially of the second and third, requires the possession of extended data that are not available. In default of such data, a comparative study of potatoes grown under controlled conditions is the only way for us to proceed, but it has been in no measure feasible for us to do this. The next best course was to study potatoes grown under what we supposed to be good conditions, on check plots. These failed us utterly and we had recourse to samples grown in other sections, but these proved wholly unsatisfactory.

In regard to the physiological features of this problem, I make no claim to the right of a judgment nor yet to the pathological features; consequently, I can address myself only to the first and third phases of it.

The killing of the plants did not appear to be in question in the Greeley problem, for the plants were killed in the worst years of the trouble by what we will designate plant diseases, attacks of fungi, etc., and were not killed outright by mineral salts. We shall present two cases of the latter, but they are not from the Greeley section. So far as the Greeley section is concerned, we have to deal in this bulletin, as in Bulletin 291, with the third phase of the problem, the change in composition, only. In preparing Bulletin 291 we had no standard for comparison, not even a good quality of tubers obtained from any source, and we could find no satisfactory analytical data in literature. If such exists, it has not come to our knowledge.

We have realized, and that very keenly, the difficulties encountered in this study, but we have gained enough to justify our efforts. The influence of the nutrition of the plant has long been considered an important factor, but an excessive and unbalanced supply of nutrients has not been made an object of study; in this far, our experience is new. The fact that this condition actually exists in our field conditions is also new, tho we have presented it before.

Bulletin 291 gives the composition of the soil used and that of the crop of 1920. We used the same plots in 1921 that we used in 1920, but used adjacent plots on the west side in 1922, and on the east side in 1923. The land is quite uniform in character and we did not deem it necessary to analyze the soil in the years 1922 and 1923. Had it been deemed desirable, our laboratory force was not adequate to do the work, and other conditions forbade it.

The soil is adequately supplied with phosphoric acid, 0.12 percent; it is abundantly supplied with potash, as it carries a total of 2.25 percent and yields to concentrated hydrochloric acid from 0.40 to 0.77 percent, and to fifth normal nitric acid from 0.11 to 0.26 percent. The total nitrogen is not very high but is about the average quantity found in our soils, 0.0862 percent.

The fixing and nitrifying capacities are very considerable, reaching 110 and even 121 p. p. m. for the former, and 39 p. p. m. for the latter in 40 days.

Nitrification proceeds so rapidly at times that we found in a composite field sample of 20 subsamples, 187 p. p. m. of nitric nitrogen in the top 4 inches of soil. The preceding sample, taken 24 days earlier, showed 70 p. p. m. These samples were taken from the crests of the rows between the plants and not from fallow ground.

Such were the chemical features of the soil. The physical features were not desirable for the culture of potatoes.

In 1920 we studied the soil, the variation of the nitric nitrogen, thruout the growing season, and the composition of the tubers. Our force and facilities were not adequate to studying the vines at the same time. In 1921 we studied the vines and tubers. In 1922 and

1923, we studied the variations in the nitric nitrogen, the composition of the vines and tubers, both fresh and after storage. The plan of experimentation was the same as in 1920. We even used the same plots in 1921 that we used in 1920.

We recognized even before our first crop, that of 1920, was mature, the need of a standard or at least of a knowledge of the composition of potatoes grown in Colorado in order to interpret the results obtained in our experiments, for it was evident that our check plots, amounting to one-fourth of the area planted, were only a little less freely supplied with nitrates than were the plots to which we had applied them. In order to meet this phase of the case, we collected samples of tubers from some other sections and examined them in the same manner that we had examined ours. This made the results comparable, even if some other method of examination might have given different and better results.

The scope of the examination covered the following: The albumin, proteose, peptone and total nitrogen in the juice of the plant, also in that of the tuber; further, the ammonia, amid, amino and nitric nitrogen, the starch and ash with its composition.

The ordinary fodder analysis of ten samples of tubers are given on page 21 of Bulletin 291.

The other factors on which stress was laid were the yield, the keeping and the cooking qualities.

We do not see any reason for discussing the individual constituents, for each of the three seasons that this bulletin covers, even tho this might be an advantage, to some slight extent in the matter of clearness.

The difficulty in obtaining a press-juice that actually represents the liquids contained in the cells of a plant is appreciated by most operators. A further question with us was to get our plants to the laboratory without loss of water. The latter was accomplished by packing the plants in tin cans as they were cut and packing the cans in ice inside of a larger can. Determinations of the loss taking place between the field and the laboratory showed it to be less than one percent. As we had to transport them about 40 miles, we considered this very satisfactory. To lessen any changes that might take place in the plants, to rupture as many cells as possible, and to enable us to cut them to a uniformly fine mass, they were next frozen and thus preserved till we were ready to analyze them, when they were ground, allowed to thaw and submitted to a strong pressure. The tubers were treated in the same manner except that they were first rasped and then frozen, thawed and pressed as required.

The dry matter in the plants was determined by drying the plants in a vacuum dryer. The plants used for the preparation of ash were treated in the same manner.

The albumin was precipitated by alcohol and ether after acidulation with acetic acid. A second portion of the juice was treated with a saturated zinc sulfate solution, and a third one with 86 percent alcohol. For the determination of ammonia, amid and amino nitrogen, we first treated the juice with Stutzer's reagent which may carry down a little amid nitrogen. The filtrate was distilled with addition of magnesic oxid and the ammonia titrated in the distillate. The residue was hydrolized by boiling with dilute sulfuric acid and the ammonia so formed distilled off and estimated. The amino nitrogen was determined by breaking it out of this second residue by means of nitrous acid. The nitric nitrogen was determined by treating the pulp with 85 percent alcohol, the nitric nitrogen was liberated as nitric oxid and finally absorbed in ferrous chlorid.

The ammonia and amid nitrogen were determined separately and also together. The sum of the separate determinations and the latter agreed sometimes but not always.

These determinations were made on the fresh vines and tubers and a second set of determinations was made on the tubers after a period of storage, so we have two series of analyses for the tubers for each year.

The title of this bulletin indicates that our purpose was not to make a general study of the potato but to answer a definite question: What are the effects of nitrates upon its composition and properties? The only work that we present on the general subject of the composition of the potato is such as we were obliged to do to obtain some sort of standards with which to compare our potatoes grown at Greeley.

We had, in the beginning, no intention of going into the cultural problems as these are generally understood, and have been worked out for the Greeley district with such success that I doubt whether we can improve on them. The Greeley farmers know what is good practice in growing potatoes, whether they follow it or not. Discussion of the seed used, of cultural details or even of rotation, simply as a cultural practice in this connection, would have no good object. The questions of irrigation as a practice have been canvassed from so many angles that it would be wholly without profit to repeat experiments whose results have been the common possession of the district for two generations. It is for such reasons that we have practically omitted these subjects.

Our analytical data for the year of 1921 are unfortunately incomplete, due to the loss of important notes in our fire of 22 December, 1921, and our work in 1922 was seriously interfered with by rebuilding operations.

We had stored portions of our 1921 samples at a temperature of 34° F. to compare the changes that took place in the respective samples, i. e., those that had been grown with and without the application of nitrates. We have been compelled to use these stored samples in lieu of fresh samples in some cases, but the character of the sample if stored is always indicated.

The development of nitrates in our check plots was so abundant that it became necessary that we should get samples from other sections in the hope that these might be more nearly normal potatoes. I am acquainted with the soil conditions in some, but not in all of these other sections. I had misgivings in regard to some of them from the first, but as I am ignorant of the conditions obtaining in some of them I can scarcely discriminate against any of them. A study of the analytical results indicates that the conditions in some of the sections were bad. Unfortunately they do not show that the conditions were good in any of them. This difficulty will be made clearer by the case of a sample of Rurals grown eight miles east of Fort Collins. It is generally acknowledged that this section is not a favorable one for the cultivation of potatoes. I do not know that any reason for this has ever been ascertained. The occurrence of very large quantities of nitrates in some of our soils has been shown in Bulletin 258 which discusses the Wellington district. This sample does not appear in the table giving the albumin forms of nitrogen which is not due to the rejection of the results, but because we had none of the samples left on which to repeat the determinations. It appears in the table giving the ammonia forms of nitrogen, and its similarity to those grown with the application of nitrates rather than to those with which it is grouped is evident.

The average percentage of dry matter in the vines up to the middle of August is the same for the checks and those grown with nitrates, i. e., 12.86 percent. The rest of our record for this year was burned. The marc is a little higher in those grown with nitrates than in the check samples, 8.14 percent against 7.74 percent. The difference between these percentages is so small that but little weight can be attached to it. The specific gravity of the juices differ by only 8 points in the third decimal place, the minimum being 1.020 and the maximum 1.028.

The total nitrogen is a little higher in the nitrate samples but the portion of it contained in the juice is higher in the check samples, 68.66 percent of the total being found in the juice of the check samples and 61.77 percent in that from the nitrate samples. The ratio

TABLE I.—POTATO VINES, CROP OF 1921

Total, Albumin and Nitric Nitrogen

Variety	Fertilizer	Date 1921	Dry Matter	Marc*	Juice	Sp. Gr.	Total Nitrogen		Albumin Nitrogen	Proteose Nitrogen	Peptone Nitrogen	Nitric Nitrogen
							Pulp	Juice				
Ohio	Check	23 July		7.44	92.56	1.0225	0.3090	0.2770	0.1695	0.0033	0.0060	0.07377
Ohio	Nitrate	23 July	9.875	7.64	92.36	1.0200	0.4571	0.2694	0.1418	0.0027	0.0018	0.08801
Pearl	Check	30 July	12.900	8.00	92.00	1.0270	0.4995	0.3333	0.1988	0.0040	0.0039	0.06876
Pearl	Nitrate	30 July	12.600	8.00	92.00	1.0260	0.4281	0.2898	0.1623	0.0097	0.0091	0.08724
Downing	Check	30 July	11.975	7.39	92.61	1.0260	0.4217	0.2894	0.1689	0.0136	0.0064	0.08722
Downing	Nitrate	30 July	12.175	8.12	91.88	1.0240	0.4335	0.2751	0.1298	0.0064	0.0127	0.10530
Rural	Check	6 Aug.	12.450	8.82	91.18	1.0260	0.4203	0.3207	0.1776	0.0052	0.0013	0.07035
Rural	Nitrate	6 Aug.	12.800	8.83	91.17	1.0280	0.4203	0.2829	0.1844	0.0011	0.0119	0.08026
Ohio	Check	6 Aug.	12.925	7.47	92.56	1.0260	0.4136	0.2715	0.1418	0.0018	0.0109	0.07509
Ohio	Nitrate	6 Aug.	12.425	7.64	92.36	1.0250	0.4242	0.2619	0.1239	0.0081	0.0093	0.07960
Downing	Check	13 Aug.	12.575	7.39	92.61	1.0265	0.4494	0.2329	0.1028	0.0107	0.0182	0.09750
Downing	Nitrate	13 Aug.	12.800	8.12	91.88	1.0260	0.4333	0.2261	0.0782	0.0012	0.0192	0.11830
	Average for 6 checks						.4189	.2875	.1599	Ratio Albumin to Total		51.6
	Average for 6 nitrates						.4329	.2674	.1368	Ratio Albumin to Total		51.2

The record for subsequent dates was lost.

*Marc is the press cake washed with cold water and dried.

TABLE II.—POTATOE VINES, CROP OF 1921

Ammonia, Amid and Amino Nitrogen, and Starch

Variety	Date of Sampling	Ammonia Nitrogen		Amid Nitrogen		Amino Nitrogen		Starch in Dry Substance*	
		Check	Nitrate	Check	Nitrate	Check	Nitrate	Check	Nitrate
Ohio	23 July	0.00280	0.00532	0.00364	0.00378	0.01322	0.01623	0.425	0.437
	6 Aug.	0.00462	0.00462	0.00392	0.00308	0.01726	0.01694	1.686	1.015
	20 Aug.	0.00238	0.00252	0.00448	0.00252	0.01101	0.01326	0.594	0.865
	3 Sept.	0.00742	No sample	0.00714	No sample	0.01438	No sample	0.583	No sample
Pearl	30 July	0.00336	0.00476	0.00686	0.00642	0.01535	0.02064	0.961	0.794
	13 Aug.	0.00812	0.00728	0.00476	0.00504	0.01893	0.01789	1.367	0.566
	27 Aug.	0.00336	0.00420	0.00448	0.00560	0.01387	0.01685	0.969	1.038
	10 Sept.	0.00420	0.00644	0.00420	0.01134	0.01311	0.02433	1.222	3.050
Downing	30 July	0.00840	0.00952	0.00350	0.00364	0.01650	0.01523	0.389	0.444
	13 Aug.	0.00294	0.00252	0.00476	0.00280	0.01343	0.00982	0.700	0.552
	27 Aug.	0.00462	0.00420	0.00252	0.00168	0.01246	0.01085	0.496	0.619
	10 Sept.	0.00532	0.00560	0.00434	0.00500	0.01522	0.01536	0.985	0.504
	17 Sept.	0.00910	0.00910	0.00658	0.00714	0.01916	0.02116	3.120	2.121
Rural	6 Aug.	0.00672	0.00728	0.00350	0.00490	0.01418	0.01453	0.987	0.881
	20 Aug.	0.00980	0.00924	0.00546	0.00378	0.01699	0.01703	1.470	1.169
	3 Sept.	0.00952	0.00910	0.00770	0.00700	0.02603	0.02271	3.061	2.899
	17 Sept.	0.00672	0.01120	0.01134	0.00980	0.02396	0.02575	11.848	10.888

*Starch done by official method

TABLE III.—POTATO TUBERS, CROP OF 1921*

Total, Albumin, and Nitric Nitrogen

Variety	Fertilizer	Dry Matter	Marc	Juice	Sp. Gr.	Total Nitrogen		Albumin Nitrogen	Proteose Nitrogen	Peptone Nitrogen	Nitric Nitrogen
						Pulp	Juice				
Rural	Check	21.00	18.48	81.52	1.045	0.3816	0.3808	0.1074	0.0259	0.0411	None
Rural	Nitrate	21.20	13.66	86.34	1.045	0.3829	0.3678	0.1026	0.0312	0.0366	0.0025
Pearl	Check	20.10	11.54	88.46	1.050	0.3643	0.3843	0.1182	0.0360	0.0271	None
Pearl	Nitrate	19.76	10.64	89.36	1.047	0.4095	0.4027	0.1231	0.0505	0.0431	None
Downing	Check	29.70	13.57	86.43	1.037	0.4211	0.4125	0.1198	0.0328	0.0363	0.0032
Downing	Nitrate	19.73	12.43	87.57	1.038	0.4225	0.4264	0.1165	0.0370	0.0372	0.0022
Ohio	Check	19.58	11.06	88.94	1.047	0.4291	0.4103	0.1100	0.0241	0.0268	0.0039
Ohio	Nitrate	20.95	11.68	88.32	1.047	0.4354	0.4326	0.1358	0.0037	0.0229	0.0023
Other Samples: i. e., grown in other localities											
Peach Blow		22.00	14.22	85.78	1.046	0.2240	0.2446	0.0689	0.0210	0.0301	None
Rural, Hill's		25.05	17.89	82.11	1.047	0.3956	0.4271	0.1221	0.0579	0.0431	None
Rural, Steppler's		20.05	12.73	87.27	1.037	0.3031	0.2945	0.1367	0.0059	0.0349	None
Red McClure		21.68	13.34	86.66	1.048	0.3279	0.3338	0.0799	0.0302	0.0187	None

The notes on the fresh potatoes were lost in the fire.

*These potatoes had been kept in cold storage at 34° F. till March, 1922.

TABLE VI.—POTATO TUBERS, CROP OF 1921

		Specific Forms of Nitrogen					
		Ammonia Nitrogen		Amid Nitrogen		Amino Nitrogen	
Variety	Date	Check	Nitrate	Check	Nitrate	Check	Nitrate
Ohio	3 Sept.	0.01204	0.00952	0.04788	0.04788	0.10621	0.09617
	28 Oct.	0.01036	0.00910	0.05264	0.05320	0.10663	0.10239
	16 Mch., 1922	0.01232	0.00994	0.04844	0.05152	0.09905	0.10373
Pearl	1 Nov.	0.00896	0.00924	0.04522	0.05166	0.07566	0.09307
	28 Nov.	0.01064	0.01344	0.04788	0.04928	0.08065	0.07927
	16 Mch., 1922	0.01288	0.01120	0.04102	0.04956	0.09571	0.11085
Downing	26 Oct.	0.01022	0.00686	0.05334	0.05600	0.10051	0.10051
	22 Nov.	0.00784	0.01022	0.05740	0.05152	0.09717	0.09717
	16 Mch., 1922	0.01736	0.01344	0.05124	0.06356	0.10939	0.11094
Rural	21 Oct.	0.00700	0.00728	0.05372	0.04810	0.09132	0.09851
	19 Nov.	0.01204	0.00952	0.05432	0.04858	0.09449	0.08451
	16 Mch., 1922	0.01246	0.01008	0.05208	0.05096	0.09794	0.09747
Average		0.01118	0.00999	0.05043	0.05182	0.09623	0.09689

Potato tubers from other localities

Rural	9 Dec.	0.01190	0.06272	0.10965	8 miles east of Fort Collins
Rural	13 Dec.	0.01190	0.05063	0.08838	Dover Dryland
	16 Mch., 1922	0.01120	0.04844	0.07369	
Rural	16 Dec.	0.01232	0.04844	0.08838	Near Colorado Springs
	16 Mch., 1922	0.01106	0.04032	0.07235	
Red McClure	13 Dec.	0.01036	0.04850	0.08694	Mountain grown
	16 Mch., 1922	0.01526	0.03598	0.07823	
Peach Blow	1 Dec.	0.00826	0.02856	0.05451	San Luis Valley
	16 Mch., 1922	0.00686	0.02296	0.04328	
Pearl, Mapes	9 Dec.	0.00994	0.03920	0.07574	Mountain grown
Pearl, Landis	16 Dec.	0.01120	0.04032	0.06836	Mountain grown
	Average	0.010936	0.04238	0.07632	

TABLE V.—STARCH AND SUGARS IN POTATOES, CROP OF 1921

Fresh and after storing

Variety	Date	Starch		Reducing Sugars		Total Sugars	
		Check	Nitrate	Check	Nitrate	Check	Nitrate
Ohio	3 Sept.	13.84	11.92	....	....	....	....
	28 Oct.	13.07	12.73	....	....	....	....
	16 Mch., 1922	7.95	9.02	2.072	2.248	4.104	4.260
Pearl	1 Nov.	13.44	13.18	....	....	....	....
	28 Nov.	12.85	11.98	1.084	1.132	1.428	1.779
	16 Mch., 1922	8.59	7.31	1.934	1.682	3.321	4.149
Downing	26 Oct.	14.99	13.92	....	....	....	....
	22 Nov.	13.52	13.57	0.492	0.836	1.344	1.662
	16 Mch., 1922	9.83	8.81	2.534	2.494	3.078	3.120
Rural	21 Oct.	14.86	14.42	....	....	....	....
	19 Nov.	13.86	14.66	0.516	0.422	1.137	0.933
	16 Mch., 1922	10.44	10.57	1.582	1.332	3.051	3.009
Potatoes grown in other localities							
Rural	9 Dec.	13.80		0.011		0.393	8 m. east Ft. Collins
	13 Dec.	16.70		0.005		0.324	Dover,
	16 Mch., 1922	14.31		1.140		2.835	dryland
	16 Dec.	13.60		0.071		0.645	Near
	16 Mch., 1922	10.51		2.562		2.964	Colo. Sp.
Red McClure	13 Dec.	16.47		0.016		0.297	Stove
	16 Mch., 1922	9.83		2.634		4.707	Prairie
Pearl	9 Dec.	15.93		0.022		0.408	Stove
	16 Dec.	14.25		0.029		0.567	Prairie
Peach Blow	1 Dec.	16.78		0.972		0.924	San Luis
	16 Mch., 1922	11.76		3.212		4.224	Valley

TABLE VI.—DRY MATTER AND ASH IN POTATO VINES AND TUBERS, 1921

Date	Vines	Check		Nitrate	
	Variety	Dry Matter	Crude Ash	Dry Matter	Crude Ash
23 July	Ohio	Lost	Lost	9.875	Lost
30 July	Pearl	12.900	Lost	12.600	Lost
30 July	Downing	11.950	Lost	12.175	Lost
6 Aug.	Rural	12.450	Lost	12.800	Lost
6 Aug.	Ohio	12.950	Lost	12.425	Lost
13 Aug.	Downing	12.575	Lost	12.800	Lost
30 July	Ohio	Lost	23.666	Lost	27.500
6 Aug.	Pearl	Lost	27.666	Lost	26.666
13 Aug.	Downing	Lost	21.333	Lost	33.833
20 Aug.	Ohio	Lost	26.000	Lost	25.666
20 Aug.	Rural	Lost	23.333	Lost	24.555
10 Sept.	Pearl	Lost	23.666	Lost	22.000
17 Sept.	Downing	Lost	22.500	Lost	23.000
Tubers, grown at Greeley					
	Ohio	19.580	4.362	20.950	4.262
	Downing	20.700	3.868	19.730	4.195
	Pearl	20.100	4.400	19.760	4.643
	Rural	21.000	4.230	21.200	4.733

TABLE VI. (Cont'd.)

Tubers, grown elsewhere

	Dry Matter	Crude Ash
Peach Blow	23.000	5.154
Rural	25.910	4.658
Rural	20.160	4.333
Pearl	23.830	4.423
Pearl	23.600	4.733
Red McClure	23.910	4.658

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*Crude Ash is in all cases carbonated crude ash

TABLE VII.—ASH OF POTATO VINES, CROP OF 1921

	Ohio Check		Ohio Nitrate		Rural Check		Rural Nitrate	
	30 Aug.	Pure Ash	30 Aug.	Pure Ash	20 Aug.	Pure Ash	20 Aug.	Pure Ash
Carbon	0.220		0.704		0.967		1.091	
Sand	22.445		25,137		35.385		38.788	
Silica	5.799		7.707		4.903		7.119	
Carbon dioxid	18.271		15.752		13.869		11.092	
Chlorin	1.932	3.645	1.682	3.307	1.364	3.019	0.995	2.370
Sulfuric acid	2.046	3.860	2.517	4.949	1.906	4.225	1.538	3.661
Phosphoric acid	2.175	4.103	2.523	4.961	2.222	4.925	2.092	4.980
Aluminic oxid	1.769	3.337	1.480	2.910	1.563	3.464	1.654	3.939
Ferric oxid	0.720	1.360	1.168	2.297	1.514	3.356	1.674	3.986
Manganic oxid (br.)	0.060	0.113	0.074	0.146	0.069	0.153	0.087	0.207
Calcic oxid	11.190	21.109	9.347	18.380	9.926	22.005	9.547	22.731
Magnesic oxid	5.149	9.713	3.962	7.792	5.459	12.102	4.946	11.776
Potassic oxid	27.838	52.514	27.680	54.433	20.775	46.057	19.300	45.951
Sodic oxid	0.563	1.062	0.798	1.570	0.617	1.367	0.392	0.934
Sum	100.177	100.816	100.531	100.745	100.593	100.673	100.315	100.535
O=Cl	0.432	0.816	0.397	0.745	0.308	0.673	0.224	0.535
Total	99.745	100.000	100.152	100.000	100.231	100.000	100.091	100.000

	Downing Check		Downing Nitrate		Pearl Check		Pearl Nitrate	
	3 Sept.	Pure Ash	3 Sept.	Pure Ash	10 Sept.	Pure Ash	10 Sept.	Pure Ash
Carbon	1.144		0.308		0.734		0.587	
Sand	43.020		29.191		34.864		30.473	
Silica	8.164		5.790		6.135		5.461	
Carbon dioxid	8.575		14.875		13.387		16.546	
Chlorin	1.693	4.292	1.742	3.520	2.143	4.798	1.770	3.741
Sulfuric acid	1.829	4.637	2.431	4.910	3.205	7.177	2.284	4.828
Phosphoric acid	0.994	2.520	2.712	5.480	1.240	2.776	1.489	3.147
Aluminic oxid	3.551	9.003	1.738	3.503	2.479	5.551	2.317	4.898
Ferric oxid	1.850	4.690	0.890	1.798	1.257	2.814	1.083	2.289
Manganic oxid (br.)	0.064	0.162	0.060	0.121	0.068	0.152	0.046	0.097
Calcic oxid	9.055	22.957	8.870	17.580	10.368	23.217	11.021	23.299
Magnesic oxid	4.657	11.807	3.869	7.818	6.452	14.448	6.771	14.314
Potassic oxid	16.101	40.827	26.925	54.408	17.635	39.490	20.655	43.666
Sodic oxid	0.030	0.076	0.644	1.301	0.292	0.654	0.267	0.564
Sum	100.727	100.971	100.045	100.430	100.259	101.077	100.770	100.843
O=Cl	0.382	0.968	0.393	0.406	0.483	1.080	0.399	0.843
Total	100.345	100.003	99.652	100.024	99.776	99.997	100.371	100.000

TABLE VIII.—ASH OF POTATO TUBERS, CROP OF 1921

	Pearl Check		Pearl Nitrate		Rural Check		Rural Nitrate	
	25 Oct.	Pure Ash	25 Oct.	Pure Ash	25 Oct.	Pure Ash	25 Oct.	Pure Ash
Carbon	0.139		0.166		0.137		0.091	
Sand	2.434		1.795		0.879		0.609	
Silica	0.853		0.634		0.228		0.570	
Carbon dioxid	19.810		21.389		18.674		19.260	
Chlorin	2.277	2.962	1.897	2.503	2.012	2.518	2.041	2.580
Sulfuric acid	4.237	5.512	3.752	4.950	4.527	5.666	4.300	5.436
Phosphoric acid	8.638	11.237	8.087	10.669	10.977	13.740	10.732	13.567
Aluminic oxid	0.221	0.288	0.134	0.177	0.133	0.167	0.164	0.207
Ferric oxid	0.344	0.477	0.359	0.474	0.220	0.275	0.235	0.297
Manganic oxid (br.)	0.110	0.143	0.093	0.123	0.099	0.124	0.075	0.095
Calcic oxid	1.836	2.389	1.974	2.604	2.226	2.786	2.004	2.534
Magnesic oxid	3.295	4.287	3.350	4.419	3.263	4.084	3.134	3.962
Potassic oxid	55.325	71.974	55.352	73.028	56.427	70.628	56.071	70.887
Sodic oxid	1.099	1.429	1.226	1.618	0.463	0.580	0.804	1.017
Sum	100.616	100.668	100.208	100.565	100.265	100.568	100.090	100.582
O=Cl	0.514	0.668	0.428	0.565	0.454	0.568	0.461	0.582
Total	100.102	100.000	99.780	100.000	99.811	100.000	99.629	100.000

	Ohio Check		Ohio Nitrate		Downing Check		Downing Nitrate	
	25 Oct.	Pure Ash	25 Oct.	Pure Ash	25 Oct.	Pure Ash	25 Oct.	Pure Ash
Carbon	0.134		None		0.113		0.105	
Sand	0.633		0.700		0.664		0.603	
Silica	0.336		0.325		0.497		0.493	
Carbon dioxid	16.098		17.486		17.971		19.589	
Chlorin	4.058	4.898	2.966	3.634	2.734	3.406	2.432	3.136
Sulfuric acid	5.193	6.268	4.707	5.766	5.507	6.860	5.026	6.482
Phosphoric acid	11.833	14.282	12.091	14.813	10.098	12.579	8.922	11.507
Aluminic oxid	0.112	0.136	0.102	0.125	0.120	0.149	0.167	0.215
Ferric oxid	0.226	0.273	0.220	0.270	0.271	0.338	2.088*	0.387
Manganic oxid (br.)	0.063	0.076	0.040	0.050	0.091	0.113	0.105	0.135
Calcic oxid	1.582	1.911	1.646	2.017	1.996	2.486	1.932	2.492
Magnesic oxid	3.893	4.699	3.719	4.556	3.787	4.718	3.446	4.444
Potassic oxid	55.428	66.906	55.208	67.635	55.806	69.520	54.847	70.735
Sodic oxid	1.372	1.655	1.596	1.955	0.481	0.600	0.911	1.175
Sum	100.961	101.105	100.806	100.821	100.136	100.769	100.666	100.708
O=Cl	0.916	1.105	0.669	0.821	0.617	0.769	0.549	0.708
Total	100.045	100.000	100.137	100.000	99.519	100.000	100.117	100.000

*This ash contained iron from storage can and in calculating the pure ash, the iron was assumed to be 0.3 percent, about the average of other samples. An incident of the fire.

TABLE IX.—ASH OF POTATO TUBERS, SPECIAL SAMPLES, 1921

	Rural		Rural		Pearl		Red McClure	
	Virgin Soil	Pure Ash	8 mi. east Ft.Collins	Pure Ash	Mountain	Pure Ash	Mountain	Pure Ash
Carbon	None		None		None		0.113	
Sand	0.72		0.59		0.46		0.275	
Silica	0.28		0.13		0.25		0.180	
Carbon dioxid	21.46		20.46		19.21		18.751	
Chlorin	2.07	2.67	3.71	4.68	1.26	1.57	1.479	1.832
Sulfuric acid	3.68	4.63	5.11	6.45	3.86	4.82	3.540	4.385
Phosphoric acid	8.40	10.88	8.38	10.58	13.34	16.68	14.724	18.240
Aluminic oxid	0.43	0.55	0.49	0.62	0.20	0.25	0.168	0.208
Ferric oxid	0.28	0.36	0.28	0.36	0.21	0.26	0.232	0.288
Manganic oxid (br.)	0.08	0.10	0.09	0.11	0.07	0.09	0.042	0.053
Calcic oxid	1.10	1.42	1.44	1.83	0.80	1.00	0.819	1.014
Magnesic oxid	2.99	3.87	4.04	5.10	4.57	5.73	3.601	4.461
Potassic oxid	58.39	75.58	55.60	70.16	55.43	69.31	55.852	69.187
Sodic oxid	0.42	0.54	0.93	1.18	0.50	0.62	0.605	0.749
Sum	100.20	100.60	101.25	101.07	100.18	100.33	100.381	100.417
O=Cl	0.47	0.60	0.84	1.07	0.28	0.33	0.334	0.417
Total	99.73	100.00	100.41	100.00	99.90	100.00	100.047	100.000
Dry matter		25.91		22.33		23.83		22.99
Ash		4.65		4.94		4.42		4.61

	Rural		Pearl		Peach Blow	
	Colo. Springs	Pure Ash	Mountain	Pure Ash	San Luis Valley	Pure Ash
Carbon	0.046		0.144		0.029	
Sand	0.527		0.454		0.175	
Silica	0.212		0.259		0.176	
Carbon dioxid	22.126		18.114		17.698	
Chlorin	0.821	1.071	1.919	2.366	6.399	7.804
Sulfuric acid	4.116	5.365	3.663	4.517	3.346	4.080
Phosphoric acid	8.581	11.183	14.014	17.280	11.532	14.064
Aluminic oxid	0.520	0.679	0.321	0.396	0.067	0.083
Ferric oxid	0.270	0.352	0.404	0.498	0.165	0.201
Manganic oxid (br.)	0.014	0.018	0.052	0.064	None	None
Calcic oxid	1.105	1.441	0.934	1.152	0.647	0.790
Magnesic oxid	3.092	4.030	3.848	4.745	3.135	3.824
Potassic oxid	58.137	75.769	55.995	69.044	57.545	70.180
Sodic oxid	0.257	0.336	0.383	0.472	0.616	0.751
Sum	99.824	100.244	100.504	100.534	101.519	101.777
O=Cl	0.185	0.244	0.433	0.534	1.444	1.777
Total	99.639	100.000	100.071	100.000	100.075	100.000
Dry matter		19.94		23.60		23.00
Ash		4.43		4.73		5.15

of the albumin nitrogen to the total in the juices is 55.6 for the check plants and 51.2 for the nitrate plants. The proteose and peptone nitrogen is small in amount and probably indicates the rate of changes going on in the plant rather than an essential feature of its composition. In this sense they may be a measure of the rate of growth of the plant at the time of cutting. As previously stated, the vines on all the plots were so rank that no differences could be recognized in vigor, color or other respects.

Observations on the growth of the beet, and especially of the wheat plant, showed remarkable differences in color, size and character of the plants. The wheat plant was large, blue green, broad-leaved, weak stemmed, and susceptible to rust. Oats growing on land adjacent to our potato plots showed these characteristics, especially in color, size and weakness of stems. The deportment of these plants corroborated the results in regard to the presence of large amounts of nitrates obtained by samplings of our check plots and also of the oat ground itself during other seasons, but this ground was not sampled during the season of 1921.

The total nitrogen given for the pulp, which is simply the finely ground plant, contains other forms of nitrogen besides the albumin. In order to obtain these, the albumin was removed and the ammonic, amid and amino nitrogen determined in the filtrate. These forms of nitrogen are present in larger amounts in the samples grown with application of nitrates than in the checks.

The starch in the dried vines was determined by the official method and the results, excluding the exceptional one for Rural vines taken 17 September, 1921, are identical, 1.129 percent. The results for these Rural vines taken 17 September are 11.848 and 10.888 respectively. I have no explanation to offer for these very high results.

All samples were gathered about the same time of day, between 9 and 10:30 a. m. The determinations were all made by the same method and the same analyst. These two determinations are very high, but they agree as well as we could expect two different samples to agree. The results probably correspond closely to the facts.

The Tubers

The determinations of total nitrogen in the tubers, made a few weeks after they were dug, were unfortunately lost and we are compelled to use results obtained with stored potatoes. These show for all of the check plots, 0.3990 percent, while the nitrate plots show 0.4125 percent. The average for other Colorado potatoes examined was 0.3126 percent. The total nitrogen in the juices bears about the same relation, 0.3970 percent in that of the checks against 0.4071 percent in that of those from the nitrate plots, and 0.3250 in the juice of those that we bought.

It will be observed that the total nitrogen in the juice of the last group of potatoes, those obtained from different Colorado localities, appears to be higher than in the whole potato. If the nitrogen actually found in the juice be calculated on the whole tuber, it will be found that the marc should contain 0.0349 percent and the juice 0.2777 percent.

The minimum nitrogen that I have found given for potato tubers is 0.288 and the average is 0.3424 percent. The percentages just given are, for our check plots, 0.3990, the nitrate plots, 0.4125, and for all other samples, 0.3126 percent. The albumin nitrogen for checks averages 0.1139, for our nitrate samples, 0.1195, and the other samples, 0.1019 percent. The ratios for the albumin to the total nitrogen are respectively 28.69, 29.35 and 32.59. This ratio is slightly higher in the tubers from our nitrate plots than in those from our check plots, but is decidedly lower for our Greeley samples than for the ones we purchased. The highest ratio found, 46.42, was in one of these purchased samples, also the lowest one, in the Red McClure grown in the mountains, in which the total nitrogen was relatively high.

The nitric nitrogen in these purchased samples, if it were ever present, had entirely disappeared before they were analyzed. While this is not impossible, as subsequent data will indicate, it is not probable that it would be the case in all four samples that were examined for this form of nitrogen.

The examination of the tubers for other than the protein forms of nitrogen gave results that are difficult to interpret. The quantities of nitrogen involved are small and their determinations somewhat difficult. The fresh samples were analyzed in September and again in October and a third time in March after storage at 34° F. The ammonic nitrogen in the fresh samples from the check plots was 0.00988, of those from the nitrate plots, 0.00940 percent, and for the stored samples, 0.01350 and 0.01117 percent respectively. The average for all of the ammonic nitrogen determinations made was 0.00999 percent.

The amid nitrogen in the fresh check samples averaged 0.05155 and in the nitrate samples, 0.05077, and in the stored samples, 0.04819 and 0.0539 percent respectively. The average amid nitrogen found in all fresh samples, not including nitrate samples, was 0.05043, and in all nitrate samples, 0.05181 percent.

The preceding statements pertain to our Greeley samples. The corresponding data for other Colorado samples are as follows: Ammonic nitrogen in seven samples fresh potatoes, 0.01084, in four samples fresh potatoes, 0.01166, in the same after storage, 0.01110 percent. Amid nitrogen in seven samples, 0.04835, in four fresh samples, 0.05259, in the same after storage, 0.03968 percent. Amino nitrogen in seven samples fresh potatoes, 0.08171, in four samples, 0.09334, in the same after three months' storage at 34° F., 0.06689 percent.

The changes in the general forms of nitrogen in the potato, total albumin and nitric nitrogen, cannot be followed during storage in this crop as the notes on the fresh potatoes were lost, but we have the ammonia forms. The ammonia nitrogen increased in both series of samples, checks and nitrates; the amid decreased slightly in the checks but shows an increase in the nitrate samples, and the amino shows an increase in both series. These changes are not so marked in our purchased samples. These tend to show a loss in these forms of nitrogen but they are generally smaller than in the case of the Greeley samples.

The starch in our samples is low to begin with and shows a considerable loss on keeping with the development of sugars up to 4.2 percent of the sample. The samples from the nitrate plots are poorer in starch than those from the check plots. The starch is perhaps a little higher in our purchased samples, but they are also low and changed appreciably in storage.

Cooking Tests with the Crop of 1921

I do not know of any conventional standards by which we may judge of the cooking qualities of potatoes. I have taken mealiness as opposed to sogginess, the color, odor and taste of the boiled potato, as my criteria. While some may object to a high degree of mealiness in a potato, I have considered it a desirable quality. In regard to color and the absence of any decided and unpleasant taste, a strong one, there will be general agreement. I chose boiling rather than baking because it is the more common method of preparation. The time required for cooking varied for different samples. This factor was not taken into consideration, for our object was to ascertain the differences in quality, if such existed, between those grown with and without the application of nitrates.

The analytical data given for the composition and deportment of this soil and the composition of the plants, including the tubers, justify the anticipation, if the quality be influenced by the supply of nitrates available to the plants, that our samples would be very much alike whether good or poor. If the nitrates suppress the quality, then they should all be poor, and the addition of nitrates, 800 pounds to the acre in this case, could only make them poorer. If, on the other hand, the nitrates have a beneficial effect, this 800 pounds should improve the quality.

There is one consideration that should not be passed over without mention, namely, the possible, in our case easily probable condition, that the whole crop was diseased. A diseased condition of the plant probably would not enhance the quality of the tubers. I have nowhere seen a statement giving the effects of mosaic, for instance, upon the cooking quality of the tubers. In the event that we had diseased plants growing on land to which we had applied nitrates, the properties of the tubers should be the product of all of the factors affecting them, and if those grown with the application of nitrates were inferior to the others, we should have to assume that the nitrates themselves had produced these results or had intensified those of the disease.

It is not to be inferred from what has just been said that our plants showed the presence of mosaic to such an extent as to justify the assumption that the crop was affected in such degree. It must, however, also be remembered that the disease may be present but the vines so stimulated in all of their functions by the conditions of the soil, atmosphere, and sunshine that it may be no easy task to definitely ascertain the actual condition of the plant. In fact, the overstimulated condition of the plant may establish a serious weakness in all of our observations.

As the results of 68 tests, we found the potatoes grown with application of nitrates poorer than those grown without them. There was but one tuber among those from the check plots that was as poor as those grown with nitrates.

We were compelled by the uniformly poor quality of our potatoes to obtain other samples in order to ascertain by such general comparisons how inferior we should consider our potatoes; for this purpose I used Russet Burbank, Brown Beauty, Peachblow, Early Ohio and Pearl. These were exhibition samples from other sections of the state. The Brown Beauty was poor in color and had a strong odor and taste; it was an inferior potato. The other samples, especially the Peachblow and Burbank, were good. The Early Ohio and Pearls were very much better than ours, whether grown with or without the application of nitrates.

The characteristics of our potatoes without regard to variety were sogginess, mealiness was almost wholly absent, objectionable color, often quite strongly yellow, a decided strong odor and a strong taste. These properties were common to all of our samples but were much more pronounced in those grown with application of nitrates than the others. All tests were made with potatoes that had been dug three weeks and stored at a temperature of 34° F. The potatoes were cooked both with and without paring but we could see no difference.

The following statements are, in a measure, anticipatory and perhaps self-evident. It is regrettable that the preceding data are fragmentary to the degree that we find them, owing to the loss of much of our data on the fresh material.

We are compelled to regret this more than the reader can appreciate from the fact that this season's work showed with more definiteness than that of either of the others, during which we have studied this subject, the effects of the nitrates on the composition of the plants and tubers. These results were more consistent thruout the season, as well as more pronounced, than during either of the other years of our study. The reasons for this are not apparent. The only feature of the experiment that possibly suggests an explanation worthy of consideration is that we used the same plot for each individual experiment that we used the preceding year and we did not have the interfering factors of fresh land and a green manuring to contend with. The regret is that the loss of our records very greatly lessens the value of our most satisfactory year's work.

The Season of 1922

Our record for the year of 1922 is as unsatisfactory as that for 1921,—not because we lost any records, but because our work was seriously interfered with by the rebuilding operations which prevented us from doing any analytical work from mid-September until the following March. Our samples were, of course, stored at 34° F. in the meantime.

The soil was sampled weekly from May until September for the determination of the nitric nitrogen. From the 12 May until 9 June samples of the field were taken, from the 16 June to 9 September the check plots and blanks were sampled. In our previous sampling we had no blanks but sampled only the check plots. This year we had blanks the same size of the plots, which were cultivated fallow. These were had to furnish a measure of the influence exerted on this factor by the plants in the check plots. An examination of the results given in the following table shows that until well along in August the nitric nitrogen was as high or higher in the check plots than in the blanks or fallow plots. The plants increased the nitrates in the surface soil by protecting the soil, or possibly by favoring the formation of nitrates in other ways. It would seem probable that this was due to the protection given the soil from sunshine and washing. Be this as it may, the table shows that it was well along in August before the nitrates in the blanks became higher than in the checks.

TABLE X.—NITRIC NITROGEN IN PLOTS TAKEN TO DEPTH OF 4 INCHES DURING SEASON OF 1922, IN P.P.M.

	Samples taken before planting					Spring Canyon*
	No. 1	No. 2	No. 3	No. 4	No. 5	
12 May	6.7	10.0	6.0	8.0	1.0	8.0
19 May	10.0	8.0	8.0	8.0	8.3	8.0
26 May	10.4	10.5	8.2	8.7	10.0	....
2 June	12.6	15.5	12.7	13.9	12.6	....
9 June	17.7	16.4	13.4	18.7	17.7	8.5
	Rural	N. Blank	Pearl	Downing	S. Blank	Ohio
16 June	22.8	22.7	22.4	21.1	20.5	23.3	....
23 June	22.8	22.7	22.6	23.1	24.2	25.8	....
30 June	13.0	16.9	19.6	16.8	20.4	24.5	11.3
7 July	31.4	19.4	34.5	18.8	17.8	22.5	11.0
14 July	38.8	41.6	28.6	27.5	29.5	26.9	13.8
22 July	23.7	17.4	23.8	18.2	18.4	23.3	8.1
29 July	28.8	20.3	23.8	17.4	18.5	24.7	10.7
8 Aug.	30.6	15.7	15.6	16.3	17.8	20.0	....
12 Aug.	29.3	29.3	22.2	21.9	26.5	25.1	9.2
19 Aug.	25.6	25.0	20.8	18.7	29.0	28.5	....
26 Aug.	24.7	33.4	13.7	15.7	28.3	19.0	7.3
2 Sept.	25.5	29.6	14.7	15.7	26.0	24.7	....
9 Sept.	25.3	26.3	18.1	23.3	33.3	24.5	....

*Spring Canyon is in the foothills.

TABLE XI.—DRY MATTER AND ASH IN CROP, 1922

Vines*

Date	Variety	Check		Nitrate	
		Dry Matter Percent	Ash Percent	Dry Matter Percent	Ash Percent
5 Aug.	Downing	13.475	29.969	14.400	30.474
5 Aug.	Ohio	13.750	33.105	12.475	30.810
12 Aug.	Pearl	11.650	22.445	12.225	24.149
12 Aug.	Rural	12.575	25.304	12.550	24.918
19 Aug.	Downing	12.550	21.833	12.350	22.118
19 Aug.	Ohio	12.100	24.633	12.100	24.632
26 Aug.	Pearl	12.300	20.552	12.280	20.049
26 Aug.	Rural	13.550	22.634	13.050	21.025
2 Sept.	Downing	19.250	24.510	23.150	23.530
2 Sept.	Ohio	19.900	24.936	18.850	26.050
9 Sept.	Pearl	15.175	16.536	14.250	16.334
9 Sept.	Rural	15.525	19.701	15.450	19.406
		Tubers			
Grown at Greeley	Downing	21.98	5.020	21.50	5.007
	Ohio	19.85	5.604	20.50	5.535
	Pearl	20.83	4.816	21.05	5.160
	Rural	21.28	5.011	19.85	5.189
Grown at Spring Canyon	Downing	23.95	5.701		
	Ohio	21.38	5.499		
	Pearl	21.93	6.200		

*No vines taken after 9 Sept.; rebuilding operations closed laboratory.

TABLE XII.—GENERAL FORMS OF NITROGEN IN VINES, CROP OF 1922

Variety	Fertilizer	Date	Dry Matter	Marc	Juice	Sp. Gr.	Total Nitrogen		Protein Nitrogen			Nitric Nitrogen
							Pulp	Juice	Albumin	Proteose	Peptone	
Ohio	Check	22 July	10.375	5.68	94.32	1.018	0.4158	0.2659	0.1262	0.0025	0.0111	0.1295
Ohio	Nitrate	22 July	10.320	5.26	94.74	1.014	0.3741	0.3156	0.1649	0.0034	0.0069	0.1140
Downing	Check	22 July	12.375	7.27	92.73	1.022	0.4242	0.2604	0.0826	0.0044	0.0178	.0983
Downing	Nitrate	22 July	10.725	7.02	92.98	1.018	0.3850	0.2621	0.0811	....	0.0084	0.1031
Pearl	Check	29 July	10.725	6.63	93.37	1.018	0.4310	0.2784	0.1297	0.0100	0.0187	0.0850
Pearl	Nitrate	29 July	10.675	6.73	93.27	1.019	0.3799	0.2781	0.1367	....	0.0288	0.0848
Rural	Check	29 July	10.775	7.30	92.70	1.015	0.3889	0.1777	0.0387	....	0.0201	0.0722
Rural	Nitrate	29 July	10.825	6.65	93.35	1.015	0.3895	0.2470	0.1072	....	0.0190	0.0735
Downing	Check	5 Aug.	13.475	8.47	91.53	1.024	0.3814	0.2861	0.1264	....	0.0088	0.0986
Downing	Nitrate	5 Aug.	14.400	9.10	90.90	1.023	0.3906	0.2948	0.1356	0.0040	0.0190	0.0867
Ohio	Check	5 Aug.	13.750	8.55	91.45	1.022	0.3892	0.2809	0.1163	0.0167	0.0050	0.0842
Ohio	Nitrate	5 Aug.	12.475	7.78	92.22	1.019	0.3920	0.2724	0.1144	0.0085	0.0074	0.1080
Pearl	Check	12 Aug.	11.650	6.71	93.29	1.018	0.3976	0.2646	0.1152	0.0092	0.0043	0.0776
Pearl	Nitrate	12 Aug.	12.225	7.09	92.91	1.022	0.3970	0.2968	0.1511	0.0077	0.0096	0.0830
Rural	Check	12 Aug.	12.575	8.05	91.95	1.017	0.4018	0.2157	0.0810	0.0027	0.0159	0.0738
Rural	Nitrate	12 Aug.	12.550	8.44	91.56	1.017	0.3766	0.27.60	0.0731	....	0.0176	0.0886
Ohio	Check	19 Aug.	12.100	6.66	93.34	1.025	0.3640	0.2627	0.1137	0.0164	0.0131	0.0929
Ohio	Nitrate	19 Aug.	12.100	6.58	93.42	1.020	0.3780	0.2911	0.1218	0.0120	0.0075	0.1120
Downing	Check	19 Aug.	12.550	7.63	92.37	1.024	0.3528	0.2375	0.0964	0.0072	0.0124	0.0940
Downing	Nitrate	19 Aug.	12.350	7.63	92.37	1.024	0.3640	0.2627	0.1187	0.0080	0.0059	0.0975
Pearl	Check	26 Aug.	12.300	8.18	91.82	1.018	0.3528	0.1889	0.0645	....	0.0114	0.1028
Pearl	Nitrate	26 Aug.	12.280	7.77	92.23	1.018	0.3486	0.2930	0.1370	0.0034	0.0131	0.1091
Rural	Check	26 Aug.	13.550	9.02	90.98	1.022	0.3514	0.1735	0.0533	....	0.0127	0.0732
Rural	Nitrate	26 Aug.	13.050	9.18	90.82	1.022	0.3889	0.1821	0.0402	0.0114	0.0184	0.0869
Ohio	Check	2 Sept.	19.900	13.73	86.27	1.038	0.4010	0.2240	0.0404	0.0213	0.0151	0.1324
Ohio	Nitrate	2 Sept.	18.850	11.91	88.09	1.038	0.4340	0.2762	0.0650	0.0150	0.0263	0.1757
Downing	Check	2 Sept.	19.250	12.97	87.03	1.035	0.3385	0.2522	0.0321	0.0100	0.0288	0.1848
Downing	Nitrate	2 Sept.	23.150	15.46	84.54	1.044	0.4427	0.3056	0.0215	0.0284	0.0193	0.1938
Pearl	Check	9 Sept.	15.175	9.57	90.43	1.030	0.3788	0.2434	0.1036	0.0005	0.286	0.0804
Pearl	Nitrate	9 Sept.	14.250	10.35	89.65	1.028	0.3898	0.2657	0.0955	0.0050	0.0167	0.1052
Rural	Check	9 Sept.	15.525	10.28	89.72	1.030	0.3567	0.1825	0.0549	0.0082	0.0082	0.0682
Rural	Nitrate	9 Sept.	15.450	9.98	90.02	1.026	0.3777	0.1695	0.0139	0.0049	0.0230	0.1017

TABLE XIII.—AMMONIA, AMID AND AMINO NITROGEN IN VINES, CROP OF 1922

Date	Variety	Ammonia		Amid		Amino		
		Check	Nitrate	Check	Nitrate	Check	Nitrate	
22 July	Ohio	0.00378	0.00427	0.00294	0.00280	0.01494	0.01272	
5 Aug.	Ohio	0.00525	0.00504	0.00483	0.00434	0.01717	0.01623	
19 Aug.	Ohio	0.00125	0.00266	0.00245	0.00336	0.01109	0.01248	
2 Sept.	Ohio	0.00441	0.00581	0.00595	0.00791	0.01495	0.01822	
20 July	Ohio	0.00658	....	0.00322	....	0.01518	....	Spring Canyon
29 July	Pearl	0.00644	0.00672	0.00553	0.00551	0.01522	0.01774	
12 Aug.	Pearl	0.00385	0.00483	0.00595	0.00469	0.01520	0.01478	
26 Aug.	Pearl	0.00252	0.00371	0.00350	0.00476	0.01043	0.01241	
9 Sept.	Pearl	0.00518	0.00427	0.00504	0.00679	0.01204	0.01387	
20 July	Pearl	0.01120	....	0.00728	....	0.01685	....	Spring Canyon
22 July	Downing	0.00339	0.00490	0.00420	0.00511	0.01887	0.01683	
5 Aug.	Downing	0.00287	0.00287	0.00343	0.00308	0.01261	0.01155	
19 Aug.	Downing	0.00315	0.00357	0.00273	0.00273	0.01137	0.01332	
2 Sept.	Downing	0.00406	0.00567	0.00455	0.00462	0.01290	0.01436	
20 July	Downing	0.00938	....	0.00364	....	0.01556	....	Spring Canyon
29 July	Rural	0.00749	0.00952	0.00434	0.00490	0.02047	0.01925	
12 Aug.	Rural	0.00574	0.00567	0.00455	0.00364	0.01752	0.01686	
26 Aug.	Rural	0.00476	0.00560	0.00476	0.00490	0.01534	0.01900	
9 Sept.	Rural	0.00490	0.00497	0.00644	0.00525	0.01721	0.01473	
20 July	Rural	0.01232	....	0.00791	....	0.02509	....	Spring Canyon

TABLE XIV.—GENERAL FORMS OF NITROGEN, TUBERS, CROP OF 1922 March, 1923*

Variety	Fertilizer	Dry Matter	Marc	Juice	Specific Gravity	Total Nitrogen		Protein Nitrogen			Nitric Nitrogen
						Pulp	Juice	Albumin	Proteose	Peptone	
Pearl	Check	20.83	13.29	86.71	1.040	0.3864	0.3551	0.1520	....	0.0196	None
Pearl	Nitrate	21.05	13.70	86.30	1.040	0.4396	0.4078	0.1591	0.0369	0.0544	None
Ohio	Check	19.85	13.23	86.77	1.036	0.4121	0.3881	0.0918	0.0468	0.0182	0.0028
Ohio	Nitrate	20.55	13.77	86.23	1.038	0.4609	0.4536	0.1306	0.0348	0.0323	0.0042
Downing	Check	21.98	15.10	84.90	1.041	0.4466	0.4351	0.1259	0.0347	0.0244	0.0014
Downing	Nitrate	21.50	14.82	85.18	1.040	0.4036	0.3922	0.1185	0.0332	0.0475	0.0031
Rural	Check	21.28	14.29	85.71	1.038	0.3780	0.3584	0.0916	0.0425	0.0320	None
Rural	Nitrate	19.85	12.97	87.21	1.040	0.3878	0.4314	0.0951	0.0482	0.0097	None
Ohio	Spring Canyon Checks	21.38	13.75	86.25	1.042	0.4816	0.5006	0.1193	0.0344	0.0446	0.0041
Pearl		21.93	13.55	86.45	1.045	0.5180	0.4857	0.1552	0.0586	0.0324	0.0038
Rural		20.03	12.12	87.88	1.048	0.4692	0.4442	0.1268	0.0418	0.0462	0.0144
Downing		23.95	16.14	83.86	1.045	0.5446	0.5640	0.1635	0.0456	0.0389	0.0061

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*The tubers could not be analyzed at digging time. Owing to rebuilding operations they were put in cold storage at 34° F. until March, 1923. Their apparent condition on removal was very good, but considerable changes take place during storage.

TABLE XV.—AMMONIA, AMID AND AMINO NITROGEN IN TUBERS, CROP OF 1922*

	Ammonia		Amid		Amino		
Variety	Check	Nitrate	Check	Nitrate	Check	Nitrate	
Ohio	0.01442	0.01260	0.04606	0.05320	0.10361	0.11764	
Ohio	0.01470	....	0.05978	....	0.12622	....	Spring Canyon
Pearl	0.01022	0.00896	0.03598	0.04200	0.07477	0.09457	
Pearl	0.00938	....	0.04760	....	0.10133	....	Spring Canyon
Downing	0.01302	0.01400	0.04900	0.04382	0.10371	0.08654	
Downing	0.01330	....	0.06174	....	0.12251	....	Spring Canyon
Rural	0.01190	0.01092	0.03962	0.04354	0.07841	0.08554	
Rural	0.01260	....	0.05278	....	0.09069	....	Spring Canyon

*These potatoes had been kept in cold storage at 34° F. until March, 1923. The percentages are, of course, on the potatoes as removed from storage.

TABLE XVI.—STARCH AND SUGAR IN POTATO TUBERS, CROP OF 1922*

	Starch		Reducing Sugars		Total Sugars		
Variety	Check	Nitrate	Check	Nitrate	Check	Nitrate	
Ohio	10.87	10.70	0.456	0.818	0.723	1.878	
Ohio	10.28	....	0.958	....	2.514	....	Spring Canyon
Pearl	10.25	10.13	1.442	1.196	3.378	3.198	
Pearl	10.02	....	0.163	....	1.557	....	Spring Canyon
Downing	11.98	12.62	1.578	1.888	2.127	2.724	
Downing	13.19	....	0.974	....	1.605	....	Spring Canyon
Rural	11.34	9.72	1.524	1.578	2.697	2.754	
Rural	8.10	....	0.646	....	3.600	....	Spring Canyon

*The potatoes of this season's crop had to be stored and these results simply indicate the conditions at the time the analyses were made. All alike were of very low starch content, certainly due to deterioration as shown in the case of the 1921 crop.

TABLE XVII.—ASH OF POTATO VINES, CROP OF 1922, GREELEY

	Ohio Check		Ohio Nitrate		Downing Check		Downing Nitrate	
	5 Aug.	Pure Ash	5 Aug.	Pure Ash	5 Aug.	Pure Ash	5 Aug.	Pure Ash
Carbon	0.133		0.109		1.070		1.344	
Sand	42.142		34.641		33.134		38.209	
Silica	6.037		4.594		6.402		7.729	
Carbon dioxid	7.035		10.204		11.008		9.299	
Chlorin	1.757	3.907	2.163	4.274	2.100	4.339	1.953	4.235
Sulfuric acid	2.687	5.976	2.198	4.343	2.072	4.280	1.933	4.197
Phosphoric acid	1.690	3.758	2.149	4.246	1.648	3.406	1.737	3.765
Aluminic oxid	3.362	7.477	3.042	6.010	2.067	4.271	1.713	3.713
Ferric oxid	1.632	3.603	1.432	2.829	1.586	3.276	1.684	3.660
Manganic oxid (br.)	0.058	0.129	0.046	0.091	0.110	0.227	0.061	0.133
Calcic oxid	8.119	18.057	8.840	17.466	10.027	20.715	9.990	21.668
Magnesic oxid	3.357	7.466	3.490	6.895	5.100	10.539	4.785	10.342
Potassic oxid	22.246	49.475	27.324	53.986	23.790	49.156	22.016	47.728
Sodic oxid	0.453	1.007	0.417	0.824	0.380	0.786	0.699	1.516
Sum	100.708	100.882	100.649	100.944	100.494	100.995	100.149	100.957
O=Cl	0.396	0.882	0.488	0.964	0.483	0.995	0.441	0.957
Total	100.312	100.000	100.161	100.000	100.011	100.000	99.708	100.000

	Pearl Check		Pearl Nitrate		Rural Check		Rural Nitrate	
	12 Aug.	Pure Ash	12 Aug.	Pure Ash	12 Aug.	Pure Ash	12 Aug.	Pure Ash
Carbon	0.469		0.726		0.407		0.883	
Sand	21.604		24.473		27.635		24.128	
Silica	5.587		7.912		7.595		10.623	
Carbon dioxid	12.307		9.916		11.096		8.342	
Chlorin	2.438	4.054	2.417	4.277	2.216	4.142	2.018	3.578
Sulfuric acid	3.298	5.483	2.781	4.921	2.917	5.452	2.913	5.165
Phosphoric acid	2.388	3.970	1.903	3.363	2.802	5.237	2.779	4.963
Aluminic oxid	2.222	3.694	2.737	4.844	3.279	6.128	2.888	5.121
Ferric oxid	1.423	2.366	1.854	3.287	1.510	2.822	1.463	2.594
Manganic oxid (br.)	0.170	0.283	0.110	0.195	0.069	0.129	0.068	0.121
Calcic oxid	11.404	18.960	10.733	18.995	10.365	19.372	11.384	20.186
Magnesic oxid	6.287	10.453	6.238	11.040	5.602	10.470	6.497	11.521
Potassic oxid	30.320	50.411	27.980	49.518	25.114	46.938	26.382	46.781
Sodic oxid	0.746	1.240	0.298	0.526	0.131	0.245	0.439	0.778
Sum	100.933	100.914	100.078	100.961	100.738	100.935	100.827	100.808
O=Cl	0.550	0.914	0.544	0.961	0.500	0.935	0.455	0.808
Total	100.383	100.000	99.534	100.000	100.238	100.000	100.372	100.000

TABLE XVII, (cont'd.)

	Ohio Check		Ohio Nitrate		Downing Check		Downing Nitrate	
	19 Aug.	Pure Ash	19 Aug.	Pure Ash	19 Aug.	Pure Ash	19 Aug.	Pure Ash
Carbon	0.404		0.597		0.701		0.478	
Sand	21.239		16.667		15.799		19.587	
Silica	5.379		4.162		4.294		4.294	
Carbon dioxid	12.543		16.776		14.853		15.014	
Chlorin	2.197	3.621	2.729	4.425	3.784	5.879	3.002	4.991
Sulfuric acid	4.175	7.870	4.095	6.640	3.761	5.829	3.395	5.645
Phosphoric acid	1.873	3.087	2.040	3.308	2.138	3.313	2.052	3.412
Aluminic oxid	2.387	3.934	1.716	2.782	1.577	2.444	1.431	2.378
Ferric oxid	1.151	1.897	0.960	1.557	0.707	1.096	1.076	1.804
Manganic oxid (br.)	0.058	0.096	0.049	0.079	0.066	0.102	0.078	0.129
Calcic oxid	13.083	21.563	13.321	21.598	12.860	19.930	12.155	20.214
Magnesic oxid	5.164	8.511	4.840	7.848	8.105	12.561	7.908	13.147
Potassic oxid	30.286	49.915	32.370	52.484	31.793	49.272	29.278	48.677
Sodic oxid	0.196	0.323	0.171	0.277	0.589	0.912	0.450	0.748
Sum	100.735	100.817	100.493	100.998	101.027	101.338	100.198	101.145
O=Cl	0.495	0.817	0.615	0.998	0.854	1.338	0.678	1.145
Total	100.240	100.000	99.878	100.000	100.173	100.000	99.521	100.000

	Pearl Check		Pearl Nitrate		Rural Check		Rural Nitrate	
	26 Aug.	Pure Ash	26 Aug.	Pure Ash	26 Aug.	Pure Ash	26 Aug.	Pure Ash
Carbon	0.496		0.637		0.535		0.579	
Sand	17.938		16.293		26.155		20.531	
Silica	5.596		3.784		6.644		7.821	
Carbon dioxid	12.597		14.797		11.953		11.338	
Chlorin	3.231	5.132	4.252	5.391	2.649	4.817	2.264	3.774
Sulfuric acid	4.380	6.957	3.748	6.584	3.892	7.077	3.689	6.150
Phosphoric acid	1.907	3.029	2.303	3.566	2.202	4.004	2.485	4.143
Aluminic oxid	1.744	2.770	2.254	3.491	2.655	4.828	2.293	3.823
Ferric oxid	1.244	1.967	0.904	1.399	1.274	2.316	1.285	2.143
Manganic oxid (br.)	0.108	0.171	0.105	0.163	0.079	0.143	0.117	0.195
Calcic oxid	14.887	23.644	13.593	21.052	12.811	23.299	14.400	24.006
Magnesic oxid	7.027	11.161	7.458	11.547	7.119	12.946	8.767	14.615
Potassic oxid	29.020	46.092	30.309	46.936	22.417	40.763	25.176	41.970
Sodic oxid	0.143	0.227	0.701	1.085	0.492	0.894	0.020	0.033
Sum	100.318	101.159	100.835	101.214	100.877	101.087	100.765	100.852
O=Cl	0.724	1.159	0.785	1.214	0.597	1.087	0.510	0.852
Total	99.589	100.000	100.050	100.000	100.280	100.000	100.255	100.000

TABLE XVII, (cont'd.)

	Ohio Check		Ohio Nitrate		Downing Check		Downing Nitrate	
	2 Sept.	Pure Ash	2 Sept.	Pure Ash	2 Sept.	Pure Ash	2 Sept.	Pure Ash
Carbon	0.598		0.751		0.651		0.500	
Sand	19.389		19.025		17.963		15.360	
Silica	4.251		4.241		4.634		3.860	
Carbon dioxid	14.209		16.859		16.357		18.871	
Chlorin	2.822	4.572	2.775	4.696	3.775	6.307	3.278	5.342
Sulfuric acid	5.454	8.835	3.873	6.554	3.525	5.889	2.956	4.817
Phosphoric acid	1.373	2.224	1.395	2.361	0.976	1.631	0.999	1.628
Aluminic oxid	1.959	3.174	2.082	3.523	0.877	1.465	0.520	0.847
Ferric oxid	0.981	1.589	0.933	1.579	1.055	1.763	0.810	1.321
Manganic oxid (br.)	0.059	0.096	0.046	0.078	0.062	0.103	0.061	0.100
Calcic oxid	14.358	23.259	13.528	22.893	13.693	22.876	14.584	23.771
Magnesic oxid	5.340	8.651	4.647	7.864	8.456	14.128	7.840	12.778
Potassic oxid	29.895	48.430	30.201	51.107	27.667	46.221	30.547	49.789
Sodic oxid	0.125	0.202	0.239	0.404	0.624	1.042	0.499	0.794
Sum	100.813	101.032	100.595	101.059	100.315	101.427	100.685	101.187
O=Cl	0.636	1.032	0.626	1.059	0.852	1.427	0.740	1.187
Total	100.177	100.000	99.969	100.000	99.463	100.000	99.945	100.000

	Pearl Check		Pearl Nitrate		Rural Check		Rural Nitrate	
	9 Sept.	Pure Ash	9 Sept.	Pure Ash	9 Sept.	Pure Ash	9 Sept.	Pure Ash
Carbon	0.221		0.290		0.507		0.382	
Sand	10.607		10.607		23.440		20.800	
Silica	2.852		3.848		6.571		7.275	
Carbon dioxid	16.380		14.876		12.457		12.098	
Chlorin	4.476	6.415	4.622	6.571	2.800	4.877	2.887	4.832
Sulfuric acid	6.258	8.969	6.020	8.559	4.736	8.249	4.446	7.445
Phosphoric acid	1.230	1.763	1.657	2.356	1.929	3.360	1.848	3.094
Aluminic oxid	3.359	4.814	2.161	3.072	2.193	3.820	2.355	3.943
Ferric oxid	0.728	1.043	0.770	1.095	1.336	2.327	1.215	2.095
Manganic oxid (br.)	0.085	0.122	0.073	0.104	0.129	0.225	0.096	0.161
Calcic oxid	15.687	22.482	15.317	21.777	13.530	23.567	14.267	23.890
Magnesic oxid	8.561	12.269	9.593	13.354	8.505	14.814	8.790	14.719
Potassic oxid	29.672	42.525	30.862	43.877	22.320	38.876	24.336	40.750
Sodic oxid	0.721	1.042	0.506	0.719	0.566	0.986	0.097	0.162
Sum	100.846	101.444	101.002	101.484	101.109	101.101	100.928	101.091
O=Cl	1.010	1.444	1.043	1.484	0.631	1.101	0.651	1.091
Total	99.836	100.000	99.959	100.000	100.388	100.000	100.277	100.000

TABLE XVIII.—ASH OF POTATO TUBERS, CROP OF 1922, GREELEY

	Ohio Check		Ohio Nitrate		Downing Check		Downing Nitrate	
	10 Oct.	Pure Ash	10 Oct.	Pure Ash	10 Oct.	Pure Ash	10 Oct.	Pure Ash
Carbon	0.160		0.092		0.194		0.276	
Sand	0.663		0.506		0.249		0.295	
Silica	0.312		0.215		0.144		0.230	
Carbon dioxid	14.682		14.968		17.686		17.757	
Chlorin	4.018	4.767	4.108	4.876	3.232	3.960	3.178	3.889
Sulfuric acid	5.904	7.004	5.899	7.002	5.953	7.292	6.364	7.788
Phosphoric acid	13.059	15.493	13.074	15.518	9.128	11.180	9.119	11.160
Aluminic oxid	0.209	0.248	0.149	0.177	0.059	0.072	0.094	0.115
Ferric oxid	0.207	0.246	0.181	0.215	0.176	0.216	0.141	0.173
Manganic oxid (br.)	0.257	0.305	0.196	0.233	0.131	0.160	0.117	0.143
Calcic oxid	1.604	1.903	1.591	1.888	1.609	1.971	1.680	2.056
Magnesic oxid	3.718	4.411	3.927	4.661	4.077	4.994	4.211	5.154
Potassic oxid	54.730	64.929	54.675	64.894	57.546	70.489	56.504	69.152
Sodic oxid	1.493	1.771	1.378	1.636	0.456	0.559	1.019	1.247
Sum	101.016	101.077	100.959	101.100	100.640	100.893	100.985	100.877
O=Cl	0.907	1.077	0.927	1.100	0.729	0.893	0.717	0.877
Sum	100.100	100.000	100.032	100.000	99.911	100.000	100.268	100.000

	Pearl Check		Pearl Nitrate		Rural Check		Rural Nitrate	
	10 Oct.	Pure Ash	10 Oct.	Pure Ash	10 Oct.	Pure Ash	10 Oct.	Pure Ash
Carbon	0.056		0.048		0.119		0.389	
Sand	0.336		0.515		0.744		0.696	
Silica	0.116		0.167		0.363		0.392	
Carbon dioxid	17.208		18.003		17.211		16.610	
Chlorin	2.607	3.185	2.283	2.814	2.847	3.506	2.573	3.074
Sulfuric acid	7.142	8.726	6.569	8.098	6.263	7.713	5.963	7.294
Phosphoric acid	8.748	10.689	8.316	10.250	10.266	12.642	10.352	12.662
Aluminic oxid	0.143	0.179	0.537	0.662	0.210	0.259	0.348	0.426
Ferric oxid	0.148	0.181	0.181	0.223	0.246	0.303	0.224	0.274
Manganic oxid (br.)	0.061	0.073	0.060	0.074	0.073	0.089	0.083	0.102
Calcic oxid	1.284	1.569	1.564	1.929	1.495	1.842	1.808	2.211
Magnesic oxid	3.984	4.861	3.809	4.695	3.717	4.517	3.517	4.302
Potassic oxid	57.934	70.790	58.084	71.600	56.728	69.858	57.004	69.724
Sodic oxid	0.376	0.459	0.235	0.290	None	None	0.508	0.621
Sum	100.143	100.712	100.371	100.635	100.282	100.789	100.407	100.690
O=Cl	0.588	0.712	0.515	0.635	0.642	0.789	0.567	0.690
Total	99.555	100.000	99.856	100.000	99.640	100.000	99.840	100.000

If we deduct the sand from the crude ash as determined, we obtain an approximate figure for the crude ash of the clean vine and we see that the amount changed but little between 5 August and 2 September for two varieties, or from 12 August to 9 September for two other varieties. The amount of crude ash ranged between 15 and 20 percent. The Ohios and Downings were practically, if not wholly, mature by 9 September. The Pearls and Rurals were not. We took no samples after 9 September because our laboratory was closed by the 15th.

We observe that the crude carbonated ash of the Downings and Ohios carried about 9.4 percent carbon dioxid on 5 August and 16.0 percent on 2 September, 1922. The phosphoric acid had fallen in the meantime from 3.8 to 1.9 percent, or by one-half. The lime increased from 19.5 to 23.3, the magnesia from 8.8 to 10.8 percent. The potash fell from 50.06 to 48.9 percent. The averages for the Pearls and Rurals on 12 August and 9 September respectively were, carbon dioxid 10.4 and 14.0 percent, for the phosphoric acid 4.2 and 2.6 percent, for the lime 19.4 and 23.3 percent, for the magnesia 10.9 and 13.8 percent. The potash fell from 48.4 to 44.0 percent.

The carbon dioxid percentages given in these approximations have been calculated on the crude ashes, but the others are for pure ashes. These averages are based on the nearest one-tenth percent. It would be folly to pretend to any great degree of accuracy when it is evident that these ashes of field samples of vines are contaminated with dust and soil particles to such an extent that we attach no value to the ferric and aluminic oxide present. We do not believe, however, that the features to which attention has been called have been distorted in any serious degree.

The table giving the Dry Matter and Ash, Table XI, taken with Table XVII, shows that the samples are very much alike. The varieties show some differences but to what extent these are accidental we have no means of judging. If the nitrates applied have made any differences in the composition of the ashes, they are not large enough or consistent enough, except in the cases of the sulfuric and phosphoric acids and the potash, to be beyond the uncertainties introduced by the material contamination of the ash with dust and dirt. Be this as it may, the characteristics of the ashes of the vines are clearly presented. It would be expected that the vines would be richer in ash than the tubers. We see from Table XI that after the sand has been deducted they are nearly four times as rich in crude ash. This ash is high in sulfuric acid, low in phosphoric acid, very high in lime which strongly predominates over the already high magnesia, (the ratio of lime to magnesia is about 2:1) and, compared to other plant ashes, is rich in potash. This statement is relative. If we compare the potato vines with alfalfa hay in regard to ash content and composition, we obtain one set of comparative facts, but we get a different set if we compare potato vines and beet tops in the same respects. Alfalfa hay contains about 10.0 percent ash, of which 21 to 30 percent is potash. Sugar beet tops carry about 10.0 percent dry matter, of which 26 to 30 percent is ash, of which 20 to 28 percent is potash, or if the carbon dioxid be deducted, the potash will range from 29 to 35 percent. The potato vines yield from 10 to 12 percent dry matter which carries from 15.6 to 20 percent ash (sand only deducted) whose potash content is about 50 percent. Compared with the ash of alfalfa hay or with that of dried beet tops, the ash of potato vines is very rich in potash, at least one and a half time as rich. On the other hand, compared with the ash of its own tuber it is poor, carrying only about three-fourths as much. The contamination is unfortunate, but it does not, after all, conceal the characteristics of the ashes which have been given.

The effects of the nitrates do not appear. They may have been so small that this contamination has obscured them, but a more important factor is that all of the samples had excessive quantities of nitrates at their disposal and the soil conditions eliminated the differences that we had hoped to find. This is, I believe, the fact in the case. Our soil samples taken 12 August of this season show that all of the plots had the equivalent of 175 pounds of sodic nitrate per acre in the top 3 to 4 inches of soil. This is the depth to which we sampled. The rest of the surface foot was probably not so rich, but as the roots of the potato plant penetrate to a depth of three and even four feet, we do no violence to the facts in assuming that more than 525 pounds per acre were available to the crop.

As elsewhere stated, I neither know the minimum amount that may suffice to prejudicially affect a potato plant nor the period in its growth when the plant is most susceptible to an excessive supply of nitrates. I do not know that such data have been ascertained for any plant. It has been established that the beet plant appropriates nitrogen most rapidly during June and July. During these months this crop appropriates about three-fourths of all of the nitrogen that it uses, but the application of nitrates subsequent to July, i. e., during August and September, will produce the same effects as an earlier application but to a less extent.

According to our observation in 1920 on the development of nitrates in this soil, they reached their maximum in August but continued abundant thruout September. The minimum that we found in this soil, 16 September, 1920, was 153 pounds sodic nitrate per acre to the depth of 3-4 inches, and on 9 September, 1922, it was 108 pounds.

The subject of ash composition will be considered again under the 1923 crop but from a somewhat different standpoint.

TABLE XIX.—ASH OF POTATO VINES*, CROP OF 1922

	Ohio		Downing		Pearl		Rural	
	17 July	Pure Ash	17 July	Pure Ash	17 July	Pure Ash	17 July	Pure Ash
Carbon	0.559		1.341		0.685		0.435	
Sand	17.136		16.314		26.205		12.791	
Silica	5.129		5.442		5.686		4.160	
Carbon dioxid	18.312		17.686		15.168		19.048	
Chlorin	0.965	1.638	1.115	1.889	0.548	1.046	0.769	1.206
Sulfuric acid	2.126	3.608	1.681	2.849	1.865	3.561	2.508	3.934
Phosphoric acid	2.996	5.084	2.125	3.600	2.614	4.991	2.937	4.607
Aluminic oxid	3.384	5.742	2.303	3.901	2.724	5.201	4.261	6.684
Ferric oxid	1.501	2.547	1.205	2.041	1.863	3.557	1.405	2.204
Manganic oxid (br.)	0.059	0.100	0.059	0.100	0.059	0.113	0.039	0.061
Calcic oxid	14.304	24.275	13.606	23.050	12.227	23.347	14.351	22.510
Magnesic oxid	4.073	6.912	5.108	8.654	4.222	8.062	5.773	9.055
Potassic oxid	29.355	49.817	31.587	53.510	26.028	49.699	30.863	48.410
Sodic oxid	0.392	0.665	0.491	0.832	0.345	0.659	1.020	1.600
Sum	100.291	100.369	100.063	100.426	100.239	100.236	100.360	100.271
O = Cl	0.228	0.369	0.249	0.426	0.123	0.236	0.173	0.271
Total	100.063	100.000	99.814	100.000	100.116	100.000	100.187	100.000

*Spring Canyon samples.

The ranch of Mr. Charles Stobbe is located at Spring Canyon, at the foot of the mountains. The soil varies but that which we chose was such as is common in the little valleys of the mountains. We arranged with Mr. Stobbe to grow small plots of the same varieties that we were growing at Greeley and we furnished the seed. The soil developed nitrates rather freely, a condition that we hoped to avoid. The analyses of the vines and tubers of the 1922 crop are given in the following tables:

TABLE XX.—ASH OF POTATO TUBERS, CROP OF 1922, SPRING CANYON

	Ohio		Downing		Pearl	
	10 Oct.	Pure Ash	10 Oct.	Pure Ash	10 Oct.	Pure Ash
Carbon	0.268		....		1.160	
Sand	0.653		0.610		0.747	
Silica	0.248		0.611		0.319	
Carbon dioxid	15.979		15.313		18.288	
Chlorin	1.645	1.987	1.551	1.855	1.314	1.656
Sulfuric acid	4.822	5.821	4.366	5.221	3.283	4.137
Phosphoric acid	12.048	14.550	13.204	15.791	11.038	13.911
Aluminic oxid	0.170	0.201	0.482	0.577	0.231	0.291
Ferric oxid	0.310	0.375	0.213	0.255	0.243	0.306
Manganic oxid (br.)	0.666	0.080	0.067	0.080	0.073	0.092
Calcic oxid	1.715	2.071	1.477	1.767	2.200	2.773
Magnesic oxid	3.684	4.450	4.277	5.115	3.044	3.836
Potassic oxid	57.371	69.282	58.008	69.371	56.103	70.705
Sodic oxid	1.350	1.631	0.308	0.369	2.116	2.667
Sum	100.329	100.448	100.487	100.399	100.159	100.374
O = Cl	0.371	0.448	0.333	0.399	0.297	0.374
Total	99.958	100.000	100.154	100.000	99.862	100.000

The ashes of these samples are lower in chlorin and sulfuric acid, higher in phosphoric acid and about the same in potash as the Greeley samples. The nitrogen and its distribution is given in Tables XIV, XV and XVI.

The Crop of 1923

We had fresh ground again this year, after alfalfa. We had heavy rains, a little hail and a good deal of blight, but we were able for the first time in four years to carry out our full plan of work.

The development of nitrates in the soil was followed as in preceding years, with widely different results. The wet condition of the soil may have at times been a factor, but evidently other factors varied too. In 1922 we did not find the difference between the check rows and the fallow ones that we had expected; in 1923 this difference existed and the nitrates found in the check rows were very low. According to previous observations we could not conclude that the occupancy of the soil had either led to the appropriation of the nitrates by the plants or to the prevention of their development. During this season one or the other, possibly both, took place.

This year there was a decided difference in the deportment of the different checks during the latter part of the season, corresponding apparently to the degree of maturity of the plants. In the case of the Ohios the nitric nitrogen was very low until the end of August, but during the next three weeks the nitric nitrogen very nearly doubled, rising from 9.8 to 18.8. I do not know what part the blight may have played in this; it practically killed the plants. In the case of the Pearls and Rurals this change did not take place until October, and in the case of the Cobbler it took place about 20 September. The blight probably played no part in any of these three cases.

There was not the same wide difference between the fallow plots and the checks in the sampling of 20 October, by which time the check plots had approached them in content of nitric nitrogen. There was apparently a great falling off between 20 and 27 October. The potatoes had been dug prior to 20 October. This falling off was general, including the fallow, and continued for the following three weeks, when we ceased sampling. Had this falling off shown in one sampling only, we would have attributed it to a mistake, and as it is we omit the samples taken after the crop had been gathered. A falling off in September was observed in 1920 but it was neither so sudden nor so great as in 1923. In the case of the wheat crop we found that it had fallen very low at the time of harvest and immediately began to increase on the removal of the crop when the ground was irrigated and disced. The results thruout the season were low, but the same method was used thruout and the same analyst made the determinations, so they are at least comparable among themselves. The same method was used by the same analyst in 1922 and the results were higher and concordant thruout the season.

These facts make for the reliability of the determinations. The two series are very different and necessitate contradictory conclusions. According to the 1922 results, the occupancy of the ground by the potato crop was favorable to the development of nitrates, for it is to be assumed that the crop used up some of the nitrates formed. Still there was as much nitrate in the check plots, if not more, than in the fallow ones. For instance, the average for the two fallow plots in 1922 was 22.8 p. p. m. of nitric nitrogen, that of the plots planted to Pearls and Rurals, both late varieties, was 23.9 p. p. m. or taken individually, the Rural and its adjacent fallow averaged 26.3 and 24.6 p. p. m. respectively and the Pearl, with the other fallow, 21.6 and 20.9 p. p. m. The averages for the plots planted to Downing and Ohios were 19.4 and 23.9 respectively. The general average for the planted plots was 22.8 p. p. m., the same as the average for the two fallows. This does not seem consistent with other observations. First, nitrates accumulate in fallow ground; second, the crop uses some nitrate and as a rule tends to inhibit the formation; at least this is the case with beets, wheat, oats and some other grasses. This deportment of the plots appears remarkable, but it seems to be consonant with the results obtained for 1920.

Each sample in these records is composite, made up of 20 subsamples, and the determinations were made in duplicate with every precaution taken by the operator to obtain correct, as well as concordant results. These statements are true of the 1923 series, but the results are very different. The 1923 sample-taking began earlier and continued later. This was done to get a better idea of the variations during the season, but even the fallow plots in 1923 did not become nearly so rich in nitrates, according to the determinations, as the check plots were in 1920. This simply shows how greatly this factor may vary in the growing of a crop. There is, of course, no reason why the same ground should be the same from year to year in any character that is dependent upon biological conditions. This is one of the most evident things observed in the occurrence of nitrates.

We had the same relations in 1920 and 1922 in regard to the large and uniform occurrence of nitrates in the check rows or in ground occupied by plants. In 1923 we had other results, more in harmony with our notions of the effects that should be produced; the fallow land increased more rapidly and remained fairly high until 20 October when it, and all of the other plots, dropped quite abruptly. The nitrates were kept down during the growing of the plants and rose as the plants matured. The average nitrate present from 19 May to 28 July expressed as sodic nitrate in top 3-4 inches of soil per acre of the different checks and blanks was as follows: Ohio 42.8 pounds, North Blank 44.9 pounds, Rurals 39.6, Pearls 43.2, South Blank 55.8 and Cobblers 43.6 pounds.

These are nearly the same and all low. For all the determinations made between 5 and 25 August, both dates inclusive, we have Ohios 67.8, North Blank 155.4, Rurals 45.0, Pearls 49.2, South Blank 159.0 and Cobblers 63.0 pounds. Here again we find the checks comparatively low, but the blanks have about three fold, that is, the nitrates present during this period averaged three times as much as they averaged during the period from 9 May to 28 July. From 4 September until 20 October, we had in Ohio checks 94.8, in North Blank 155.4, in Rural check 57.6, in Pearl check 42.0, in South Blank 174.6 and in the Cobbler check 78.0 pounds. The average for the two blanks or fallow plots is 165.0 pounds and for the four check plots 66.6 pounds.

The Ohios, an early variety, were severely attacked by blight about the first of September; the exact date I do not know. At the end of August the nitrates present were about 59 pounds. We attribute this rapid increase to the fact that the plants were practically dead by the first of September and the nitrates were neither inhibited nor appropriated by the crop.

This effect of the ripening of the crop is shown in the case of the Cobblers which is not complicated by the blight; in this case the average nitrate for the six weeks from 11 August to 15 September, both dates inclusive, was 61.8 pounds; for the five weeks, 22 September to '20 October, it was 80 pounds. This was still more marked in the cases of the Rurals and Pearls, in which we had no increase until well along in October in the rural check and none in the Pearl check until the crop was dug, when the amount jumped to over three times as much.

Nineteen hundred and twenty-three was the wettest season on record in the college meteorological department and the crops were irrigated just the same as tho it had been an ordinarily dry season. The rainfall during the growing season, May until October, was 17.17 inches, just about twice as much as usual. This would leach ordinary amounts of nitrates down to a greater depth than four inches. I can scarcely think that this has changed the effects of the plants as exhibited in the results obtained for the check plots. It may have and undoubtedly did lower the results that we otherwise would have got for our fallow plots. If it had any effect upon the check plots it has probably served to make the effects of the growing plants more evident. The cooking qualities of the potatoes of this crop were extremely poor.

TABLE XXI.—NITRIC NITROGEN IN PLOTS TO DEPTH OF 4 INCHES IN P. P. M., 1923

Date	Ohio	N. Blank	Rural	Pearl	So. Blank	Cobbler	Spring Canyon
19 May	6.5	6.0	7.0	5.2	4.8	4.2	
26 May	9.4	5.4	7.1	9.5	6.7	6.8	
2 June	9.2	11.0	8.8	11.4	9.1	9.8	5.6
14 June	1.9	2.4	0.1	0.9	3.2	3.7	
23 June	5.8	4.5	5.1	5.6	6.2	5.5	
30 June	5.8	6.9	7.0	7.0	8.4	7.3	5.4
7 July	6.9	9.1	6.6	5.9	8.7	7.7	8.1
14 July	7.7	12.0	9.2	7.8	12.9	8.4	8.2
21 July	8.0	12.6	6.7	7.4	13.2	7.3	7.7
28 July	10.2	17.5	8.4	11.5	23.5	11.9	
5 Aug.	12.2	24.9	11.5	12.1	23.0	9.7	
11 Aug.	11.7	30.2	10.1	10.7	27.4	12.0	4.3
18 Aug.	9.7	26.2	4.3	7.1	30.1	8.4	
25 Aug.	9.8	22.3	3.3	3.0	25.3	11.5	
4 Sept.	12.4	26.5	2.3	2.2	30.0	9.3	
10 Sept.	15.3	27.3	5.0	3.4	32.6	10.0	
15 Sept.	15.5	32.0	5.7	2.4	20.8	9.1	
22 Sept.	13.8	32.5	8.9	5.9	33.6	13.1	
29 Sept.	18.8	23.1	8.7	4.0	25.5	15.5	
6 Oct.	16.0	21.3	12.5	6.4	31.3	14.7	
13 Oct.	18.1	21.7	13.0	6.7	30.8	16.1	
20 Oct.	16.9	24.0	12.5	24.8	27.4	16.3	

TABLE XXII.—DRY MATTER AND ASH IN POTATO VINES, CROP OF 1923

		Check		Nitrate	
Date	Variety	Dry M.	Ash in D. M.	Dry M.	Ash in D. M.
28 July	Cobbler	12.90	30.33	13.15	32.33
	Ohio	12.68	32.83	13.13	32.17
5 Aug.	Pearl	13.30	30.30	11.93	27.97
	Rural	12.85	28.67	12.50	27.50
11 Aug.	Cobbler	14.13	27.67	13.98	27.50
	Ohio	13.95	26.53	13.60	27.50
18 Aug.	Pearl	16.98	22.97	13.25	22.87
	Rural	15.05	25.63	15.88	26.93
25 Aug.	Cobbler*	23.18	32.86	21.83	35.90
	Ohio	24.30	37.27	30.87	37.71
4 Sept.	Pearl	16.78	25.73	14.23	27.73
	Rural	17.28	30.23	17.03	38.93
15 Sept.	Pearl	19.40	21.17	16.47	17.73
	Rural	18.78	22.17	24.35	24.20

*The ashes of Cobbler and Ohio taken 25 August were exceptionally sandy and the vines were quite or wholly mature.

TABLE XXIII.—DRY MATTER AND ASH IN TUBERS, CROP OF 1923, GREELEY

	Check			Nitrate		
Variety	Dry M.	Ash in D.M.	Ash in fresh tubers	Dry M.	Ash in D.M.	Ash in fresh tubers
Cobbler	18.50	4.36	0.980	19.58	4.74	1.025
Ohio	19.05	5.25	1.055	17.38	5.61	1.080
Pearl	20.70	4.60	1.002	18.55	4.57	0.940
Rural	18.65	4.46	0.948	20.30	4.48	0.943
Average	19.23	4.67	0.996	18.95	4.85	0.997
Cobbler, Spring Canyon	18.53	5.69	1.053			
Ohio, Spring Canyon	18.15	4.85	0.880			

TABLE XXIV.—POTATO VINES, CROP OF 1923; GENERAL FORMS OF NITROGEN

Variety	Fertilizer	Date	Dry Matter	Marc	Juice	Sp. Gr. Juice	Total Nitrogen		Protein Nitrogen			Nitric Nitrogen
							Pulp	Juice	Albumin	Proteose	Peptone	
Ohio	Check	14 July	12.15	6.13	93.87	1.025	0.4053	0.3116	0.1581	0.0004	0.0050	0.1297
Ohio	Nitrate	14 July	11.43	6.55	93.45	1.022	0.4309	0.3060	0.1528	....	0.0050	0.1295
Cobbler	Check	14 July	11.13	6.94	93.06	1.020	0.4231	0.2542	0.1400	0.0057	0.0047	0.0609
Cobbler	Nitrate	14 July	11.68	7.19	92.81	1.018	0.3842	0.1825	0.0959	0.0087	0.0062	0.0263
Rural	Check	21 July	11.70	6.18	93.82	1.022	0.4323	0.3268	0.1306	0.0072	0.0059	0.1116
Rural	Nitrate	21 July	11.40	7.31	92.69	1.021	0.4452	0.2783	0.1084	0.0089	0.0215	0.1081
Pearl	Check	21 July	11.10	7.69	92.31	1.019	0.3850	0.2011	0.0965	....	....	0.1001
Pearl	Nitrate	21 July	11.63	7.83	92.17	1.018	0.4172	0.2368	0.1005	....	0.0096	0.1348
Ohio	Check	28 July	12.68	6.88	93.12	1.027	0.4200	0.3434	0.1460	0.0131	....	0.1440
Ohio	Nitrate	28 July	13.13	8.33	91.67	1.028	0.4396	0.3648	0.1689	0.0063	....	0.1478
Cobbler	Check	28 July	12.90	7.92	92.08	1.025	0.4102	0.2624	0.1203	0.0116	....	0.0609
Cobbler	Nitrate	28 July	13.15	8.13	91.87	1.022	0.3875	0.2379	0.1237	0.0129	0.0047	0.0384
Rural	Check	5 Aug.	12.85	8.21	91.79	1.022	0.4194	0.2867	0.1182	0.0126	....	0.0954
Rural	Nitrate	5 Aug.	12.50	8.94	91.60	1.018	0.4128	0.2184	0.0405	0.0058	0.0211	0.0931
Pearl	Check	5 Aug.	13.30	9.32	90.68	1.019	0.3884	0.2292	0.0110	0.0627	0.0004	0.0284
Pearl	Nitrate	5 Aug.	11.93	8.23	91.77	1.017	0.4119	0.1407	0.0111	0.0185	0.0098	0.1033
Ohio	Check	11 Aug.	13.95	7.60	92.40	1.030	0.4079	0.3263	0.1501	0.0191	....	0.1225
Ohio	Nitrate	11 Aug.	13.60	7.43	92.57	1.031	0.4242	0.3218	0.1423	0.0198	....	0.1225
Cobbler	Check	11 Aug.	14.13	9.61	90.39	1.032	0.3570	0.1897	0.1140	0.0123	0.0019	0.0080
Cobbler	Nitrate	11 Aug.	13.98	8.68	91.32	1.022	0.3483	0.1433	0.0678	0.0078	0.0068	0.0222
Rural	Check	18 Aug.	15.03	10.07	89.93	1.029	0.4158	0.2748	0.1331	0.0147	0.0029	0.0806
Rural	Nitrate	18 Aug.	15.88	11.41	88.59	1.027	0.3945	0.2725	0.1313	0.0131	....	0.0944
Pearl	Check	18 Aug.	16.98	12.74	87.26	1.025	....	0.1891	0.0697	0.0159	0.0088	0.0484
Pearl	Nitrate	18 Aug.	13.25	8.95	91.05	1.019	0.3836	0.2189	0.0507	0.0112	0.0099	0.1029
Ohio	Check	25 Aug.	24.30	19.05	80.95	1.030	0.4841	0.2905	0.0391	0.0190	0.0088	0.1500
Ohio	Nitrate	25 Aug.	30.87	25.74	74.26	1.031	0.5488	0.2727	0.0365	0.0202	0.0111	0.1638
Cobbler	Check	25 Aug.	23.18	17.69	82.31	1.031	0.4292	0.2660	0.0333	0.0206	0.0126	0.0279
Cobbler	Nitrate	25 Aug.	21.83	19.86	80.14	1.031	0.3903	0.1508	0.0441	0.0168	0.0115	0.0288
Rural	Check	4 Sept.	17.28	11.36	88.64	1.029	0.4116	0.1827	0.0099	0.0157	0.0196	0.0540
Rural	Nitrate	4 Sept.	17.03	11.38	88.62	1.027	0.4228	0.2484	0.0739	0.0125	0.0082	0.0985
Pearl	Check	4 Sept.	16.78	11.86	88.14	1.028	0.4186	0.1933	0.0598	0.0128	0.0092	0.0595
Pearl	Nitrate	4 Sept.	14.23	9.41	90.59	1.023	0.3962	0.2355	0.0539	0.0091	0.0166	0.0598
Rural	Check	10 Sept.	19.25	12.73	87.27	1.037	0.4676	0.2663	0.0895	0.0144	0.0108	0.0824
Rural	Nitrate	10 Sept.	22.65	15.51	84.49	1.036	0.5285	0.2946	0.0847	0.0121	0.0096	0.0109
Pearl	Check	10 Sept.	16.40	10.79	89.21	1.029	0.3898	0.1888	0.0257	0.0192	0.0159	0.0498
Pearl	Nitrate	10 Sept.	16.35	10.23	89.77	1.029	0.3870	0.2846	0.0751	0.0114	0.0143	0.1089
Rural	Check	15 Sept.	18.78	12.26	87.74	1.033	0.4836	0.2604	0.0366	0.0279	0.0099	0.1110
Rural	Nitrate	15 Sept.	24.35	17.70	82.30	1.043	0.5892	0.3023	0.0613	0.0243	0.0155	0.1228
Pearl	Check	15 Sept.	19.40	13.44	86.56	1.034	0.4060	0.2596	0.0799	0.0221	0.0043	0.0565
Pearl	Nitrate	15 Sept.	16.47	10.43	89.57	1.030	0.4416	0.2940	0.0667	0.0134	0.0149	0.0938

TABLE XXV.—AMMONIA, AMID AND AMINO NITROGEN IN POTATO VINES, CROP OF 1923

Variety	Fertilizer	Date	Ammonia Nitrogen	Amid Nitrogen	Amino Nitrogen
Ohio	Check	14 July	0.00567	0.00462	0.01149
Ohio	Nitrate	14 July	0.00490	0.00378	0.01142
Cobbler	Check	14 July	0.00532	0.00252	0.01359
Cobbler	Nitrate	14 July	0.00532	0.00252	0.01327
Rural	Check	21 July	0.00462	0.00504	0.01592
Rural	Nitrate	21 July	0.00525	0.00350	0.01585
Pearl	Check	21 July	0.00595	0.00602	0.02023
Pearl	Nitrate	21 July	0.00742	0.00700	0.02218
Ohio	Check	28 July	0.00455	0.00644	0.01779
Ohio	Nitrate	28 July	0.00511	0.00609	0.01909
Cobbler	Check	28 July	0.00378	0.00322	0.01548
Cobbler	Nitrate	28 July	0.00336	0.00245	0.01367
Rural	Check	4 Aug.	0.00350	0.00516	0.01511
Rural	Nitrate	4 Aug.	0.00364	0.00448	0.01387
Pearl	Check	4 Aug.	0.00336	0.00352	0.01253
Pearl	Nitrate	4 Aug.	0.00602	0.00574	0.01868
Ohio	Check	11 Aug.	0.00336	0.00385	0.01321
Ohio	Nitrate	11 Aug.	0.00525	0.00406	0.01482
Cobbler	Check	11 Aug.	0.00287	0.00217	0.01115
Cobbler	Nitrate	11 Aug.	0.00287	0.00259	0.01076
Rural	Check	18 Aug.	0.00406	0.00532	0.01649
Rural	Nitrate	18 Aug.	0.00483	0.00539	0.01643
Pearl	Check	18 Aug.	0.00504	0.00434	0.01565
Pearl	Nitrate	18 Aug.	0.00567	0.00609	0.01700
Ohio	Check	25 Aug.	0.00882	0.00875	0.02202
Ohio	Nitrate	25 Aug.	0.00812	0.00707	0.01917
Cobbler	Check	25 Aug.	0.00763	0.00266	0.01764
Cobbler	Nitrate	25 Aug.	0.00609	0.00259	0.01318
Rural	Check	1 Sept.	0.00518	0.00637	0.01814
Rural	Nitrate	1 Sept.	0.00616	0.00777	0.01820
Pearl	Check	1 Sept.	0.00917	0.00504	0.02843
Pearl	Nitrate	1 Sept.	0.00651	0.00630	0.01776
Rural	Check	8 Sept.	0.00602	0.00833	0.02125
Rural	Nitrate	8 Sept.	0.00819	0.01302	0.03487
Pearl	Check	8 Sept.	0.00749	0.00651	0.01972
Pearl	Nitrate	8 Sept.	0.00945	0.01064	0.01827
Rural	Check	15 Sept.	0.00665	0.00917	0.02276
Rural	Nitrate	15 Sept.	0.00917	0.01134	0.02489
Pearl	Check	15 Sept.	0.00833	0.00756	0.02023
Pearl	Nitrate	15 Sept.	0.01043	0.01190	0.02522

TABLE XXVI.—TOTAL ALBUMIN AND NITRIC NITROGEN IN POTATO TUBERS, CROP OF 1923

						Total Nitrogen		Protein Nitrogen			Nitric
Variety	Fertilizer	Dry Matter	Marc	Juice	Specific Gravity	Pulp	Juice	Albumin	Proteose	Peptone	Nitrogen
Ohio	Check	19.05	15.34	84.66	1.022	0.3934	0.3782	0.1266	0.0290	0.0568	0.0029
Ohio	Nitrate	17.38	13.03	86.97	1.020	0.4094	0.4106	0.1382	0.0208	0.0186	0.0065
Cobbler	Check	18.50	14.07	85.93	1.022	0.3969	0.3468	0.1283	0.0259	....	0.0008
Cobbler	Nitrate	19.58	15.35	84.65	1.020	0.3276	0.3090	0.1162	0.0203	0.0043	....
Rural	Check	18.65	15.99	84.01	1.018	0.3703	0.3431	0.0957	0.0335	0.0187	Trace
Rural	Nitrate	20.30	16.24	83.76	1.018	0.3346	0.3138	0.0820	0.0374	0.0197	None
Pearl	Check	20.70	16.33	83.67	1.024	0.3780	0.3666	0.1306	0.0255	0.0124	None
Pearl	Nitrate	18.55	14.86	85.14	1.021	0.3436	0.3280	0.1115	0.0207	0.0198	None
Ohio	Mountain	18.05	14.32	85.68	1.023	0.4035	0.3793	0.1292	0.0212	0.0187	0.0040
Cobbler	Mountain	18.53	13.85	86.15	1.022	0.3115	0.3235	0.1183	0.0168	0.0204	0.0011
After being stored until 5 January, 1924, Ohios slightly sprouted											
Ohio	Check	19.45	15.42	84.58	1.025	0.3828	0.3818	0.1415	0.0081	0.0412	0.0030
Ohio	Nitrate	20.23	15.58	84.42	1.027	0.4347	0.4385	0.1551	0.0281	0.0237	0.0071
Cobbler	Check	17.80	14.55	85.45	1.020	0.3856	0.3843	0.1386	0.0118	0.0262	0.0025
Cobbler	Nitrate	17.63	14.34	85.66	1.024	0.3087	0.3297	0.1239	0.0184	0.0114	None
Rural	Check	19.60	15.07	84.93	1.020	0.3576	0.3503	0.0933	0.0387	0.0158	None
Rural	Nitrate	20.53	15.78	84.22	1.020	0.3556	0.3410	0.1054	0.0308	0.0247	None
Pearl	Check	20.50	15.48	84.52	1.024	0.3800	0.3854	0.1288	0.0471	0.0169	Trace
Pearl	Nitrate	20.18	14.55	84.45	1.024	0.3731	0.3724	0.1345	0.0346	0.0166	None
Cobbler	Mountain	19.60	14.48	85.52	1.025	0.3528	0.3434	0.1405	0.0221	0.0167	None

TABLE XXVII.—AMMONIA, AMID AND AMINO NITROGEN, ALSO NITRITE NITROGEN IN POTATO TUBERS, BEFORE AND AFTER STORAGE, CROP OF 1923

Date	Variety	Fertilizer	Ammonia Nitrogen	Amid Nitrogen	Amino Nitrogen	Nitrite Nitrogen P.P.M.
6 Nov. '23	Cobbler	Check	0.01176	0.03934	0.08194	4.24
8 Jan. '24	Cobbler	Check	0.00868	0.04116	0.08938	3.83
6 Nov. '23	Cobbler	Nitrate	0.00882	0.03318	0.07012	0.74
8 Jan. '24	Cobbler	Nitrate	0.00756	0.03080	0.06448	3.17
8 Nov. '23	Ohio	Check	0.00966	0.04480	0.09067	1.52
4 Jan. '24	Ohio	Check	0.00994	0.04998	0.09836	7.37
8 Nov. '23	Ohio	Nitrate	0.00830	0.04900	0.09648	2.30
4 Jan. '24	Ohio	Nitrate	0.01078	0.05558	0.10730	8.18
15 Nov. '23	Rural	Check	0.00980	0.05264	0.09479	0.51
14 Jan. '24	Rural	Check	0.00840	0.05306	0.09721	2.65
15 Nov. '23	Rural	Nitrate	0.01162	0.04340	0.08478	0.74
14 Jan. '24	Rural	Nitrate	0.00924	0.04704	0.08882	2.96
19 Nov. '23	Pearl	Check	0.00784	0.04564	0.08391	Trace
10 Jan. '24	Pearl	Check	0.01106	0.04172	0.08938	6.20
19 Nov. '23	Pearl	Nitrate	0.00904	0.04102	0.07641	1.25
10 Jan. '24	Pearl	Nitrate	0.00882	0.04200	0.07443	12.80
21 Nov. '23	Cobbler	Check	0.00924	0.02884	0.06455	1.43*
16 Jan. '24	Cobbler	Check	0.00910	0.03080	0.06802	12.00*

*Spring Canyon

TABLE XXVIII.—STARCH AND SUGARS IN POTATO TUBERS, CROP OF 1923, BEFORE AND AFTER STORAGE

Date	Variety	Fertilizer	Starch	Reducing sugars	Total sugars	
6 Nov. '23	Cobbler	Check	11.338	0.000	0.000	
8 Jan. '24	Cobbler	Check	11.149	0.266	0.381	
6 Nov. '23	Cobbler	Nitrate	13.052	0.000	0.000	
8 Jan. '24	Cobbler	Nitrate	11.696	0.338	0.411	
8 Nov. '23	Ohio	Check	12.562	0.000	0.000	
4 Jan. '24	Ohio	Check	11.188	0.168	0.339	
8 Nov. '23	Ohio	Nitrate	9.040	0.000	Trace	
4 Jan. '24	Ohio	Nitrate	9.323	0.108	0.282	
15 Nov. '23	Rural	Check	13.843	Trace	Trace	
14 Jan. '24	Rural	Check	13.899	0.090	0.191	
15 Nov. '23	Rural	Nitrate	13.508	Trace	Trace	
14 Jan. '24	Rural	Nitrate	12.751	0.134	0.240	
19 Nov. '23	Pearl	Check	13.579	Trace	Trace	
10 Jan. '24	Pearl	Check	12.562	0.208	0.277	
19 Nov. '23	Pearl	Nitrate	11.923	Trace	Trace	
10 Jan. '24	Pearl	Nitrate	12.035	0.276	0.330	
21 Nov. '23	Cobbler	Check	13.108	0.000	Trace	Spring Canyon
16 Jan. '24	Cobbler	Check	13.221	0.582	0.729	

The storage plant did not operate the room at 34° F. this year, and we were compelled to store our potatoes in a cellar where drying out would proceed faster than in a room at 34° F. The very small amounts of sugar found in them would indicate only slight changes, assuming that the reactions going on at the temperature of the cellar and in the moderate light were the same as they would have been in the storage room.

Had we anticipated the uncertainty caused by the drying out, we would have weighed them in and out. The samples weighed about 40 pounds each and were piled up and well covered. The room was fairly moist and the change in weight was probably only moderate.

This undetermined loss during storage, whether large or small, introduces an uncertainty in regard to the amount of changes that took place in the starch which is at best low. The small amount of sugars present in January suggests that the tubers had kept rather well up to this date.

The Spring Canyon samples were grown as checks on our general crop grown at Greeley. Spring Canyon is inside of the foothills and I hoped that it would represent mountain conditions sufficiently well for our purpose, but it proved very unsatisfactory and was subject to as many and varied ills as our plains location. A few of the samples grown there were very rich in nitric nitrogen, even richer than some of our Greeley samples, and they were quite as poor in quality.

The season of 1923 was unusually wet. The rainfall during the growing season, May till September, was, in 1920, 5.45 inches, in 1921, 10.26 inches, in 1922, 3.45 and in 1923, 17.17 inches. Our average rainfall for these months is 8.91 inches, only slightly over one-half of that for 1923. This ratio held for the whole year; i. e., we had about twice our annual rainfall. The ground was so wet on some of our dates for sampling that we did not take them and the next samples taken were unusually low. During the month of June we had 6.23 inches. The irrigations were applied without regard to the peculiarities of the season, as this was the only safe method of procedure. In July we had 4.5 inches or 10.73 inches for the two months. The rainfall at Greeley was a little less than at Fort Collins and the distribution differed a little, but the general fact of unusual rainfall was also true of that locality. Our table giving the nitric nitrogen shows that for June and July it was exceptionally low, even in our fallow land, designated as north and south blanks. The nitrates were simply washed into the soil to a greater depth than our samples were taken, three to four inches.

We made no attempt to determine the movement of the nitrates in the soil this season. They may have eventually been carried down to a depth beyond the reach of the potato plant, but this scarcely seems probable.

August was a month of moderate rainfall and our blanks showed an increase in the nitrates present, which remained around 30 p. p. m. until the end of October, when they fell to very small quantities, less than 4 p. p. m. The maximum was reached about 20 September when the fallows showed an average of 250 pounds of sodic nitrate per acre to the depth of our sampling, three to four inches. We aimed to take the sample three inches deep but cultivated ground is not level and we varied a little, but I do not think that we took any less than three inches. The average for the cropped plots on this date, 20 September, was only 62.4 pounds sodic nitrate, taken to the same depth. Whether the difference between the quantities present in the fallow and the cropped plots represented the nitrates used by the plants, or the extent to which the plants had inhibited their formation, cannot be decided from our data. The data of 1920 given in Bulletin 291 taken with the data of 1922, given in this bulletin, would lead one to attribute the difference largely to the use of it by the plants.

The average amount present from 14 June until 17 July was about 44 pounds per acre to the depth of three to four inches, whereas the amount present 22 September was 134.4 pounds. These quantities were small compared with those obtained for the season of 1920, when our rainfall amounted to 5.45 inches and our samples were all taken from between plants in the check rows. The average for 19 August, 1920, was 532 pounds of sodic nitrate and on 16 September it amounted to 280 pounds. The rainfall for the whole month of September, 1920, was 0.60 inch. If it be asked what has become of the difference, some 250 pounds, between these dates, we have in answer but three suggestions to offer, leaching, due to irrigation, reduction in the soil, and appropriation by the plants.

We have repeatedly tested our soils, not these particular ones, for nitrites with negative results. We have no facts indicating that reduction takes place to an appreciable extent.

An irrigation may have been applied in early September but this would have facilitated appropriation by the plants rather than have effected leaching, for it is applied below and alongside of the row and never to the surface. If the formation of the nitrates had been continuous, there would have been no apparent falling off in their quantity; the process itself must have abated greatly.

The total nitrogen in the soil of these plots on 20 May, 1920, was 0.083 percent and the nitric nitrogen in samples taken to a depth of one foot was 11.6 p. p. m., equivalent to 278 pounds of sodic nitrate in the surface acre-foot. On 9 August, 1920, we found the equivalent of 544 pounds of sodic nitrate in the top three to four inches of soil per acre.

It would be interesting to know all the variations in the conditions, also in the development of the nitrates between our observations, but such a study was impossible for us to carry out and would have been ill-advised for us to have undertaken. The work as it was served the purpose in view, which was to show how great a supply of these salts became available to the plants during the season. We found, in 1920, the average for two sets of nine samples each, taken in July, the equivalent of 316 pounds of sodic nitrate in the top three to four inches of soil and for the same number of samples taken to the same depth in August, 511 pounds per acre. In 1922, we found 188 and 189 pounds for the respective months, and in 1923, 100 and 116 pounds respectively. These represent three very different seasons. The quantities shown in 1923 were probably as low as we would be likely to find in a long series of years, owing to the fact that we had about twice our usual rainfall plus the irrigations. The quantities given are the averages of all samples taken during the designated months, and do not represent maximum quantities.

No account has been taken of the effects of cloudiness and sunshine upon these processes in the surface portions of the soil or on those that were taking place in the plants.

We have come to believe that the effects of our sunshine are very important indeed and not always beneficial, tho usually so. The importance of these factors appears evident from our observations on the variations of the carbon dioxid in the soil atmosphere.

The point of importance for our investigation was to establish the fact that nitrates are developed in the soil during the season to such an extent as to become a factor in the development and characteristics of this crop to a prejudicial extent.

The question of how great a supply of these salts it requires to become a prejudicial factor has not been answered; in fact, I have not found the question considered in any connection except with the sugar beet. The reason why we have failed to answer it is evident when the facts in the case are considered.

We tried to obtain an answer by applying various amounts of nitrates and employing check or control plots. The data showing the supply of nitrates available to the plants, especially during the months of July and August, apply to these control plots exclusively. The results of 1920 were obtained from these cropped controls and the amounts found were greater than those applied to most of the trial plots, and no conclusion in regard to the prejudicial limit was possible. It does not matter whether the plants retard or promote the development of nitrates; these quantities were present in the soil after the plants had used the nitrates necessary to produce a strong growth of vines. Whether the vines were normal and healthy potato vines, physiologically perfect potato plants, we do not know; there were no observable differences between the trial and control plots.

We applied sodic nitrate to the trial plots at the rate of 200, 400, 600 and 800 pounds per acre and we found in the control plots nitrates in excess of the requirements of the crop in quantities approximating the larger quantities applied to the trial plots. In an extreme case in 1920 these excessive nitrates greatly exceeded the maximum quantity applied. In this respect our experiments were a complete failure. All of the potatoes that we grew were grown with an excessive supply of nitrates, the only difference between the trial and control plots was that we added 200, 400, 600 and 800 pounds per acre to the trial plots in addition to those furnished by the soil itself. These quantities did have some effect, but it was only to make a poor crop worse.

We endeavored to avoid this difficulty in another way, namely, by obtaining potatoes from other sections of the state, especially from the mountain sections, as such potatoes have a good reputation; also from dryland sections, but this did not prove altogether satisfactory.

It seems doubtful whether one can be even reasonably certain of conditions in field culture. Our effort to obtain what might be considered a potato of standard composition and quality was purely to get a standard for comparison by which to judge our Greeley potatoes, and not as a general study of either the potato plant or tuber.

The question whether the land on which our experiments were made was wisely chosen or not is not pertinent, for we had no choice. I do not know how much land like this there may be in the Greeley section but this was not favorable land for our study as the preceding tables and discussion make evident.

It is a question whether Greeley is now as favorable a section for the production of potatoes as it was formerly considered to be. Be this as it may, there is really a big problem connected with the production of this crop in the Greeley section considered from the standpoint of either volume or quality.

I have nothing to say about the diseases that affect this crop or their effects on the yield and quality of the crop. The purpose of trying to find out the effects of the nitrates was to see whether there exists any correlation between the diseases that are prevalent, and have been at times disastrous to this section, and the nitrates furnished by the soil itself under our climatic conditions.

Under climatic conditions we here understand the water supply, rainfall and irrigation, and all of those things that go to make up the weather; all degrees of cloudiness, a strong sunshine, high and hot winds, hail storms, violent changes in the temperature and even undue stillness of the atmosphere. Each one of these has decided effects on our crops, even our sunshine may be baneful, as Dr. MacMillan showed several years ago in the case of our bean crop, tho we usually consider it a beneficent factor. C. L. Fitch, at one time potato specialist for this station, was so strongly impressed with the important part he believed moisture and temperature had played in the failure of the years 1911-1914, that he obtained the consent of the station council to carry out an extensive series of experiments on this subject. My impression is that Mr. Fitch believed that he had demonstrated a relation between fusarial infection and these factors.

I do not know whether it has been, or can be shown that fusarial infection is more prevalent and dangerous in potatoes grown with an abundant supply of nitrates than such as have been grown with only a sufficient quantity to supply the needs of the crop. Our 1923 crop was in every sense very poor. The plots to which we applied nitrates gave a lower yield of poorer potatoes which were more extensively infected by fusarial rot and scab than the others. I consider these facts as due to the nitrates in the soil. The more nitrate applied to the plots, the smaller was the crop; the more strongly diseased, the poorer the quality of the potatoes. This was the case in each of the four seasons that we continued the experiment.

This was essentially the object of our whole investigation. It is very regrettable that our results are so involved, due to the conditions obtaining in the land on which our experiments were made, together with the untoward happenings of the seasons, hailstorms and excessive rains, that our results do not stand out in a clear and satisfactorily convincing light. There are reasons for dissatisfaction with the whole series that no one can see more clearly or regret as much as I, but I shall indulge in no lamentations and I have no confessions to make.

The effect of the nitrates has been to increase the total nitrogen in both vines and tubers thruout the experiment. The vines were not analyzed in 1920 but the total nitrogen in the tubers that year was, in the checks, 0.418, and in those from the nitrate plots, 0.439 percent, both higher than the general average of the analyses given in the literature which is 0.342 percent. In 1921 the total nitrogen in the vines from the check plots was 0.419 and from the nitrate plots 0.433 percent; in the tubers 0.399 and 0.413 percent respectively. In 1923 we got for the vines, 0.419 and 0.436 percent, and for the tubers 0.388 and 0.345 percent respectively. That year the total nitrogen in the tubers from the nitrate plots was less than in those from the check plots and both approach the general average for this constituent. The quality of this crop was poor and the starch at harvest time was very low; 12.29 percent was the average. The nitric nitrogen in the soil to a depth of three to four inches was lower thruout the season than during the preceding ones, probably due to the unusual amount of water received, which was at least 7½ inches more as rainfall during the five months of the growing season than usual.

The nitrite nitrogen, with one exception, increased decidedly during storage. This was due to the action of dehydrase. This determination was made on the crop of 1923 only.

Effect of Nitrates on Quality

It is well established that plants assimilate their nitrogen in the form of nitric acid, that is, get it from the nitrates occurring in the soil, and without this source of nitrogen there is no satisfactory growth; even legumes with their symbiotic organisms obtain a considerable percentage of their nitrogen from the soil nitrates. I am not aware that anyone has ascertained the minimum amount of nitric nitrogen necessary for the normal development of any crop of economic importance, or for any other crop. It has been stated, and the statement is a standard one, that a good agricultural soil should contain one-tenth of one percent of total nitrogen; this is equivalent to 12½ tons of protein matter in the surface foot per acre. There is a great deal of our soil that contains materially less than this. Much of our better soil contains not more than four-fifths of this amount which is supposed to be present in good agricultural soil.

The soil in which we grew our potatoes contains of total nitrogen less than nine hundredths of one percent, or a little less than 9 2-3 tons of nitrogenous organic matter in the surface acre-foot. The humus is one-half of one percent, or 10 tons in the surface acre-foot.

The conventional limit of one-tenth of one percent for the total nitrogen is too high for our soils. It is doubtlessly correct for many soils but the standard is not applicable in our case. I have met with but one case in Colorado in which there was a lack of nitrogen, and this soil was practically a quartz sand. Usually the nitrogen supply is sufficient.

Reference is always made, so far as I know, to the lower limit of total nitrogen necessary to grow remunerative crops. No other nitrogen than the total present at the time the analysis is made is considered. The fixing power of the soil is not considered especially in the older statements, and I do not recall having seen it considered in more recent discussions. The assumption of the older statements is that with one-tenth of one percent of total nitrogen present, enough of it will become available during the growing period of a crop to meet the requirements of a remunerative one; i. e., that it will furnish thru nitrification a sufficient quantity of nitrates. How much nitric nitrogen is required to grow a good crop is nowhere stated. It is easy to calculate how much nitrogen is removed by a harvested crop, but this is not the question. The question is, what is the optimum supply and at what period in the development of the crop is it required in the greatest abundance. We do not know the ratio of the appropriated to the total nitric nitrogen, not even approximately. There can be too much nitric nitrogen as well as not enough for the production of normal crops. There may be so much nitric nitrogen in the soil that well-established plants may be killed. Such extreme quantities are not here had in mind, but such as may influence the volume and quality of the crop advantageously.

I think that one will search our literature in vain for data on the effects of nitrates in these respects. I am aware that the appropriation of nitrogen by the beet plant has been studied and the period of most rapid appropriation ascertained to be the latter part of June and July. This is only a small portion of the question and incidental to the development of the crop under the conditions of the experiment. The question of the effects of nitrates at different periods in the development of the crop came up in our study of the sugar beet.

We had established several things in this connection. First, that the application of 500 to 700 pounds of sodic nitrate, applied in portions of 250 pounds each at intervals of four weeks beginning at the time of planting, lowered the yield of beets and the percentage of sugar; also, that the character of the beets was prejudicially affected in several other respects. Second, we had found that in some fields materially larger quantities of nitrates than these were developed during the month of August. The average, for instance, of seven samples taken to the depth of one foot in a certain field on 25 August showed the presence of 1050 pounds per acre. The beets grown in this field carried 12.6 percent sugar; those from the field against which these were checked carried 16.0 percent sugar, and the nitrates found on 25 August were equivalent to 193.6 pounds of sodic nitrate taken to the same depth, one foot. How much effect may be produced upon the quality of sugar beets by nitrates developing in the soil or applied subsequent to the period of most active appropriation, i. e., subsequent to July, was ascertained by applying it at the rate of 750 pounds per acre in five portions, the first one at the rate of 250 pounds per acre on 4 August and three subsequent ones of 150 pounds each at intervals of 14 days. The effects of the first application were evident within ten days and at the end of the season we found that we had depressed the sugar content by 1.0 percent, increased the injurious nitrogen by 53.0 percent, the nitric nitrogen by 100 percent, and reduced the phosphoric acid in the pure ash from 10.1 to 7.8 percent. These experiments do not answer the question suggested, they only show that amounts of nitrates less than are necessary to cause evident physical injury to the plants effect radical changes in their composition and properties, and that these injurious effects will be produced by nitrates applied or becoming available later than the period of the greatest normal appropriation of them by the plant under ordinary conditions.

The application of excessive nitrates reduced the yield of beets, lowered the percentage of sugar and changed the composition of the ash as well as that of the juices.

In experimenting with wheat we had a different plant and a different measure, for here we were chiefly concerned with the seed. In the case of the beet we dealt exclusively with the plant; in the wheat the yield and character of the grain were the considerations of economic importance, but the plant too was of interest. Our knowledge of conditions in this case was fuller than in that of the beets for we determined the nitrates in the wheat plots during the growing season every two weeks during the first year and every four weeks during the third season.

We are aware that weekly determinations would have been better but these are the best data that we have.

We applied nitrates at the rate of 250 pounds per acre, at the time of seeding to all plots that were to receive nitrates. Four weeks later we applied a second 250 pounds to two-thirds of the plots, and four weeks later one-third of the plots received a dressing at the rate of 250 pounds per acre, so that in the respective series we had the quantities of 250, 500 and 750 pounds.

The addition of 250 pounds at the time of sowing produced almost as big effects as the application of the larger quantities added later in successive portions. The effects varied some with the varieties of wheat, being the most pronounced in the case of the Defiance. The nitrates in the other plots were determined once a month during the season.

For our present purpose we are concerned only with the nitrates present during the occupancy of the ground by the crop· The total nitrogen in the top foot of this soil varied between twelve and fourteen hundredths of one percent. The nitric nitrogen varied; the land in 1915 that was cropped, showed in May 103.0 pounds, in June 34.2, and in July 260 pounds in the top foot. The grain was harvested in early August.

These facts state the case as fully as we can state it in regard to the supply of nitric nitrogen. Other data show that the land occupied by the wheat crop contained much less than adjacent fallow plots; the difference was two to five times as much in the fallow.

The effects of these nitrates on the plants was to produce large green leaves, very much darker than normal, weak haulms that kneed at the lower nodes. The wheat lodged and was very susceptible to rust. In most cases in which rust did not appear there was a slight increase in the crop. In the case of the Defiance there was a reduction in the yield of from 4 to 9 bushels, while the maximum increase in any instance was seven bushels per acre. These practical features were not the only ones of interest; the composition of the plants as well as of the grain was markedly influenced, the nitrogen was increased, the silicon and phosphorus were decreased and the potassium increased. The character of the grain was changed and its quality for bread-making was improved.

In our experiments with potatoes we have results similar to those obtained in the case of the beets and in the mineral constituents of the wheat plant. The increase in the nitrogen of the wheat grain is desirable but is undesirable in the case of the beet roots and potato tubers. The changes in the properties of beets and potatoes accompanying these changes in composition are undesirable. Further, the yield is depressed which was also often the case with the wheat.

There are other general facts apparent in our agriculture not the results of comparative experimentation, which, however, have a significance of their own. For instance, the canteloupe in the Arkansas Valley has not been the success of late years that it was formerly. Its flavor and shipping qualities have deteriorated. The production of cucumber seed is becoming less profitable; the fruits are large enough but yield a small amount of good seed and the vines are less prolific than desirable. The yield of alfalfa seed in the valley is very small tho the plants grow luxuriantly.

These ills are believed to be due to the effects of an over-supply of nitrates and probably are. It is not uncommon to find the equivalent of from 100 to 200 pounds and often very much more sodic nitrate per acre in the surface portions of the soil. I found in a beet field the equivalent of 26,000 pounds of sodic nitrate per acre in the top three inches of the soil. It is, therefore, a very reasonable supposition that these salts are the cause of the ills complained of. This complaint is made by both grower and shipper and is not confined to the crops just mentioned.

The quality of the potato grown in the Greeley district in the early days was such that it won a high reputation, but at the present time it is inferior, so much so that commission men find it difficult to dispose of them without information as to their source. This can scarcely be considered as a matter for surprise when our record shows that in our check plots, with samples taken under the vines in July, the nitrates were equivalent to from 250 to 400 pounds of sodic nitrate, and in August from 300 to 500 pounds in the top three to four inches of soil per acre. These figures are not results based upon a few individual samples taken irregularly as a matter of curiosity, but the results of systematic sampling in which 1200 individual samples were used. We obtain in this manner total results but establish no maximum limit for the quantities that will act beneficially nor the minimum that will act detrimentally.

I have searched for definite data regarding the effects of nitrates on the development and composition of plants, especially those of economic importance, but I have not found such concerning any plants. Of course, it is stated that nitrogen is necessary for the development of plants and that the nitrates in the soil are its essential source. Occasionally one may meet with some discussion of how the proteins are formed, but these discussions do not concern our problem, at least so directly as to throw any light on the matter. The only data in a measure applicable are found in the literature of the sugar beet.

One of the effects of nitrates, on grasses in particular, is to intensify their green color. I have found the statement that nitrates promote the formation of chlorophyll, but this is all. The development of chlorophyll in our potato plants is intense, but it is perhaps an important question whether this development is due more to an abundant supply of nitrates or to an intense sunshine peculiarly rich in certain rays. It is probable that this intensely active sunshine, together with an abundant supply of nitrates, induces unusual processes in the plants or stimulates the usual ones to an exceptional degree which may not be to the advantage of the plant or to any part of it. I have seen no data regarding these relations which may be of very great importance to the health of the plants and the character of their products.

I do not think that any adequate examination of our sunshine has been made nor any study of its variations. That it varies greatly is evident from certain effects it sometimes produces and at others it does not produce. Our atmosphere has a great deal to do with this, but there are probably other factors that play a part. These problems have not been studied. The studies made on the effects of light that I have seen recorded have been confined wholly to the consideration of the visible spectrum. With the exception of the preceding statements, the possible importance of our light in these questions has been omitted entirely.

Temperature and moisture were mentioned as the possible factors that caused the failures of the years 1911-1914, but no question arose as to the light itself. The temperature was probably in a way considered as dependent on the sunshine but the temperature of the soil alone is considered as the effecting agent. That temperature is often an important factor independently of sunshine is not doubted, but the sunshine is, I conceive, the direct cause of many things good and bad in the development of our crops, and these effects have been studied in only a few individual instances. I know of only one, that of the sunburning of the bean plant observed and explained by Dr. H. G. MacMillan, Pathologist of the U. S. Bureau of Plant Industry at the Colorado Potato Experiment Station at Greeley. Dr. MacMillan's experiments make it very probable that neither the visible spectrum nor heat causes the injury but rays that lie only a little beyond the limit of the visible spectrum.

The effects of ultra-violet light have been studied to some extent but not in connection with our sunshine and the well-being or ills of our economic crops. I do not know whether it plays any part in the development of nitrates. We would be inclined to look for an unfavorable effect upon it unless a very slight soil protection suffices to protect the organisms on which it depends.

It is possible that in the leaves of plants the sunshine and nitrates may work together to determine the vigor, health and products of the plant. The soil is the source of the nitrates and in a sense these are the cause of the peculiarities in the composition of the plants, tubers and ashes. Sunshine plays an important part in the processes by which the components are worked up in the leaves of the plant, but it cannot account for everything, for instance, the depression in the percentage of phosphoric acid or the increase of that of potassium, due to an excessive supply of nitrates in the soil. Such relations probably lie in another province, but all of those constituents that owe their existence to the changes effected in the leaves and stems, whether it be thru the agency of chlorophyll or not, may be more or less deeply affected. The sunshine of the East and West differ greatly, which must depend largely upon the differences of their atmospheres. Wherein these differences consist is not for us to consider at this time.

We present only four pairs of ashes of vines for the crop of 1921. These were the useable ones left. These are fortunately paired so that each pair represents plants of the same degree of development.

We have the analyses of the crude carbonated ash and the results as calculated on the pure ash. A glance at the analysis of the crude ash shows that it was contaminated by dust and soil particles. This contamination of field-grown plants is unavoidable. Its significance cannot be passed without some notice, for with from 5 to 15 or even more percent of the dried material consisting of soil particles, much of it dust distributed on the plants by winds, the amount of fluxing that may take place on ashing is too much to be left out of consideration. The soil that is involved in the analyses carries about 0.3 percent of alkalies soluble in strong hydrochloric acid cal-

TABLE XXIX.—ASH OF POTATO VINES, CROP OF 1923, GREELEY

	Cobbler Check		Cobbler Nitrate		Ohio Check		Ohio Nitrate	
	28 July	Pure Ash	28 July	Pure Ash	28 July	Pure Ash	28 July	Pure Ash
Carbon	0.767		0.844		0.860		0.790	
Sand	25.781		32.310		23.908		24.505	
Silica	1.879		1.148		5.654		6.033	
Carbon dioxid	16.114		13.131		16.555		16.933	
Chlorin	2.304	4.162	2.368	4.509	2.433	4.588	1.699	3.264
Sulfuric acid	3.912	7.055	3.784	7.205	2.200	4.149	2.149	4.128
Phosphoric acid	2.410	4.346	2.467	4.697	2.424	4.571	2.407	4.623
Aluminic oxid	2.404	4.335	2.806	5.343	1.857	3.502	2.598	4.990
Ferric oxid	1.195	2.155	1.378	2.624	1.076	2.029	1.073	2.061
Manganic oxid (br.)	0.068	0.123	0.067	0.128	0.074	0.140	0.089	0.171
Calcic oxid	10.859	19.582	9.494	18.077	9.757	18.360	10.685	20.524
Magnesic oxid	3.594	6.481	3.526	6.714	3.718	7.011	3.827	7.351
Potassic oxid	29.042	52.372	26.851	51.126	29.109	54.889	27.569	52.954
Sodic oxid	0.182	0.328	0.312	0.594	0.953	1.797	0.349	0.670
Sum	100.515	100.939	100.486	101.017	100.558	101.036	100.706	100.736
O=Cl	0.521	0.939	0.534	1.017	0.548	1.036	0.383	0.736
Total	99.994	100.000	99.952	100.000	100.010	100.000	100.323	100.000

	Pearl Check		Pearl Nitrate		Rural Check		Rural Nitrate	
	5 Aug.	Pure Ash	5 Aug.	Pure Ash	5 Aug.	Pure Ash	5 Aug.	Pure Ash
Carbon	0.843		0.787		0.779		0.839	
Sand	28.830		26.324		25.054		25.235	
Silica	6.649		6.615		6.797		6.477	
Carbon dioxid	13.967		15.141		15.516		15.371	
Chlorin	1.717	3.434	1.417	2.766	1.742	3.353	1.411	2.742
Sulfuric acid	2.469	4.938	2.259	4.410	2.365	4.552	2.360	4.557
Phosphoric acid	2.693	5.385	2.597	5.070	2.925	5.632	2.674	5.161
Aluminic oxid	2.355	4.709	2.192	4.279	2.236	4.340	2.232	4.310
Ferric oxid	1.162	2.324	1.198	2.339	1.131	2.177	1.246	2.456
Manganic oxid (br.)	0.049	0.098	0.049	0.095	0.059	0.113	0.058	0.112
Calcic oxid	9.573	19.142	9.477	18.502	11.351	21.851	11.210	21.635
Magnesic oxid	4.484	8.966	4.562	8.906	5.653	10.882	5.695	10.903
Potassic oxid	25.617	51.224	27.443	53.578	24.559	47.276	24.862	47.984
Sodic oxid	0.277	0.554	0.347	0.677	0.320	0.614	0.426	0.822
Sum	100.685	100.774	100.408	100.622	100.487	100.754	100.096	100.614
O=Cl	0.387	0.774	0.319	0.622	0.392	0.754	0.318	0.614
Total	100.298	100.000	100.088	100.000	100.095	100.000	99.778	100.000

TABLE XXIX, (Cont'd.)

	Cobbler Check		Cobbler Nitrate		Ohio Check		Ohio Nitrate	
	11 Aug.	Pure Ash	11 Aug.	Pure Ash	11 Aug.	Pure Ash	11 Aug.	Pure Ash
Carbon	0.921		0.780		0.751		0.534	
Sand	21.185		24.584		23.571		23.127	
Silica	5.084		5.641		4.162		4.106	
Carbon dioxid	13.413		13.126		15.412		18.682	
Chlorin	4.423	7.474	4.281	7.695	2.857	5.072	1.775	3.322
Sulfuric acid	5.364	9.066	5.439	9.777	4.282	7.604	2.913	5.451
Phosphoric acid	2.037	3.443	1.948	3.501	2.091	3.713	2.220	4.154
Aluminic oxid	1.532	2.589	1.468	2.640	1.354	2.404	0.755	1.412
Ferric oxid	1.275	2.155	1.322	2.376	1.091	1.937	1.038	1.943
Manganic oxid (br.)	0.065	0.106	0.071	0.128	0.063	0.112	0.066	0.120
Calcic oxid	12.205	20.627	11.585	20.825	11.216	19.916	12.024	22.500
Magnesic oxid	3.435	5.806	3.322	5.971	4.427	7.861	4.421	8.273
Potassic oxid	29.719	49.300	27.160	48.823	29.579	52.522	28.497	53.326
Sodic oxid	0.116	0.197	None	....	None	....	0.129	0.242
Sum	100.772	101.689	100.727	101.736	100.856	101.141	100.287	100.743
O=Cl	0.998	1.689	0.966	1.736	0.644	1.141	0.401	0.743
Total	99.774	100.000	99.761	100.000	100.212	100.000	99.886	100.000

	Pearl Check		Pearl Nitrate		Rural Check		Rural Nitrate	
	18 Aug.	Pure Ash	18 Aug.	Pure Ash	18 Aug.	Pure Ash	18 Aug.	Pure Ash
Carbon	0.544		0.449		0.522		0.608	
Sand	30.247		25.317		28.547		31.396	
Silica	4.091		3.097		2.687		3.663	
Carbon dioxid	14.638		18.784		16.639		15.269	
Chlorin	2.512	5.016	2.054	3.909	2.266	4.397	1.575	3.217
Sulfuric acid	2.843	5.677	2.404	4.576	3.215	6.239	2.817	5.753
Phosphoric acid	2.123	4.239	2.318	4.412	2.507	4.865	2.282	4.660
Aluminic oxid	1.537	3.068	1.285	2.438	1.516	2.942	1.905	3.891
Ferric oxid	1.210	2.420	0.982	1.869	1.146	2.224	1.259	2.571
Manganic oxid (br.)	0.074	0.148	0.089	0.170	0.075	0.146	0.079	0.161
Calcic oxid	11.188	22.335	10.338	19.677	11.850	22.995	11.315	23.109
Magnesic oxid	4.245	8.474	5.283	10.055	6.277	12.181	6.181	12.623
Potassic oxid	24.924	49.761	28.253	53.775	23.191	45.003	21.669	44.255
Sodic oxid	....	....	....	....	....	....	0.238	0.486
Sum	100.176	101.138	100.650	100.881	100.438	100.992	100.256	100.726
O=Cl	0.567	1.138	0.464	0.881	0.511	0.992	0.355	0.726
Total	99.609	100.000	100.186	100.000	99.927	100.000	99.901	100.000

TABLE XXIX, (Cont'd.)

	Cobbler Check		Cobbler Nitrate		Ohio Check		Ohio Nitrate	
	25 Aug.	Pure Ash	25 Aug.	Pure Ash	25 Aug.	Pure Ash	25 Aug.	Pure Ash
Carbon	0.800		0.903		0.862		1.026	
Sand	44.287		53.859		59.561		52.040	
Silica	3.670		3.600		3.684		8.651	
Carbon dioxid	8.327		6.446		5.747		7.588	
Chlorin	2.929	6.817	1.656	4.703	1.545	5.133	1.202	3.893
Sulfuric acid	3.626	8.440	2.946	8.366	1.756	5.834	1.120	3.627
Phosphoric acid	1.551	3.610	1.425	4.047	1.286	4.273	0.999	3.236
Aluminic oxid	3.241	7.543	3.221	9.147	2.935	9.751	3.386	10.966
Ferric oxid	1.546	3.598	1.803	5.121	1.792	5.954	1.781	5.768
Manganic oxid (br.)	0.087	0.202	0.143	0.406	0.110	0.365	0.043	0.139
Calcic oxid	8.701	20.252	7.179	20.388	7.006	23.276	7.718	24.996
Magnesic oxid	2.755	6.412	2.436	6.919	2.557	8.495	2.520	8.162
Potassic oxid	19.034	44.302	14.428	40.976	11.139	37.008	12.097	39.178
Sodic oxid	0.155	0.361	0.348	0.988	0.322	1.067	0282	0.913
Sum	100.709	101.537	100.393	101.061	100.302	101.158	100.453	100.878
O=Cl	0.661	1.537	0.374	1.061	0.349	1.158	0.271	0.878
Total	100.048	100.000	100.019	100.000	99.953	100.000	100.182	100.000

	Pearl Check		Pearl Nitrate		Rural Check		Rural Nitrate	
	1 Sept.	Pure Ash	1 Sept.	Pure Ash	1 Sept.	Pure Ash	1 Sept.	Pure Ash
Carbon	0.528		0.642		0.559		0.698	
Sand	27.989		37.756		31.385		34.763	
Silica	5.059		6.094		6.015		6.654	
Carbon dioxid	15.062		12.773		14.822		12.911	
Chlorin	2.838	5.549	2.040	4.769	1.627	3.438	1.837	4.107
Sulfuric acid	3.174	6.206	2.363	5.524	2.253	4.766	2.572	5.751
Phosphoric acid	1.915	3.745	1.510	3.530	1.711	3.616	1.733	3.875
Aluminic oxid	2.195	4.292	2.606	6.093	2.545	5.339	3.015	6.741
Ferric oxid	1.091	2.133	1.294	3.025	1.191	2.517	1.189	2.658
Manganic oxid (br.)	0.039	0.076	0.037	0.086	0.038	0.081	0.038	0.085
Calcic oxid	10.240	20.022	8.225	19.231	11.056	23.368	10.224	22.861
Magnesic oxid	5.501	10.757	4.639	10.847	6.051	12.789	5.423	12.126
Potassic oxid	24.363	47.637	20.285	47.430	21.106	44.613	18.655	41.715
Sodic oxid	0.427	0.835	0.312	0.729	0.117	0.248	0.450	1.006
Sum	100.421	101.252	100.567	101.264	100.467	100.775	100.162	100.925
O=Cl	0.640	1.252	0.541	1.264	0.360	0.775	0.414	0.925
Total	99.781	100.000	100.035	100.000	100.109	100.000	99.748	100.000

TABLE XXIX, (Cont'd.)

	Pearl Check		Pearl Nitrate		Rural Check		Rural Nitrate	
	15 Sept.	PureAsh	15 Sept.	PureAsh	15 Sept.	PureAsh	15 Sept.	PureAsh
Carbon	0.459		0.390		0.423		0.808	
Sand	19.336		15.099		25.759		31.290	
Silica	4.240		1.847		2.198		5.862	
Carbon dioxid	19.311		22.866		17.593		14.989	
Chlorin	3.589	6.345	2.999	5.016	2.165	4.842	1.545	3.274
Sulfuric acid	3.275	5.789	3.602	6.025	4.037	7.842	2.841	5.971
Phosphoric acid	1.740	3.076	2.310	3.864	2.045	3.786	1.657	3.483
Aluminic oxid	1.912	3.380	0.128	0.214	1.740	3.221	2.693	5.658
Ferric oxid	0.874	1.545	0.686	1.147	1.150	2.142	1.372	2.885
Manganic oxid (br.)	0.039	0.069	0.084	0.141	0.065	0.120	0.071	0.149
Calcic oxid	12.078	21.353	12.393	20.729	13.649	25.272	12.457	26.182
Magnesic oxid	6.353	11.231	7.659	12.812	7.207	13.344	6.947	14.600
Potassic oxid	27.016	47.764	30.564	51.152	21.989	40.713	17.299	36.360
Sodic oxid	0.497	0.878	0.035	0.059	0.096	0.178	1.045	2.196
Sum	100.719	101.430	100.662	101.132	100.933	101.092	100.876	100.731
O=Cl	0.809	1.430	0.677	1.132	0.590	1.092	0.348	0.731
Total	99.910	100.000	99.785	100.000	100.343	100.000	100.528	100.000

TABLE XXX.—ASH OF POTATO TUBERS, CROP 1923, GREELEY

	Pearl Check		Pearl Nitrate		Rural Check		Rural Nitrate	
	5 Oct.	Pure Ash	5 Oct.	Pure Ash	5 Oct.	Pure Ash	5 Oct.	Pure Ash
Carbon	0.180		0.165		0.119		0.098	
Sand	1.923		1.045		0.586		0.873	
Silica	0.491		0.157		0.270		0.240	
Carbon dioxid	16.121		18.378		16.697		16.589	
Chlorin	2.109	2.598	1.257	1.572	1.970	2.394	1.686	2.049
Sulfuric acid	5.015	6.178	5.073	6.346	4.620	5.616	4.651	5.651
Phosphoric acid	10.741	13.233	9.969	12.469	12.924	15.709	12.766	15.511
Aluminic oxid	0.219	0.270	1.134	1.418	0.423	0.514	0.256	0.311
Ferric oxid	0.304	0.375	1.073	1.342	0.325	0.395	0.277	0.361
Manganic oxid (br.)	0.090	0.111	0.098	0.122	0.096	0.117	0.085	0.103
Calcic oxid	1.321	1.629	2.335	2.921	1.732	2.105	2.236	2.717
Magnesic oxid	3.343	4.119	3.000	3.752	2.761	3.356	2.752	3.344
Potassic oxid	57.168	70.431	55.708	69.680	57.846	70.334	57.259	69.570
Sodic oxid	1.331	1.641	0.585	0.732	None	....	0.697	0.846
Sum	100.356	100.585	99.977	100.354	100.387	100.540	100.454	100.463
O=Cl	0.475	0.585	0.284	0.354	0.445	0.540	0.381	0.463
Total	99.881	100.000	99.693	100.000	99.942	100.000	100.109	100.000

TABLE XXX, (Cont'd.)

	Cobbler Check		Cobbler Nitrate		Ohio Check		Ohio Nitrate	
	5 Oct.	Pure Ash	5 Oct.	Pure Ash	5 Oct.	Pure Ash	5 Oct.	Pure Ash
Carbon	0.149		0.358		0.108		0.507	
Sand	1.259		0.998		1.279		2.399	
Silica	0.685		0.567		0.754		0.773	
Carbon dioxid	14.941		15.560		15.760		14.764	
Chlorin	3.339	4.025	3.845	4.662	3.334	4.063	2.946	3.589
Sulfuric acid	4.215	5.081	4.320	5.238	4.321	5.265	3.623	4.444
Phosphoric acid	12.922	15.578	12.521	15.182	12.820	15.621	14.042	17.226
Aluminic oxid	0.783	0.944	0.505	0.612	0.224	0.273	0.236	0.290
Ferric oxid	0.423	0.509	0.341	0.413	0.365	0.445	0.272	0.334
Manganic oxid (br.)	0.050	0.060	0.048	0.058	0.029	0.035	0.097	0.119
Calcic oxid	1.517	1.828	1.830	2.219	2.031	2.452	2.414	2.961
Magnesic oxid	3.021	3.641	3.229	4.000	3.125	3.808	3.026	3.712
Potassic oxid	56.154	67.694	55.698	67.534	55.269	67.345	54.206	66.493
Sodic oxid	1.284	1.547	0.933	1.133	1.319	1.608	1.338	1.641
Sum	100.742	100.907	100.850	101.051	100.720	100.916	100.644	100.809
O=Cl	0.753	0.907	0.867	1.051	0.750	0.916	0.664	0.809
Total	99.989	100.000	99.983	100.000	99.970	100.000	99.980	100.000

	Cobbler		Ohio	
	Spring Canyon	Pure Ash	Spring Canyon	Pure Ash
Carbon	0.086		0.062	
Sand	0.850		0.966	
Silica	0.192		0.378	
Carbon dioxid	16.687		17.386	
Chlorin	1.686	2.048	1.131	1.393
Sulfuric acid	4.018	4.881	3.239	3.988
Phosphoric acid	14.018	17.030	13.426	16.531
Aluminic oxid	0.700	0.850	0.529	0.651
Ferric oxid	0.365	0.443	0.341	0.420
Manganic oxid (br.)	0.120	0.146	0.122	0.150
Calcic oxid	2.139	2.599	2.815	3.466
Magnesic oxid	2.908	3.533	2.942	3.623
Potassic oxid	56.640	68.809	56.870	70.024
Sodic oxid	0.102	0.123	0.055	0.068
Sum	100.511	100.462	100.262	100.314
O=Cl	0.358	0.462	0.255	0.314
Total	100.130	100.000	100.007	100.000

culated on the crude ash, which of itself would not be a serious matter.

We ash at the lowest possible temperature to avoid both volatilization and fluxing; still it is probable that some fluxing takes place. There may not have been so much fluxing as one would expect; still a large percentage of the crude ash is made up of soil particles which expresses itself in the amount of ferric and aluminic oxids soluble in hydrochloric acid. The ferric oxid and perhaps a little of the alumina is derived from the hydrated oxids of iron deposited on the particles of soil rather than from the decomposition of these particles by the acid. It sometimes happens that a very sandy soil is quite brown as collected, but becomes very nearly white when washed with dilute hydrochloric acid, imparting a yellow color to the solution due to the going into solution of the hydrated oxids of iron that coated the grains. The presence of ferric oxid in the analyses is not proof of either fluxing or decomposition of soil particles by the acid, but some of it at least does not belong to the ash. These oxids are very much higher than one would expect from the agricultural analyses of the soil, even when made by digestion with concentrated hydrochloric acid.

Owing to these unsatisfactory features, due to the fact that our samples were contaminated with dust blown upon the plants in the field to such an extent that the crude ashes contained one-quarter or more of their weight of sand, we got other samples in 1924 from Estes Park, altitude 7500 feet, where the soil and other conditions are different.

This contamination with sand cannot but affect the determination of silicic acid, alumina, iron oxid and possibly lime. Besides, it is unsatisfactory to have to take out, say 45.0 percent of your analysis in calculating the pure ash. The samples of 1920 and 1921 were not very bad, but those of 1923 were extremely dirty, due to the repeated, heavy rains.

In addition to this, we still desired to get some assurance that we had a representative analysis of the potato vine. We have not much assurance of this now, but we have endeavored to obtain it whether it was worth the while or not.

TABLE XXX a.—ASHES OF VINES GROWN IN ESTES PARK, 1924.

Variety	Triumph		Cobbler	
	Crude Ash	Pure Ash	Crude Ash	Pure Ash
Carbon	0.882		0.491	
Sand	10.636		9.433	
Silica	6.671		4.076	
Carbon dioxid	21.476		24.498	
Chlorin	0.209	0.347	1.606	2.609
Sulfuric acid	1.967	3.268	2.134	3.467
Phosphoric acid	1.564	2.599	1.698	2.759
Aluminic oxid	2.134	3.546	1.448	2.353
Ferric oxid	1.716	2.851	1.320	2.145
Manganic oxid (br.)	0.107	0.177	0.093	0.151
Calcic oxid	20.586	34.213	20.054	32.588
Magnesic oxid	8.171	13.580	4.738	7.699
Potassic oxid	23.302	38.726	28.468	46.262
Sodic oxid	0.464	0.771	0.342	0.555
Sum	99.885	100.078	100.399	100.588
O=Cl	0.047	0.078	0.362	0.588
Total	99.838	100.000	100.037	100.000

It seems probable, considering all of the analyses presented, that only a small part of the silicic acid, alumina and iron oxid belongs to the ash of the vines, and that much the larger part of it is derived from the contaminating dust.

The Estes Park samples are higher in lime and lower in potash than our Greeley samples, but they agree in showing that our analyses give the composition of the ash or mineral constituents of the potato vine for our conditions, and that the variations produced by the application of nitrates can properly be interpreted on this basis.

The soluble silicic acid is decidedly high and quite consistently so. This is probably due to the action of potassic carbonate formed during the ashing process on extremely fine quartz particles which were blown on to the plants as dust, in which case it would be entirely proper to reject it as foreign to the ash, which we have done.

The presence of aluminic oxid in the ash of the potato plant may be doubtful and the ferric oxid that appears in the analyses is certainly too high, but we have no definite ground for rejecting either of these wholly, nor have we any basis for making corrections, so I have included them in the pure ash. I do not think that the other constituents that appear in the statement of the pure ash are in any case seriously affected thereby. The percentages of lime, magnesia, potash, chlorin, sulfuric and phosphoric acids are so large and so consistent thruout the series of analyses that it is evident they are not seriously affected. The soda in the ash is possibly wholly accidental. If not, its amount is so small and irregular that but little importance can attach to it. Manganese is probably an essential constituent of the plant but is never present in large quantities. The error in this instance is undoubtedly relatively large, tho the amount that appears in the statement of pure ash is usually less than two-tenths of one percent.

These statements concerning the contamination of the ashes and its effects cannot be neglected if one is to attach any importance to the analytical results. The significance of this dirty condition of the plants is not at all great except in such determinations as we have been making on dried material, in which it is a strongly disturbing factor especially as the amount of the contaminating material is difficult to ascertain. In some cases a determination made with the greatest care has no value except to establish qualitatively the presence of the constituent.

In the case of these ashes we have different portions of the plant, the vines and tubers whose ashes differ so greatly that the fact that the vines were dirty does not in the least obscure them. These differences pertain to practically all of the constituents of the ash. The chlorin, lime and magnesia are decidedly higher in the vines, while the sulfuric and phosphoric acids and potash are much higher in the tubers. The dry matter in the tubers, about 20.0 percent of the fresh tuber, carries from 4 to 5 or even 6 percent of ash, while that of the vines about 12.0 percent of the fresh, green, not dead vines, carries from 12 to 16.0 percent after deducting the dirt. This is, of course, an approximation based on the analyses. The pure ash of the tubers carries about 70.0 percent of potash, that of the vines 55.0 percent; that of the tubers carries from 11 to 17 percent of phosphoric acid; that of the vines about 5.0 percent.

Our object was not to ascertain these differences between vines and tubers in general, but to study the effects of nitrates in their ratios. Our check plots were so abundantly supplied with nitrates that we have no standards by which to judge. There are no differences between trial samples and checks taken on the same dates that consistently show any differences. In a few instances, for example, we may find more potash in the ash of vines grown with the application of nitrates, but often it is equal or even greater in the ash of the checks.

The series of analyses, had we known it, might well have been made much shorter and they are given *in toto* only to present the case for all varieties and for the whole season. We have gained nothing by so full a set of samples, even in the case of the ashes of the vines and tubers. These differences are constant. The ashes of the vines are poor in phosphoric acid and potash and rich in lime and magnesia compared with those of the tuber. The lime in the ash of the vines exceeds the magnesia, but this ratio is reversed in the ash of the tuber.

It appears that the ash in our fresh tubers is about 20.0 percent higher than is given in the literature. It does not appear that the richness of our soils in water-soluble salts is the cause of this, for these water-soluble salts are almost exclusively lime, magnesia and soda salts, mostly sulfates, but it is not uncommon to find potash and sometimes phosphoric acid. I know that the soil should absorb the former and that the latter should be precipitated from such a mixture, especially as a little sodic carbonate is so good as always present; still we sometimes find them present even in our ground waters. This large water-soluble portion is characteristic of our alkali soils. The land alloted to us at Greeley was rich enough in such salts to give a slight efflorescence under favorable conditions.

This high ash content in the tubers is not characteristic of those grown on our plots at Greeley but is common to all that we have tested. If the high ash be a result of this factor in our soils, I think that it should be common to all the potatoes grown in the state. The principal salts of the alkalis are not found in the ash of these potato tubers except in very small quantities. Lime, for instance, whose salts constitute about one-half of the water-soluble portion of the soil, occurs very sparingly in the tuber, approximately 0.01 percent of the fresh tuber, and soda salts that make up from 17 to 30 percent of the water-soluble (not identical with the so-called alkalis) are sometimes so good as wholly absent and seldom amount to more than 0.01 percent. The small amounts of potash and phosphoric acid sometimes present in this water-soluble would probably be appropriated by the plants, but it is doubtful whether this has anything to do with the high potash content of our potato tubers and certainly not with the low phosphoric acid content. The lime in the pure ash is lower than is given in the literature, but the principal differences are in the phosphoric acid and potash which are the ash constituents in other crops most largely affected by the application of nitrates. These differences are characteristic of our Greeley samples; they are all low in phosphoric acid and high in potash. We have but a single one in the samples taken in three years—one grown in the dryland section—in whose ash the phosphoric acid approaches the average of the analyses that I have found given by others, 17.33 percent. In the case of the dryland sample the phosphoric acid in the pure ash is 16.68 percent and we have but one sample in four years that equals it. The lime is also low which, considering the amount of soluble lime salts present in our soils, would not be expected provided the water-soluble portion of the soils is an important factor.

These statements concerning low lime do not apply to the ashes of the vines. I have only some very old data based on Wolffs' Aschenanalysen with which to compare them and these appear to relate to the leaves. According to these, the ash constituents vary somewhat with the age of the leaves, as the following percentages show:

	SO_3	P_2O_5	SiO_2	Cl	K_2O	CaO	MgO
Green leaves	4.66	7.32	7.00	5.31	27.0	30.9	19.5
Mature leaves	5.73	7.22	3.93	3.93	19.8	30.7	15.0

This is the nearest approach to data for vines that I have found.

We took, in 1923, fourteen sets of samples, seven sets from the check plots and as many from the nitrates, always in pairs—a check and one of the same variety to which the nitrate had been applied at the rate of 800 pounds per acre. We exhibit the results in a form similar to that above, but we divide the season into the first and second halves or the averages for the first seven and the second seven series, but make no distinctions between the varieties.

	SO_3	P_2O_5	Cl	CaO	MgO	K_2O
		NITRATES				
First half season	6.14	4.48	4.73	20.26	7.93	51.05
Second half season	6.44	3.87	5.23	22.36	10.60	43.86
Whole season	6.29	4.17	4.98	21.31	9.27	47.46
		CHECKS				
First half season	5.73	4.51	4.03	20.25	8.31	51.65
Second half season	5.85	3.81	4.14	22.50	11.15	44.44
Whole season	5.79	4.16	4.08	21.37	9.73	48.05

A glance at these tabulations shows that in this detailed form there is no agreement between them nor is there any agreement in the amount of ash in the dry matter. The German results show 9.42 percent and ours from 12 to 16 percent, after deducting the dirt. In our results we have rejected the silicic acid but it is included in the German statement and is more in amount than we find in our crude ash. There may be silicic acid in the potato vine proper but our plants were so dirty that we have not felt justified in considering the silica as derived from the plants. Besides, it varies too much, from 1¼ to 8 percent of the crude ash. We are probably justified in considering the German results as more nearly representing the mineral constituents of a normally fed potato plant than ours, and comparing our results with them, tho we have no idea of the character of the land on which they were grown nor what fertilization they may have received. But we know that ours were grown with a large supply of nitric nitrogen available thruout the season, even on those plots to which we had not applied nitrates, which was established by systematic sampling. As stated elsewhere, we could not distinguish any difference in the growth and color of the plants grown with the application of nitrate at the rate of 800 pounds per acre and those that had received none. The plants were equally large and equally green. This was a surprise to us as in experiments with beets and wheat such differences were distinguishable, in the case of the wheat, even to the drill row.

We compare briefly the results produced by our conditions upon the quantities of the mineral constituents common to the preceding tabular statements. The sulfuric acid in the vines grown on our check plots is higher and, in those grown with the application of nitrates, about the same as in the German ashes. The phosphoric acid in our samples is only about one-half of that in the German ashes; the chlorin is about the same; the lime in the German samples is 50 percent higher and the magnesia still higher, but the potash is about 50 percent lower.

If we compare our checks with our nitrates we find only one difference; the sulfuric acid in the nitrate samples is the lower, but the others, the phosphoric acid, lime, magnesia and potash are the same. I do not know how important the sulfuric acid is to the economy of the potato plant but this lower content of sulfuric acid in the ash of the nitrate samples is the rule, with few exceptions. We see, too, that there is a falling off of both phosphoric acid and potash in the second half of our samples and to the same extent in the checks and nitrates. These facts are concordant with our previous observation, that the check plots were supplied with nitrates to such an extent as to destroy their value as checks in every respect.

The German results show a few changes as the plants mature. Ours show a falling off in the phosphoric acid of about 0.5 percent; the German results show an increase of about 1.0 percent. This is a big difference and possibly a significant one. The potash in ours falls during the second period by nearly 8.0 percent and the German results show no change. There is apparently an elimination of potash from the vines as the plant matures.

If we compare our 1922 and 1923 results we find identical results for the lime and potash but lower phosphoric acid in 1922 by nearly 0.9 percent. This is a significant difference but is much less than we find between the German samples and ours where we find a difference of 3.11 percent in favor of the German sample.

We have found that the effects of nitrates are to suppress the phosphoric acid and to increase the potash; this was very marked in wheat (grain) and in the roots of the sugar beet. It was not so clear in the wheat straw and sugar beet tops; still it disturbed these ratios but not regularly as in the grain and beets. It is probable that we have in these results for 1922 and 1923 a difference directly related to the supply of nitrates during these respective years. In 1922 we had an average of 180 pounds of sodic nitrate in the top four inches of the soil thruout the season; in 1923 we had an average of only 69 pounds. These quantities are for the samples taken in rows occupied by plants, not in the fallow rows in which the nitrates were much higher. The average of 880 samples representing the field for the whole season shows 228 pounds in the top four inches. This difference in nitrates present accounts for the lower phosphoric acid in 1922.

We gave in Bulletin 291, page 29, a table showing the relative quantities of phosphoric acid and potash in the ash of the tubers of the 1920 crop. We shall give in this place the average results for the four seasons that we conducted the experiment and omit the detailed statements.

THE AVERAGE PHOSPHORIC ACID AND POTASH IN POTATO TUBERS FOR THE YEARS 1920, 1921, 1922, 1923

	Phosphoric Acid		Potash	
	Check	Nitrate	Check	Nitrate
1920	15.28	14.29	63.83	66.42
1921	12.72	12.64	69.78	70.55
1922	12.50	12.37	69.02	68.84
1923	15.04	15.09	68.95	67.82
Average	13.89	13.60	67.90	68.41
Average for all	13.75		68.16	
Averages given by others	17.33		60.37	

We realized in 1921 that our check plots, owing to the active development of nitrates in the soil, would give us no reliable basis for judging any results that we might obtain. In default of these we tried to get other Colorado-grown potatoes to substitute for them. In this endeavor we got together 12 samples of tubers, some of which we had grown for us. These tubers were examined according to the same schedule that we used in examining our principal crops. As has already been indicated in presenting the nitrogen compounds, the results were unsatisfactory so that we have no standard for the nitrogen compounds and only the very poor one of averages for the ash constituents. Our own are not satisfactory as standards and the data that we find in the literature on this subject are of little value for our purposes. We have been compelled to use such as we have found.

The twelve samples that we gathered in order to get some idea of the properties and composition of a normally grown potato, were from six localities; the major part of them was in the mountains because such potatoes have a good reputation.

The results obtained scarcely deserve mention in regard to either the nitrogenous or mineral constituents. There are two features in which some of them differ from ours. Some do not contain nitric nitrogen and the phosphoric acid in the ash is higher. Three of them average 17.40 percent phosphoric acid which is higher than the general average that we have found by 0.07 percent. The averages for the phosphoric acid and potash for the 12 samples are, phosphoric acid 14.62 and potash 70.58 percent, very similar to the averages of our check samples, 13.89 and 67.90, and lower in phosphoric acid than our 1923 samples with 15.04, during which year we had our lowest nitrates.

We have not proved why the nitrates were lower in 1923 than in 1920 or 1922, but 1923 was the wettest year that the station has record of and we have attributed it to this cause, both in regard to the organisms involved and to leaching.

We had no way of attacking the questions here suggested; the weekly determination of the nitrates in the soil was about the best that we could do. I think that the results obtained in the plots cultivated fallow compared with those obtained in cropped land during other seasons are conclusive as to the abated activity of the nitrifying organisms and indirectly of the fixing organisms during this season. The variation in the nitrate is the only measure that we have of the biological processes going on in this soil and it is a very limited one, practically confined to one class of organisms whereas many others are present.

The troubles of the period 1911-1914 were very largely due to fusaria which we believed found a better medium for their development in the over-fed plants than usual, so much so that they became decidedly pathogenic. Whether or not previous conditions had led to an unusually vigorous development of these organisms has not been ascertained, as far as I know.

The object of this study is to find out, if possible, the effects of nitrates on the growth, composition and properties of the potato plant and tuber—also upon its susceptibility to disease.

During the seasons of 1921, '22 and '23, observations were made on the amount of carbon dioxid in the soil atmosphere to get an idea of the total biological activity of our soils. These experiments had to be carried on at Fort Collins and not at Greeley, which would have been more desirable if feasible. In these experiments it became evident that fallow land gives very different results from cropped land, and that this difference varied with the crop and the temperature. The crop varied in its growth with its water supply, and with this, the amount of carbon dioxid in the soil atmosphere. The moisture supplied by our rainfall during the three seasons seemed quite sufficient to keep the soil population very active, and the carbon dioxid in the atmosphere of fallow land did not vary with the application of water, as it does in cropped land. The plant residues and like organic matter were already somewhat exhausted in the fallow land, and it was kept entirely free from vegetation. The data gathered in these experiments have been presented in Bulletin 319, pages 21 and 23, and would constitute Tables XXXI and XXXII of this bulletin.

Observations of 1924

In the summer of 1924, Prof. O. B. Whipple called my attention to two fields of potatoes on the bottom lands along the Gunnison river in Delta County, Colorado. In each of these cases a part of the field had previously been planted to a hay or grain crop and the other part to potatoes or other cultivated crop. There were many differences between the two sections in each case. While these differences manifested themselves in different degrees, they were of the same general character so that a full account of one will answer for both.

The one that we have chosen to describe lies immediately along the river. The soil is sandy, alluvial loam and is perfectly drained. Under ordinary conditions it is very fertile. Four years ago it yielded 400 sacks of onions per acre, and the harvest of potatoes in 1924, after alfalfa, was 140 sacks. I have observed this land for many years and have seen it in various crops which did well.

Part of this land was planted to potatoes and sugar beets in 1923. I did not obtain the yields. The other part was planted to alfalfa in 1922 and 1923, and was broken up in 1924. The line separating the alfalfa from the cultivated crops in 1922 and 1923 ran diagonally across the field. The whole field was planted to potatoes in 1924. The cultivation up to the end of July was good and the land was free from weeds.

The stand in the portion that had been in alfalfa for the two preceding years was good and the plants thrifty, but in the portion that had been in potatoes and sugar beets, there was no stand and the few plants that remained were dying. In the other field referred to the stand after potatoes was a little better, but the plants did not do well in the early part of the season. Grain had been grown the preceding season on the other portion of this field and the stand, as well as the condition of the crop, was very much better.

Prof. Whipple kindly photographed the field by the river at my request. This photograph was taken in August and some grass and weeds have partially occupied the land in the foreground. The crests of the rows are still almost free from vegetation of any sort, but the background is a solid mass of potato vines. A superficial examination revealed the cause of this. It was due to the soil; there was no disease to cause the trouble. The whole field was planted to the same variety of potatoes and out of the same lot of seed. In that portion of the field that had been occupied by alfalfa the soil had a normal appearance; it was neither in clods nor mealy and showed no ordinary alkali. The portion that had been in potatoes was mealy and, on the crests of the rows, puffed up. The former, the alfalfa soil, was poor and the latter rich in nitrates right up to the line where the alfalfa had grown.

On digging up some of the few plants that were still alive, the tips of the roots were found to be dead—they had all been killed back in the same manner. The portion of the roots remaining showed no disease but were at this time clean and had a natural color. The whole plant subsequently disappeared. The portion of the field here considered produced no crop but that where the alfalfa had grown produced 140 sacks to the acre. These potatoes were only fairly good in quality.

The crop in the other field was not so large, 20 sacks per acre after potatoes, 75 sacks after grain, and the quality of the potatoes was very poor. No part of the crop in this field was as good as that of the other field after alfalfa, nor was any of it as poor as that after potatoes in the other field. Only one pair of soil samples was taken in this field and that from the poorer or worse part of it; one sample represents the mealy surface soil on top of the ridges taken to a depth of not more than three inches, probably more nearly two inches, and the other represents the whole soil between the rows to a depth of six inches. The former showed the presence of 2161 p. p. m. of nitric nitrogen; the latter 111 p. p. m., equivalent to 12,966 and 666 p. p. m. respectively of sodic nitrate. The 6-inch section of this soil, assuming its weight to be 2,000,000 pounds, contained 1332 pounds of nitrates, calculated as sodic nitrate. The surface soil carried about six tons per million pounds. It is evident that a rain or perhaps an irrigation would have brought about a very different distribution of these nitrates in the top six inches, or perhaps to a greater depth in this soil.

While these results are striking, they are much less so than those obtained in the other case, where we have the effects of an alfalfa rotation for two years, illustrated in a most forceful manner. It also shows how and to what extent we were thwarted in our Greeley experiments by the fact that we were compelled to use land after a 2-year period in alfalfa. It also explains why our results in 1921, when we used the same plots that we used in 1920, were much more conclusive than those of the other years when we planted in rotation after alfalfa.

We have only two pairs of soil samples from this field, one pair from each section taken 16 July, 1924, which is a little earlier in the season than the nitrates attain their maximum in our section. The results might have been more valuable and interesting if we could have taken samples at short intervals up to the first of October, but this was not feasible as it would have required a round trip of more than 1000 miles for each sampling.

The two pairs of samples that we took represent, in this case as in the other, the surface mealy soil from the crests of the ridges to a depth of about three inches, and of six inches of soil between the rows

These samples were taken with an irrigating shovel and weighed at first several pounds and were afterwards cut down to 5 or 7 pounds. The second sample in each case was made by taking several six-inch sections from the sides and bottom of the creases, mixing them and cutting them down to about five to seven pounds. The samples are, of course, composite ones, taken in this manner to make them as nearly representative as possible. The results obtained were for the mealy samples from the crests: 2297 p. p. m. of nitric nitrogen in the soil from the portion that had been in potatoes, and 270 p. p. m. in that that had been in alfalfa. This is equivalent to 13,782 pounds of sodic nitrate per million pounds of surface soil after the potatoes, and 1,620 after the alfalfa. For the samples taken six inches deep, we found in the sample after potatoes, 4,692 pounds, and after the alfalfa, 324 pounds; assuming as before that this soil taken to this depth weighs 2,000,000 pounds.

We made the following examinations of these soils. A mechanical analysis, an analysis of the water-soluble portion, a mass analysis, and the ordinary agricultural analysis, using two methods of extraction, i. e., concentrated hydrochloric acid and N|5 nitric acid. The results are given in the following tables:

TABLE XXXIII.—MECHANICAL ANALYSIS OF THE SOIL FROM THE FIELD BY THE RIVER. TWO 6-INCH SAMPLES WERE COMBINED.

Coarse sand	1.00-0.50 mm.	0.321
Medium sand	0.50-0.25 mm.	2.361
Fine sand	0.25-0.05 mm.	51.347
Silt	0.05-0.01 mm.	25.935
Dust	0.01—Clay	9.573
Clay		4.381
Ignition		6.083
		100.001

Concerning the mass and agricultural analysis made with N|5 nitric acid, it should be stated that, owing to the abundance of water-soluble material present, we washed the soil slightly by taking 100 grams, shaking it for one-half hour with 1000 c.c. of water, allowing it to settle and separating the solution by decantation and filtering. The analysis in which hydrochloric acid was used as the solvent was made on the sample without washing.

In the case of the ranch referred to as No. 1, it might be argued that the soluble salts were foreign to the soil and that they owe their origin to seepage from a neighboring mesa. Such an argument would be entitled to serious consideration and would be very difficult to rebut in an entirely satisfactory way. If it were urged, however, the rejoinder would be that we present the conditions under which the crops were grown and that the good and bad portions of the field have the same relation to the mesa and both irrigated with river water; the differences found in the two portions would still be accounted for by the different cropping and the nitrates in the soluble salts in the portion previously planted to potatoes would still remain as the direct cause of the failure.

TABLE XXXIV.—ANALYSES OF THE WATER-SOLUBLE PORTIONS OF THE SOILS FROM POTATO FIELDS IN DELTA COUNTY

	Field 1		Field 2			
			After Potatoes		After Alfalfa	
	Mealy surface soil 2-3 inches	Soil taken 6 ins. deep	2-3 ins. deep	6 ins. deep	2-3 ins. deep	6 ins. deep
Sand	0.035	0.053	0.023	0.065	0.016	0.112
Silica	0.406	1.247	0.269	1.624	1.001	3.719
Carbon dioxid	0.478	0.317	0.314	2.060	0.495	2.746
Chlorin	9.449	3.047	10.792	4.002	6.772	3.233
Sulfuric acid	17.666	42.066	20.483	28.652	31.041	31.146
Nitric acid (N_2O_5)	23.716	5.371	19.862	15.041	13.962	4.554
Aluminic oxid	0.076	0.043	0.252	1.433	0.521	1.031
Ferric oxid	0.013	0.020	0.014	0.035	0.023	0.024
Calcic oxid	12.767	17.335	10.305	17.798	15.577	16.833
Magnesic oxid	3.557	2.936	5.156	5.985	5.078	4.071
Potassic oxid	0.569	1.021	0.886	1.838	2.329	2.897
Sodic oxid	21.956	18.548	21.030	12.537	16.079	15.375
Ignition	11.579	7.949	13.105	9.767	8.604	15.263
Sum	102.267	100.430	102.491	100.837	101.498	100.902
O=Cl	2.133	0.688	2.436	0.903	1.528	0.730
Total	100.134	99.742	100.055	99.934	99.979	100.172
Total water soluble	3.48	0.794	4.46	0.692	1.08	0.46

TABLE XXXV.—MASS ANALYSES OF THESE SOILS

	No. 1, Lab. No. 2862	No.2, Lab. No. 2866
Carbon	3.150	3.275
Silicic acid	65.400	66.783
Sulfuric acid	0.158	0.127
Chlorin	0.105	0.070
Carbonic acid	3.105	1.379
Phosphoric acid	0.215	0.203
Titanic acid	0.420	0.248
Aluminic oxid	10.011	13.346
Ferric oxid	5.809	4.610
Manganic oxid (br)	0.160	0.170
Calcic oxid	5.390	3.280
Magnesic oxid	1.444	1.321
Potassic oxid	2.425	2.739
Sodic oxid	1.681	1.797
Water	....	....
Sum	100.208	100.108
O=Cl	0.023	0.016
Total	100.185	100.092

TABLE XXXVI.—AGRICULTURAL ANALYSES, HYDROCHLORIC ACID SOLVENT

	Field 1		Field 2 After potatoes		Field 2 After alfalfa	
	No. 2861 surface	No. 2862 6 inches	No. 2863 surface	No. 2864 6 inches	No. 2865 surface	No. 2866 6 inches
Moisture	1.801	0.735	1.650	1.410	1.240	0.660
Sand	70.224	69.048	68.970	73.328	70.610	74.907
Silica	4.957	7.594	6.568	7.050	7.871	7.156
Sulfuric acid	0.624	0.345	1.087	0.161	0.319	0.086
Carbonic acid	2.835	3.105	1.581	1.519	1.671	1.379
Chlorin	0.186	0.105	0.051	0.105	0.114	0.070
Phosphoric acid	0.370	0.165	0.182	0.188	0.185	0.198
Titanic acid	0.350	0.420	0.370	0.348	0.432	0.348
Ferric oxid	4.710	3.800	3.760	3.520	3.930	3.880
Aluminic oxid	2.885	4.255	3.995	4.222	4.453	3.667
Manganic oxid (br)	0.075	0.130	0.070	0.090	0.075	0.085
Calcic oxid	3.200	4.375	3.380	2.795	2.985	2.465
Magnesic oxid	2.035	1.298	1.432	1.083	1.263	1.096
Potassic oxid	0.538	0.585	0.514	0.519	0.754	0.578
Sodic oxid	1.042	0.544	1.297	0.295	0.249	0.122
Ignition	3.890	3.150	5.359	3.805	3.920	3.257
Sum	99.720	99.666	100.366	100.438	100.071	99.972
O=Cl	0.042	0.023	0.012	0.047	0.026	0.016
Total	99.678	99.643	100.354	100.391	100.045	99.956

TABLE XXXVII.—AGRICULTURAL ANALYSES, FIFTH-NORMAL NITRIC ACID SOLVENT

	Field 1		Field 2 After potatoes		Field 2 After alfalfa	
	No. 2861 surface	No. 2862 6 inches	No. 2863 surface	No. 2864 6 inches	No. 2865 surface	No. 2866 6 inches
Moisture	1.535	0.735	1.650	1.310	1.257	0.660
Sand	82.726	83.707	81.650	87.639	86.421	89.200
Silica	1.714	1.570	1.766	1.315	1.307	1.188
Sulfuric acid	0.561	0.292	0.995	0.132	0.281	0.086
Chlorin	0.186	0.105	0.051	0.105	0.114	0.070
Carbonic acid	2.835	3.105	1.581	1.519	1.671	1.379
Phosphoric acid	0.173	0.182	0.128	0.049	0.057	0.121
Ferric oxid	0.220	0.181	0.643	0.398	0.490	0.275
Aluminic oxid	0.735	0.705	0.655	0.177	0.204	0.475
Manganic oxid (br)	0.065	0.055	0.070	0.133	0.140	0.055
Calcic oxid	4.290	4.485	2.935	2.580	2.840	2.255
Magnesic oxid	0.798	1.414	0.925	0.542	0.635	0.478
Potassic oxid	0.111	0.106	0.146	0.103	0.131	0.078
Sodic oxid	1.522	0.276	1.084	0.402	0.374	0.186
Ignition	2.985	3.150	5.790	3.805	3.920	3.275
Sum	100.456	100.068	100.072	99.939	99.842	99.781
O=Cl	0.042	0.023	0.012	0.024	0.026	0.016
Total	100.414	100.045	100.060	99.915	99.816	99.765
Total nitrogen	0.2632	0.0749	0.3367	0.1022	0.1323	0.0735

The water-soluble salts extracted from the soil of ranch No. 1—mealy sample from crest of the rows—amounted to 3.48 percent of the sample and carried 23.7 percent of nitric acid (N_2O_5); in other words, one-third of the soluble salts consisted of nitrates.

In the case of ranch No. 2, no plausible claim of translocation of the salts can be made, nor of concentration of salts from the lack of drainage. The amount of water-soluble in the mealy portion of the crests amounts in this case to 4.46 percent, of which 30.19 percent consists of nitrates. In this case the bad portion is limited by a line running diagonally across the field which coincides exactly with the edge of the portion occupied for the two preceding years by the alfalfa which is well shown in Plate I. The figures given for the nitric nitrogen have been calculated from the analyses of the water-soluble in which the nitric acid was determined by converting it into nitric oxid (NO) and absorbing it in ferrous chlorid. It is, consequently, not too high.

The vines and potatoes grown on these fields, either on the better or the worse parts, were not grown under normal conditions, but under very bad conditions and present very clear evidence of the effects of these conditions, the principal one being the presence of excessive quantities of nitrates, together with the effects of rotation to grain or to alfalfa in ameliorating them. This constitutes a definite advance over the experiences of the preceding four years, and this is the reason for our giving so much analytical data for these soils and crops.

The question of the effects produced by the large amounts of water-soluble salts in our soils has recurred very often in our experience. We have assumed that the concentrations of these salts that we frequently find in the surface portions of the soil are prejudicial, but we have been unable to establish this by observation. We have seen good crops, both in quantity and quality, grown on land heavily charged with alkalis, i. e., with the sulfates of lime, magnesia and soda, with smaller portions of carbonates and chlorids. We have seen corn, wheat, beets and other crops, even garden truck, growing well on land as heavily charged with soluble salts, so far as the total amount is concerned, as these soils, but they contained only small amounts of nitrates.

I have observed these facts in cases where I would have judged the water to be present in injurious quantities and also in its absence.

I am fully convinced that it has been very general with us to attribute too much importance to these alkalis, and our water problems are quite as perplexing. The practice of sub-irrigation in some sections of the state presents this latter question in a strong light. The section of country is, generally speaking, strongly alkaline.

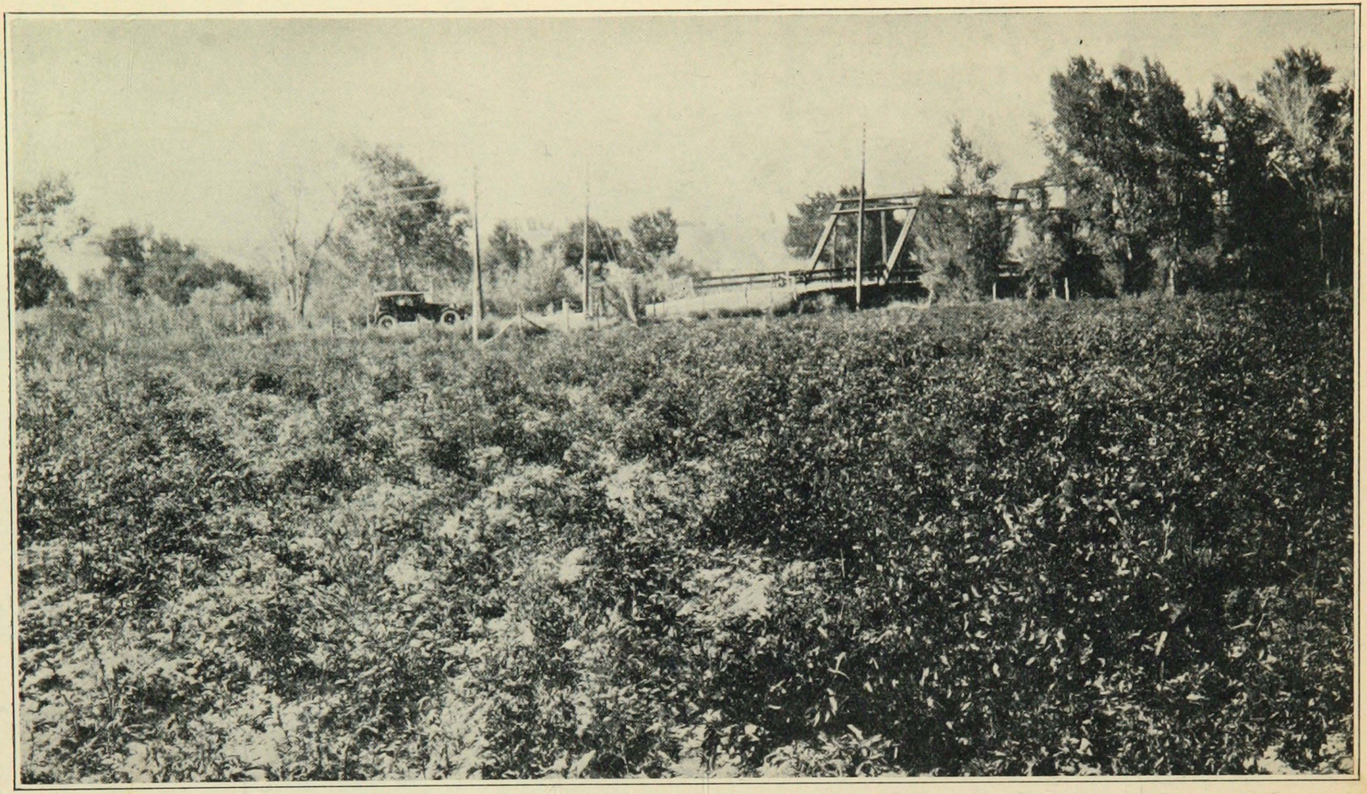

Plate I.—Field on Ranch 2, showing marked difference in crops. On the right, potatoes after alfalfa.

I have seen square miles of it covered with an efflorescence fully one-quarter of an inch thick. Objection may be made to speaking generally but when one has an area of more than 3,000 square miles in mind, he has to be general, for it is understood, without statement, that there will be local variations in these conditions. The general practice here is to sub-irrigate. This means to raise the water-plane to within a few inches of the surface and hold it there during the greater part of the growing season. The general practice is to hold it from 22 to 20 inches of the surface. I have been assured that it is sometimes held within 12 inches of the surface. These are perplexing facts when one tries to convince oneself that the alkalis and a water-plane 3 or 3½ feet below the surface are doing damage in another section. The facts may be as stated in both cases, but it is difficult to harmonize them.

I know of a piece of land that was used for a number of years as a truck garden. I have seen the ground-water filling cow tracks in portions of it, only a few inches lower than the highest portions of the piece, with masses of sulfate of soda an inch or more in diameter crystallized out. A sample of this ground-water taken under the cropped portion carried 6,914 p. p. m. of total solids, 27 percent of which was magnesic sulfate and 26 percent sodic sulfate. The surface of this garden under favorable conditions was white. The soil carried 1.314 percent water-soluble. There was an apple orchard on an adjoining piece of land in which the trees had attained to a size of average trees of their age, say about 20 years.

Another piece of land on which fair corn and excellent wheat grew carried 4.8 percent water-soluble in a surface sample and was irrigated with seepage water. The water-plane in this land was low —how low I do not know—but there was no trouble about high water.

These are not isolated facts; they can be duplicated. Such facts as these have led me to doubt whether we know enough about these phases of our problems to justify the views very generally held on the subject. There are many facts that justify us in assuming that there is some peculiar character in the water-soluble portion rather than its quantity that is to be taken into consideration in cases where injury is done.

I find that I took samples from ranch No. 1 some years ago and examined them. The samples were not taken from the same field that those of the past season were taken. The field at the time was planted to beets and they were doing fairly well. The water-soluble consisting of ordinary alkalis amounted to 7.16 percent. The ground is rather lower than that from which last season's samples were taken. It is, then, not the amount but the kind of salts present. The analysis of the 7.16 percent water-soluble showed the presence of 13.4 percent magnesic sulfate and 60.0 percent sodic sulfate with a trace of nitrates. The water-soluble in the sample taken in 1924 amounted to 3.48 percent, one-third of which was nitrates.

We endeavored for more than fifteen years to ascertain the lower limit of the amount of alkalis in the soil, also in irrigating water that would prove injurious. We found this limit so high that we deemed it a futile effort to establish any limit and concluded that, if established, it would have no practical value.

It will be noticed that the alkalis mentioned in the preceding paragraphs are rather rich in magnesian salts, calculated as sulfate, and the water-soluble of these samples is fairly so, from 0.36 to 0.70 percent of the sample. In the sample taken some years ago the magnesic sulfate amounted to 0.93 percent of the surface soil. Such quantities do not seem to be unusual, especially in some sections, and yet we cannot convince ourselves that these salts actually do any damage.

The other side of the question, i. e., Do they do any good? is also an open one. The analyses of the water-soluble portions of these soils agree in showing enough potash to justify its consideration, as it amounts to several hundredths of one percent of the dry soil, but the mass analyses show 2.4 and 2.7 percent respectively, and the importance of the few hundredths of a percent in the water-soluble is overshadowed.

Neither the quantity of the water-soluble nor anything in it, except the nitrates, is either peculiar or injurious. Larger amounts of water-soluble salts, commonly called alkalis, in the soil of this same ranch did no perceptible damage, and the potash found is not peculiar to these samples. The water-soluble from the land on which the corn and wheat grew carried 1.3 percent potash. The lime appearing in the water-soluble may be principally present as sulfate but some of it may be present as nitrate. We have found cases in which calcic nitrate associated with magnesic nitrate was clearly the principal salt.

The amount of the water-soluble was depressed by the alfalfa from 4.46 percent in the surface mealy soil after potatoes to 1.03 percent in a comparable sample taken after alfalfa. How this has been brought about is not clear. It does not seem probable that this is due solely to the shading of the ground by the potato vines during the season, which may have retarded evaporation from the surface, but our results show this difference. It was probably due to the occupancy of the ground for two seasons by the alfalfa.

The mass analyses are very similar to those of other Colorado soils. The carbonic acid and lime in the soil from ranch No. 1 are rather higher than usual for soil of the same class; otherwise there is nothing in them to call for particular notice. The phosphoric acid and potash are abundant. While the total potash is high, about 2.5 percent, it is not unusually so for our soils. On the other hand, there is nothing in the composition indicating any deficiency, and the mechanical condition of the field on ranch No. 2 is excellent. The conclusion concerning the adequacy of the food supply in these soils is strongly supported by the results of the agricultural analyses, especially by those made with N|5 nitric acid after washing to remove the soluble salts, which might possibly be considered as detracting from the conclusiveness of the results by extracting with hydrochloric acid without washing. The same is the case in regard to the total nitrogen, except for the surface samples in which the water-soluble portions indicate an excess of nitric nitrogen. If the total nitrogen were not so largely in the form of nitrates, it would not do any injury, but it is in this injurious form up to 82 percent of the total in the mealy surface soil from ranch No. 1, and 62 percent from ranch No. 2; whereas, in the six-inch sample from the soil that had been occupied by alfalfa for the two preceding years, it amounted to only 7.3 percent of the total, and the total itself was low—only 0.0735 percent.

The ratio of nitric nitrogen to the total nitrogen is given as 5.0 percent for a maximum, and even the alfalfa soil is a little higher than this. The preceding ratios are based on our analytical results. In order to check these, we washed some surface samples which are very rich in nitric nitrogen and determined the total in this washed soil. The washing was not carried to an extreme. The soil was shaken up with 10 parts of water three times, filtered, dried, and the total nitrogen determined in the washed soil. The original determinations gave 0.2632, 0.2863 and 0.2865 percent, the washed soil gave 0.0714, 0.0861, 0.0924 percent respectively, or about 66.0 percent of the total nitrogen was soluble in water.

In other words, neither the mass nor agricultural analyses show any reason for the failure, but the analyses of the water-soluble show a very excessive amount of nitrates in the soil. The abundance of the water-soluble and its character, together with the calcic carbonate in the soil, indicate excellent conditions for the processes of fixation and nitrification.

The surface soil from ranch No. 1 yielded 3.48 percent of soluble matter to water, one-third of which consisted of nitrates, while a similar sample from ranch No. 2 yielded 4.46 percent soluble, 30.19 percent of which was nitrates.

We have known these ranches for a long time and these extreme conditions have not heretofore existed. It is not to be understood that we have not previously known of the occurrence of nitrates, even in excessive quantities in this section previous to this time, for the contrary is the case, but we had never seen it so prevalent as in the season of 1924. The appearance of these nitrates in these fields in excessive quantities are not isolated instances. We have given many instances in former publications and have insisted on their variability from year to year. These instances do, however, illustrate conditions that favor, and others that hold their development in check better than any others known to me. Besides, they show the effects of the nitrates in the development and properties of a given crop better than any other that we have had opportunity to study. It was fortunate that the crop planted in 1924 was potatoes, as the results articulate with the work that we had in hand.

There are other points of interest connected with the water-soluble portions. These portions are considerably lower in both the shallower and deeper samples from the land that had been in alfalfa than those from land that had been in potatoes. The sample of surface soil that had been in potatoes in 1922 and 1923 yielded 4.46 percent to water. A similar sample taken from the land that had been in alfalfa for these two years gave only 1.08 percent soluble. In the samples taken six inches deep the amounts found were 0.692 and 0.460 percent respectively. The nitric acid is very high, 19.9 percent N_2O_5 in the water-soluble portion of the surface soil that had been in potatoes for two years. This corresponds to about 0.9 percent nitric acid in the air-dried soil, but in the corresponding sample after alfalfa we have 13.9 percent N_2O_5, equal to 0.15 percent of the air-dried soil. In the samples taken six inches deep we find after the potatoes 0.10 percent and after the alfalfa 0.02 percent of nitric acid. After the potatoes we had no crop, but after the alfalfa we had 140 sacks to the acre.

In the six-inch sample taken after alfalfa, we find the soluble silicic acid rather high, 3.72 percent. This was not due to colloidal clay suspended in the solution, at least the solution was filtered clear after concentrating the last wash water to coagulate any clay that might be present.

Another notable point in this connection is the amount of potash that is present in all of them, particularly so in the six-inch sample after alfalfa. These two constituents, silicic acid and potash, have been noticed in many extracts from different soils. The silicic acid has been looked upon as doubtful but not the potash. In this case we believe that we find an answer to the doubts heretofore entertained relative to the silicic acid and a suggested explanation of its source; to wit, the increased rate of decomposition of the silicious constituents of the soil, especially of felspars which may account for both the silicic acid and the potash.

These lands are somewhat alkaline, which is indicated by the amounts of sulfuric acid, chlorin, lime, magnesia and especially soda present. The carbonic acid is low in these extracts, as is usual in our white alkali. The similarity of the amounts of sulfuric acid and soda found in a sample of alkali from a beet field on ranch No. 1, in which the beets did very well, will illustrate this fact. The water-soluble in the alkali soil of the beet field amounted to 7.19 percent; this contained 53.86 percent sulfuric and 27.96 percent of soda. The water-soluble, 0.79 percent, from the six-inch sample from the potato field carried 42.06 sulfuric and 18.55 percent of soda. When the former sample was taken, the owner was using a seepage water for irrigating the land. This water contained 2994 p. p. m. of total solids. An analysis of these showed the presence of 50.89 percent sulfuric acid, SO_3, 17.13 percent lime and 17.04 percent of soda. The magnesia was 6.71 percent and the potash 0.45 percent. Potash occurs quite regularly in extracts from such soils and in corresponding ground-waters. This is not the case with phosphoric acid, tho small amounts are sometimes found in the ground-waters.

These analyses were made for two reasons; first, to ascertain the amounts of nitrates in this direct way, and secondly, to obtain an idea of what influence the other water-soluble constituents may have on the crops. The nitrates overshadow the others so greatly in importance that we really gain but little idea of the influence of the latter, which constitute our ordinary white alkali with rather more potash than usual.

While the writer does not share the prevalent opinion regarding the prejudicial action of white alkali upon our crops, the large amount of soluble salts in our soils compared with those of humid regions would seem to be sufficient to make observable differences in our agricultural results. We have, for instance, an abundant supply of lime, magnesia and potash which are all more or less soluble in water, and which, in part at least, may be derived from felspars or by the interaction of soda salts on zeolitic constituents of the soil. This neither changes nor adds to the force of preceding statements, but it does emphasize the reactive properties of our soils.

The nitrates in these cases so overshadowed the other constituents in their effects that we are left in doubt as to the injurious character of any other constituent. There really seems to be no other constituent present in sufficient quantity to do any injury. I do not think that I have seen the statement made, but it is my impression that experienced ranchmen do not object to the presence of ordinary amounts of white alkali in the soil.

Potato Vines from Ranches 1 and 2

Turning from the soils to the crops, we found the stand in the field on Ranch 1 poor, both after grain and after potatoes, but very much better after the grain than after the potatoes. The yields correspond to the conditions; there were after the grain 75 sacks, after the potatoes 20 sacks.

On Ranch 2 one portion had been in alfalfa for two years, 1922 and 1923, and the other in potatoes and beets for two years and had probably been in cultivated crops for several years before 1922. This field is illustrated in Plate I, page 74, photograph by Prof. O. B. Whipple. After the alfalfa the stand was perfect; after the potatoes there was no stand. In July, there was only here and there a plant left. The crop in this section was so much of a failure that a large portion had to be dug over to get a sample of 40 pounds.

The individual plants on the alfalfa land were thrifty and large; on the potato land they were small and many of them burned up. Samples of these vines were treated exactly as we treated our Greeley samples and they reached the laboratory in good condition. The analyses of these vines follow, (Tables XXXVII-XLI).

We have given in these tables as complete analyses of vines and tubers as we have made of any samples. All of these samples were grown on bad land, some of it so bad that the crop was a complete failure. Even the better portion of the field on Ranch 1 was not good except in comparison with that which had been in potatoes in 1923. The total nitrogen in the whole vine shows the effects of these conditions better than any other feature of the composition, which is greater in the vines after potatoes than after the grain or alfalfa. One should remember, however, that the vines in the plots grown after potatoes were not only unhealthy but were small and, of course, abnormal in development.

We had in the surface soil after alfalfa 391 p.p.m. nitric nitrogen and in the top six inches, 54 p.p.m. The vines grown on this land contained 0.378 percent total nitrogen; in the surface soil after potatoes we have 2297 p. p. m. and in the sample to the depth of six inches, 270 p.p.m. of nitric nitrogen; the vines grown on the land contained 0.5866 percent total nitrogen. The vines from the other field after potatoes where the surface soil carried 2161 p.p.m. and taken to a depth of six inches 111 p.p.m. nitric nitrogen, contained 0.5269 percent total nitrogen. The average found for three seasons in the Greeley experiments was, for the nitrate plots, 0.415, and for the check, 0.405 percent. These percentages are higher than we found in the Delta samples grown after alfalfa, which was 0.3780. The Greeley samples were also grown on land that had been in alfalfa for two years.

TABLE XXXVIII.—ANALYSES OF POTATO VINES, DELTA, COLORADO

	Dry Matter	Marc	Juice	Sp.Gr. of Juice	Total Nitrogen in pulp	Nitric Nitrogen in pulp	Ammonia Nitrogen in pulp	Amid Nitrogen in pulp	Amino Nitrogen in pulp	Total Nitrogen in juice	Albumin Nitrogen in juice	Proteose Nitrogen in juice	Peptone Nitrogen in juice
FIELD I													
After grain	15.05	9.04	90.96	1.035	0.4900	0.0365	0.0198	0.0056	0.0336	0.2416	0.0724	0.0116	0.0103
After potatoes	15.96	9.10	90.90	1.042	0.5269	0.0387	0.0153	0.0066	0.0398	0.2655	0.0642	0.0161	0.0132
FIELD II													
After alfalfa	12.93	8.76	91.24	1.024	0.3780	0.0205	0.0050	0.0029	0.0148	0.1534	0.0405	0.0129	0.0051
After potatoes	14.73	9.18	90.82	1.030	0.5866	0.0632	0.0130	0.0074	0.0308	0.2691	0.0724	0.0094	0.0141
ANALYSES OF POTATOES, DELTA, COLORADO													
FIELD I													
After grain	25.45	17.32	82.68	1.026	0.3853	0.0021	0.0104	0.0466	0.0749	0.3920	0.1280	0.0384	0.0245
After potatoes	21.60	16.65	83.35	1.028	0.3870	....	0.0102	0.0469	0.0762	0.3712	0.1226	0.0440	0.0250
FIELD II													
After alfalfa	21.75	16.36	83.64	1.024	0.2941	Trace	0.0099	0.0333	0.0608	0.3248	0.1157	0.0145	0.0382
After potatoes	22.30	15.89	84.11	1.025	0.3520	0.0011	0.0118	0.0385	0.0710	0.3584	0.1278	0.0190	0.0261
ANALYSES OF POTATOES, DEL NORTE, COLORADO													
Burbank	23.55	18.44	81.56	1.030	0.2764	....	0.0101	0.0409	0.0751	0.2964	0.0770	0.0197	0.0206

NITROUS ACID, STARCH, AND SUGARS IN POTATOES

	Nitrous acid p.p.m.	Starch	Reducing Sugars	Total Sugars
Field I, grain	6.90	14.86	0.479	0.614
Field I, potatoes	9.40	15.03	0.702	0.879
Field II, alfalfa	Trace	16.78	0.380	0.370
Field II, potatoes	5.00	12.77	0.468	0.720
Burbank, Del Norte	6.00	16.39	1.328	1.560

TABLE XXXIX.—ASHES OF POTATO VINES, DELTA COUNTY, COLO., 1924

	Ranch 2* After alfalfa	Pure Ash	Ranch 2 After potatoes	Pure Ash
Carbon	0.362		0.675	
Sand	6.571		8.206	
Silica	5.311		6.599	
Carbon dioxid	15.348		13.442	
Chlorin	4.478	6.197	6.604	9.297
Sulfuric acid	11.801	16.332	7.988	11.246
Phosphoric acid	1.649	2.282	2.354	3.314
Aluminic oxid	2.053	2.841	2.718	3.826
Ferric oxid	0.846	1.170	1.107	1.558
Manganic oxid (br)	0.051	0.070	0.047	0.066
Calcic oxid	13.607	18.832	16.696	23.507
Magnesic oxid	6.766	9.364	8.210	11.558
Potassic oxid	31.854	44.086	21.230	29.890
Sodic oxid	0.156	0.218	5.565	7.834
Sum	100.855	101.392	101.441	102.096
O=Cl	1.006	1.392	1.489	2.096
Total	99.849	100.000	99.952	100.000
Ash in dried vines	15.050		16.800	

(*)No ash of the vines from Ranch 1 was analyzed; the sample became contaminated with salt in shipment.

TABLE XLI.—ASH OF POTATO TUBERS, DEL NORTE, COLORADO

	Burbank	Pure Ash	Ohio*	Pure Ash
Carbon	0.143		0.141	
Sand	0.594		0.602	
Silica	0.542		0.497	
Carbon dioxid	17.823		15.978	
Chlorin	2.061	2.546	3.679	4.446
Sulfuric acid	5.196	6.418	4.744	5.732
Phosphoric acid	10.449	12.908	11.851	14.320
Aluminic oxid	0.250	0.309	0.372	0.450
Ferric oxid	0.273	0.337	0.292	0.353
Manganic oxid (br)	0.096	0.119	0.086	0.104
Calcic oxid	2.227	2.751	1.796	2.170
Magnesic oxid	4.566	5.640	4.566	5.517
Potassic oxid	56.222	69.451	56.202	67.911
Sodic oxid	0.078	0.096	None	....
Sum	100.520	100.575	100.806	101.003
O=Cl	0.465	0.575	0.830	1.003
Total	100.055	100.000	99.976	100.000
Percent ash in fresh potatoes	1.034		0.996	

*These Ohios were very scabby and were not well adapted to our purpose.

TABLE XL.—ASH OF POTATO TUBERS, DELTA COUNTY, COLORADO, 1924

	Ranch 1 After Grain		Ranch 1 After Potatoes		Ranch 2 After Alfalfa		Ranch 2 After Potatoes	
		Pure Ash		Pure Ash		Pure Ash		Pure Ash
Carbon	0.137		0.168		0.097		0.049	
Sand	0.791		0.765		0.481		0.351	
Silica	0.587		1.134		0.525		0.466	
Carbon dioxid	17.056		16.996		18.785		16.833	
Chlorin	5.228	6.427	4.605	5.693	4.099	5.131	6.628	8.013
Sulfuric acid	6.997	8.602	7.214	8.919	5.938	7.433	6.349	7.676
Phosphoric acid	7.424	9.127	7.537	9.319	7.172	8.978	9.263	11.199
Aluminic oxid	0.602	0.740	0.943	1.166	0.387	0.484	0.147	0.178
Ferric oxid	0.405	0.498	0.293	0.362	0.496	0.621	0.317	0.383
Manganic oxid (br)	0.028	0.034	0.027	0.033	0.041	0.051	0.025	0.030
Calcic oxid	1.500	1.844	1.886	2.331	2.338	2.927	1.833	2.216
Manganic oxid (br)	3.478	4.276	3.692	4.564	3.457	4.327	3.122	3.774
Potassic oxid	53.501	65.779	52.213	64.557	55.453	69.413	53.663	64.877
Sodic oxid	3.353	4.122	3.526	4.355	1.432	1.793	2.864	3.462
Sum	101.087	101.449	100.999	101.299	100.701	191.158	101.910	101.808
O=Cl	1.179	1.449	1.051	1.299	0.925	1.158	1.496	1.808
Total	99.908	100.000	99.948	100.000	99.776	100.000	100.414	100.000
Ash in fresh potato	1.142		1.128		1.034		1.063	

Of the other forms of nitrogen, the nitric nitrogen shows this relation most plainly. In the vines grown after alfalfa we have 0.0205 and after potatoes, 0.0630; after the grain, 0.0365, after potatoes, 0.0387 percent. The average in our Greeley samples was considerably higher, especially in those grown with the application of sodic nitrate at the rate of 800 pounds per acre.

The yield of potatoes has been given as 20 sacks after potatoes and 75 sacks after grain on Ranch 1, and as a total failure after potatoes and 140 sacks per acre after alfalfa on Ranch 2. There is a further difference than the mere difference in the volume of the yield. The potatoes from this ranch after alfalfa were of good size and fair in quality, while those after the potatoes were unfit for use. Plate II will convey an idea of this difference.

The ashes of these potatoes show the same characteristics of composition as the Greeley samples already discussed.

We observe that all of the tuber ashes examined are low in phosphoric acid and high in potash. The average of the three highest percentages of phosphoric acid found in all Colorado samples analyzed is just equal to the averagd found for the analyses given in the literature. If this were the case with a single set of samples it might be dismissed as an accident, but we have 45 samples gathered over an interval of five years, and the percentages found are characteristic; namely, low phosphoric acid and high potash. We find

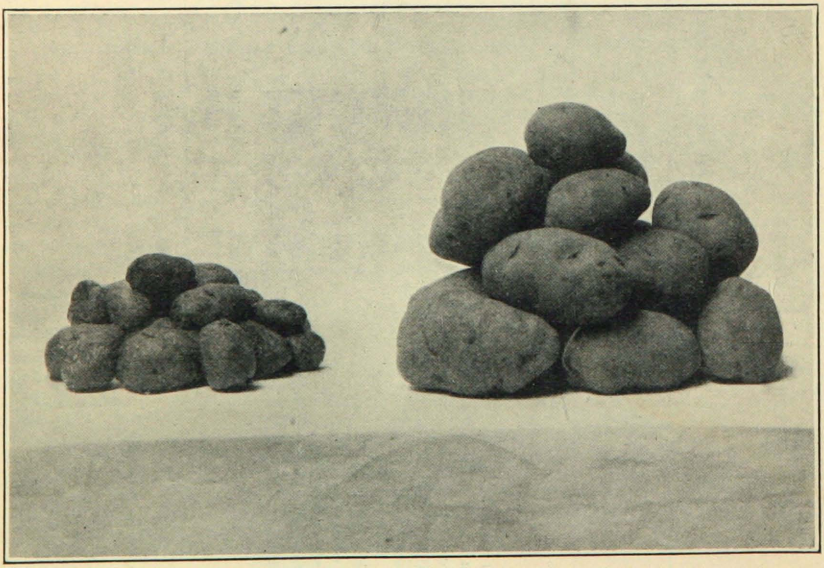

Plate II.—This illustrates the difference in production on the two parts of the same field.

13.75 percent as the average percentage of phosphoric acid for all samples of tubers grown with the application of nitrates during four seasons, and 68.16 as the average percentage of potash for the same samples. The average phosphoric acid in the ashes of the tubers of the four samples gathered in 1914 all of which were grown on ground exceptionally rich in nitric acid is 9.656 percent and the potash in the same is 66.156 percent. The average given for all other analyses that we have been able to find is 17.33 percent for the phosphoric acid and 60.37 percent for the potash.

We have been unable to find any satisfactory data pertaining to the ashes of the vines. Such as we *have found* indicate differences in the same direction as we found in the ashes of the tubers but in a very much larger degree. The phosphoric acid in our vines was only about one-half as much as was given for German vines and the lime two-thirds as much, but the potash was just about twice as much as in the German vines.

Our Delta samples do not agree well with one another; the conditions, however, under which they were grown justify us in being surprised that they agree as well as they do, for the vines grown after potatoes were scarcely enough like ordinary potato vines to justify comparison with either those grown after alfalfa or with the Greeley vines. The ashes of the vines grown after alfalfa differ from the ashes of the Greeley vines in containing more sulfuric acid, SO_3, and less phosphoric acid, but the lime and potash are nearly the same.

I have claimed that these characteristics are due to the influence of the nitrates. I have been convinced that this is the proper explanation by the study of these relations in the ashes of beets and also of wheat. The application of nitrates to these crops uniformly produces a disturbance in the ratios of these constituents and always in the same direction. This experiment has been repeated very many times on different soils and crops with this uniform result.

Two other possible explanations suggest themselves in connection with the Delta County samples and deserve some measure of consideration, even tho they would not apply in the case of the wheat and only in a measure to the beets. The first one is that the low phosphoric acid in the ashes of both the vines and the tubers may be due to an insufficient supply of available phosphoric acid in the soil which applies to the ashes of the wheat and beets as well as to those of the potatoes. There are two answers to this point; the first one is that it is not a fact that there is a deficiency of phosphoric acid in these soils. The beet soils carried from 0.160 to 0.188, the wheat soils, from 0.120 to 0.217, and the potato soils, from 0.096 to 0.153 percent. The Delta County soils carried from 0.165

to 0.215 percent of phosphoric acid. This was freely soluble in fifth-normal nitric acid. These percentages constitute under our conditions an ample supply of phosphoric acid. The second answer is that we have applied superphosphates in varying quantities without any decisive results. With beets we had varying results, some times a slight benefit and others none at all. With wheat and potatoes we have never gotten any beneficial results.

The objection to the second statement that I have made, namely, that the potash is very high, is that it may be due to the large amount of soluble salts in the soil and to the otherwise large supply of potash. We have published a great deal of data showing the presence of potash in many of the aqueous extracts of our soils, but none of these data supports the point raised more strongly than those of these Delta County soils.

The soil from Ranch 2 carries a total of 27,400 pounds of potash, K_2O, per million pounds of soil. Of this from 129 to 248 pounds are soluble in water. If this fact be appealed to as the explanation for the excessive potash in the ashes, our answer is that we have not found this relation between the potash content of the ash and the amount of potash applied to the soil; whereas, the application of nitrates did increase the potash in the ash.

The writer has repeatedly called attention to the very high potential supply of potash in the average Colorado soil and the actually available supply is usually very liberal. This may have some influence upon our crops but the relation to the amount in the ashes of these crops seems to be remote and unaffected by the application of very large amounts of potash in the form of the chlorid. Of all the results that we have obtained, the one most unfavorable to the views that I have expressed is in the case of the potato vines grown on Ranch 2 on land which had been in potatoes for two succeeding years and which was exceedingly rich in nitrates. The potash is much lower in the ashes of these vines than in those grown after alfalfa, but it is still higher than the amount given for vines of the same age in general.

The potash in the ash of tubers from this section, however, is quite high—approximately five percent above the 60.37 percent average found in the literature. These are the most unfavorable data that we have gathered, but even these would justify our inferences if we had not others very much stronger. Our wheat plants grown in 1915, for instance, analyses given in Bulletin 217, p.38, show that those grown with the application of 500 pounds of sodic nitrate or 80 pounds of nitrogen per acre contained in the dried plant, 1.376 percent potassium (K), whereas those grown with the application of 150 pounds of potassium (K) per acre contained 0.980 percent, and those from the check plot contained 0.972 percent. Many other instances of such results could be given. The differences in the percentages of potassium in the wheat kernel are necessarily small as the total amounts to only 0.4 to 0.5 percent and this is not affected by the addition of either nitrates or potassium. On the other hand, the phosphorus is decidedly depressed by the application of sodic nitrate.

In the earlier portions of this bulletin we called attention to the lack of samples that we could consider normal or standard for our purposes. The same difficulty presented itself in 1924 in regard to both tubers and vines and again we tried to meet it without satisfactory results. We had already considered mountain-grown potatoes; we even tried growing them in the foothills with disconcerting results. We also tried the San Luis Valley which has an altitude of 7500 feet in its lowest parts. Nitrates develop strongly in the soils of the valley. Some of the richest nitrate samples that we have gathered were found north of Del Norte, Rio Grande County, Colorado, at an altitude of 7800 feet.

The occurrence of nitrates is common in this district, also in other parts of the valley, so that high altitude is not an assurance of freedom from this question. We also tried Estes Park with an altitude of 7500, where we obtained some samples of vines. The composition of the ashes of these vines showed the same characteristics as those of the Greeley samples—low phosphoric acid and lime but high potash.

We did not find an altogether satisfactory sample of tubers to use as a standard. We have given the best that we have found and while they are better than our Greeley samples in that they have less total nitrogen and more starch, they are not satisfactory.

The maximum amount of starch found in our Greeley samples for any season was about 15.0 percent. This fell in other seasons to 13, 12 and even 10.8 percent. The highest starch content that we found for any single sample during the five seasons that we have prosecuted this study was 16.8 percent.

We give the two samples richest in starch. The conditions under which these samples were grown were different; the Burbanks were grown in a silty loam with 35.7 p. p. m. nitric nitrogen in surface portions of the rows, on 24 September, 1924; the unknown variety was grown after alfalfa and the soil taken to a depth of six inches showed 54 p. p. m. nitric nitrogen in July. We give the analysis of this latter sample beside that of the Burbanks for the sake of comparison. The same analysis is given in its proper order beside the one grown after potatoes in the same field. The total nitrogen in these Burbanks and unknown variety is very low. Our Greeley samples average 0.408, but these contain 0.2764 and 0.2941, which is as low as the lowest that I have found given, 0.288 percent. All of the Greeley samples, except those for the year 1921, were grown after a 2-year stand of alfalfa. Still we find the nitric nitrogen in the soil and the total nitrogen in the tubers very high and the properties of the tubers very inferior.

EFFECT OF EXCESSIVE NITROGEN ON THE POTATO

By H. G. MacMillian, Pathologist, Bureau of Plant Industry,
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There is for all plants a condition which may be regarded as one of optimum health. Health in a plant is a state of being, difficult to describe or define. It would include first of all, complete freedom from any parasitic organism causing a fungous or bacterial disease. There would have to be an absence of those mysterious viruses, the presence of which are revealed by such curious symptoms as mosaic, leafroll, and spindle-tuber. Such causes bring about the commonly recognized diseases of the potato. However, a potato plant having no association with pathogenic life may not necessarily exist in a state of health.

Potatoes, as do other plants, have nutritional disorders. The food elements which the plant requires may be present in the soil in varying amounts. A deficiency of some one element may in part be compensated for by the excess of another, and no obvious harm is done. But certain elements have to be available or the hunger which results in the plant is acute, and usually manifest in the appearance of the plant. When foods are present in the soil in such amounts that the selective function of the roots is of no avail, the foods enter the plant in amounts far in excess of its need or its ability to use, the health of the plant is again violated, and it is truly diseased. The normal course of life is disturbed, the functions of parts become altered or suppressed. The reaction of the plant is evidenced in external symptoms, or yields to chemical analysis. What such excesses of food have actually meant in the life of the plant is unknown.

Excessive nitrogen in the potato is revealed by chemical analysis and indicated by several symptoms. The analysis is by nature more precise and effective in detecting the changes when they are small. But analysis indicates nothing directly of the changes in the life of the plant, any disturbed function of its parts, or developed weaknesses. No extreme change is so quickly evident in the appearance of the potato as happens with the sugar beet, which goes largely to top, with a small and deficient root. But there is similarity of reaction in the marked depression of carbohydrates in storage tissues. The starch content of the tubers is lowered. As pointed out by Headden[1], potatoes in an experimental field suffered a depression of 2.5 percent in the tuber starch content. But regarded as a decline in the starch itself, it amounts to 14.7 percent loss from the reputed normal. Tubers having a depleted

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[1] Headden, Wm. P. Colo. Exp. Sta. Bul. 291. 1924.

starch content revealed an increase in sugar. The potatoes lose flavor, become soggy and heavy when cooked, are less palatable.

During the growing season the plant shows the presence of excessive soil nitrogen. Some varieties make a larger and more luxuriant growth of vine, spreading well over the ground and filling the row. On experimental plots at Greeley the Peachblow develops a heavy, upright vine growth. But the tuber production is small and profitless. Seed of the same stock planted in mountain soil develops a more normal appearing vine and with better tuber production. A mixture of the Peachblow in other varieties, and this is true of certain other sorts as well, by their habit of growth and large size might easily be mistaken for the "giant hill" disease.

The general non-appearance of potato blossoms at Greeley and in some other sections of Colorado has frequently been a cause for comment. Usually the flower buds form, but either fall or remain small, closed, and green. Frequently in fields of the Rural or Pearl varieties not a blossom can be found. Occasionally a limited few are conspicuous. Yet in some years all varieties bloom profusely and seed balls are abundant. Nitrogen suppresses flower development. In an experimental plot of the Rural variety at Greeley drenched with irrigation water, flowers appeared in profusion, while the same stock growing in an adjacent plot and watered sparingly was barren of blossoms. Those years of excessive rainfall during the growing months are found to be years of flower production. The rain washes the nitrates from the soil and relieves the plant of the excess. It would appear that tubers of better eating quality come from fields which bloomed during the growing season.

In the tuber some symptoms are to be observed. At harvest time tubers crushed or bruised quickly develop a decided pink tinge on the surface of the injured flesh. It is particularly to be observed in the Pearl. Graebner[2] found this phenomenon directly associated with excessive available nitrogen. Other tuber symptoms, as a grayish cast to the freshly cut tuber, a spotted condition showing minute rust-like specks in the tuber flesh, are sometimes due to the same cause.

What the specific relationship between nitrogen unbalance and invasion of parasitic organisms is in the potato has not been proved experimentally. With the wheat plant there is a correlation of a kind between nitrogen excess and rust invasion. There are many suggestive relationships between excessive nitrogen in Colorado potatoes and some of the diseases occurring in them. The potato will endure fairly large amounts of nitrogen without being killed. It is not as sensitive to nitrogen as the cherry tree or apple tree. It doesn't depart from the commercially desirable plant as widely and seriously as does the sugar beet. But that its health is impaired and its susceptibility to parasitic disease increased seems to be evident beyond a reasonable doubt.

SUMMARY

The work recorded in Bulletin 291 and the present one, No. 325, was begun in 1920. The years from 1911 to 1914 had been

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[2] Graebner, Paul. Lehrbuch d. nicht-par. Pflanzenkr. 1920.

disastrous ones to the potato-growers in the Greeley district. Our potato experts had studied the situation but had arrived at no satisfactory conclusions. About 1914 the Potato Experiment Station was established and has been conducted by the United States Bureau of Plant Industry up to the present time.

In the early part of this trouble we advocated the view that the trouble was due to some abnormality of the plant rather than to any of the causes suggested as the direct agents. The causes suggested were not new to the district; they had been present during the previous years but their pathogenicity suddenly became extreme, even to the ruin of the crop.

The growth of the vines was abundant rather than otherwise, but not always healthy. We sampled the soil from the crests of the ridges and found that as much as 18 percent of the total nitrogen was present as nitric nitrogen. The amount present was not enough to kill the plants, tho the equivalent of 0.12 percent or 1200 pounds of sodic nitrate in the surface 3 inches of soil was found. Such figures impressed me with the possibility that these nitrates might have a great deal to do with the trouble.

The Potato Station at Greeley is entirely independent of the Experiment Station at Fort Collins, so we had nothing further to do with the problem until 1920 when we took up the work recorded here and in Bulletin 291.

The object was to establish the relation of this over-supply of nitrogen to the susceptibility of the plants to the diseases that had prevailed from 1911 to 1914, when the trouble abated and has not returned. Our plan was to study the soil, ascertain its fixing and nitrifying power and so ascertain how great a supply of nitrates might be furnished by the soil; then to apply nitrates in excessive amounts and ascertain their effects upon the composition of the plants, vines and tubers, also upon the properties of the tubers as well as the deportment of the plants toward the diseases that had been so destructive from 1911 to 1914.

In this study the origin of the nitrates was of no concern to us; if they were present during the growing period of the crop, that was the answer to this phase of the problem, and if their application changed the composition of the plants and tubers and the quality of the latter, that would answer a second phase of the problem—one of as much importance to the growers as their possible relation to the diseases prevalent in the section and possibly of more general interest. The fixing and nitrifying power of this soil and the extent to which nitrates develop in it during the season are given in Bulletin 291.

Our samplings of the soil made in the crests of the ridges between the plants revealed the fact that our check plots contained nitric nitrogen equivalent to larger quantities of sodic nitrate than we had applied to some of our trial plots, in some instances greater than the maximum that we had applied to any plot. Under these conditions we could expect to discover only the extent to which our maximum application had affected the composition of the vines and tubers and not the effects on the yields and properties of the latter.

Our first and best results were obtained in the study of the crop of 1921 in which we found changes in vines and tubers similar to those found in the beet crop. The nitrogenous compounds were increased in their total amount and their ratios changed. The ratios of the ash constituents were also changed. The year's work was satisfactory but there was no outbreak of any disease.

The most important part of our notes was lost in our fire of 21 December, 1921, but we have used such as escaped tho their value has been greatly impaired.

Up to this point we had obtained a good idea of the principal features of the problem and something of the issues to be expected. We had established the composition of the soil and its general behavior under ordinary conditions, and this is of the greatest importance. The fixing power of this soil, for instance, was equal to the production of from a minimum of 75 to a maximum of 650 pounds of protein matter per million per acre in 40 days. The nitric nitrogen increased in the surface portions of our check plots very rapidly from 11 p. p. m. in March to 85 p. p. m. on 9 August, which is equivalent to the application of 500 pounds of sodic nitrate on this date and distributed thru the surface 3 inches of soil.

In 1921 we did not follow the development of the nitrates; this was a mistake for it was the only opportunity that we had to study this factor in the same ground for two succeeding years. The facts observed in other cases justify the assumption that a much higher development was reached during this year than during the preceding one.

Under the given conditions the vines and tubers of different samples should be very similar, and this was the case. The total nitrogen in the vines and tubers grown with the application of 800 pounds sodic nitrate per acre was a little higher than in those of the check plots. The total nitrogen in the tubers was increased by the nitrate and it was higher in our check samples than in those that we bought.

The lowest percentage that we have found given for the total nitrogen in potatoes is 0.288, and the average found for all others is 0.3424 percent. Our check samples average 0.399 and our nitrate samples 0.4125 percent.

The nitric nitrogen in our purchased samples had entirely disappeared during storage, if it were ever present, but it was still present in our Greeley samples—more in the nitrate than in the check samples.

The ammonia, amid and amino nitrogen was so nearly the same in our samples that positive statements about differences cannot be made, but these forms are more abundant in the Greeley potatoes than in those from other parts of the state.

The changes that took place in the total nitrogen during storage cannot be given for these samples, owing to the loss of our notes on the fresh potatoes. The ammonia forms in the samples grown with nitrates changed more than in the check samples, and more in the Greeley potatoes than in the others.

The cooking qualities of our potatoes are poor, and poorer in those grown with nitrates than in the checks. Good potatoes cook white and mealy, they have no strong odor or pronounced taste; ours were more or less yellow, had a strong odor and an unpleasant taste, and were soggy. The crop of 1922 differed from that of 1921 only in the degree of its inferiority.

The development of the nitrates was followed during the seasons of 1920, 1922 and 1923. This was most pronounced in 1920; still the average found for four plots in August, 1922, corresponded to 175 pounds per acre taken to a depth of three inches. The maximum development was found to be in July and August. The effects upon the amount of the total, also the specific forms of nitrogen, were the same as in preceding years.

The year of 1923 was exceptionally wet. The development of nitrates was less than in other years—at least the amounts found in the top three inches were less—but it followed the same general course increasing as the season advanced, reaching its maximum about 20 September, and then falling. There was a decided difference in the amount of nitrates in the fallow and cropped lands this year, which was not shown in 1922. The fallow land averaged 250 pounds of sodic nitrate per acre in the top 3 inches, and the cropped land 62.4 pounds. It is not evident whether this was due to inhibition of nitrification or appropriation of the nitrates by the plants. The data of 1920 and 1922 favor the assumption that the difference is due to the appropriation of the nitrates by the plants. Observations on the effects of clover on the biological activities going on in the soil would indicate a contrary inference, namely, that it is probably due to inhibition. Clover and potatoes, however, are different plants and may not bear the same relation to this factor.

The amount of nitrates required to affect the potato prejudicially has not been made out. There is further no standard of composition or quality for the potato tuber that we have found either as a food or for making alcohol.

We now have proof that nitrates may develop so abundantly in the soil that they may kill the potato as well as other plants. The amount necessary to effect this has not been ascertained, but this was not the object of our study. Our work has all been in the field and only field results have been presented, but there must be a great concentration of these salts about an established plant in order to kill it. In Bulletin 155, p. 30, we illustrated the effects on sugar beets, but the beets grew most vigorously in the surrounding area which must have been very rich in nitrates. We know that the potato will grow well for a time, at least in soil carrying 400 p. p. m. of sodic nitrate in the top 6 inches of soil. These salts occasionally occur in such abundance that they prevent seed from coming up, and also kill established plants. In smaller amounts they induce heavy growths of tops, or leaves. This was a marked effect on wheat and beets, and our potato tops were also heavy and dark green.

In 1923 there was no doubt but that the yield was lower and the quality poorer the more nitrate we added. These results varied in intensity but were common to the four seasons.

Our potatoes are apt to be soggy as well as colored and of poor flavor. We do not know to what these qualities are due, but it does not seem probable that the percentage of starch has any direct relation to them; still we consider a mealy potato a starchy one. We take it that this is just a general inference which may or may not be right. Be this as it may, our potatoes are poor in starch. The 1923 crop carried 12.29 percent; the 1922 crop, 10.8 percent, and the average for the 1920 crop was 15.61 percent.

Tradition has it that the quality of the Greeley potato was formerly very good and won a good reputation for itself beyond the state limits, but at the present time it is so inferior that the commission men, we are told, find it difficult to dispose of Greeley stock.

Nitrates are said to promote the formation of chlorophyll. Our plants are vigorous and intensely green, which may be due to the liberal supply of these salts and the action of our intense sunshine. Our atmosphere is more transparent than that of the eastern states and permits a bright, richly actinic sunshine to play upon our plants, which may influence very greatly their character. Neither light, temperature nor moisture have been given any particular consideration. The effects of temperature and moisture constituted the subject of Mr. Fitch's study. The subject of the effects of light, for the reason already given, namely, because of the transparency of our atmosphere for ultra-violet rays, should receive consideration by competent persons.

So far we have had in mind principally the nitrogenous constituents of the potato and next to these the starch content. On these two classes of compounds probably depend the cooking qualities of the tubers; therefore, these have received mention. The mineral constituents or ash of the vines and tubers, however, are important and can be determined in their total quantity with a high degree of accuracy; just what part these respective constituents play, however, is not easily made out, but as they vary in their respective ratios with the amount of nitrates available to the plant, their relation to our problem is certainly a direct one and probably of more importance than our limited knowledge of their functions in the economy of the plant permits us to recognize.

In our study of the sugar beet, also of wheat, we found that the ash constituents stored in plant, root or grain were greatly influenced by the nitrates in the soil. While we have some apparently sufficient reasons for believing that the base or cation combined with the nitric acid or anion is of importance in this connection, we have excluded, tacitly it is true, the base from our considerations and attribute the gross results to nitrates.

Difficulties have been experienced in using field samples of vines, owing to contamination by dust blown upon them or by dirt, soil particles splashed upon them by heavy rains, and yet the results show several interesting relations. The nitrates increase the total ash and change the relative amounts of phosphoric acid and potash. The phosphoric acid is strongly depressed and the potash is increased. These results attend the application of sodic nitrate, as well as the presence of nitrates in the soil, so the reactions by which these changes are brought about are not simple nor their significance in the economy of the plant evident.

We have found so good as no data for the potato vine, but our own results establish these relations for the vines as well as for the tubers. The ash of the vine at all stages of its growth is constant within narrow limits and is marked by a low content of phosphoric acid, a high one of lime and magnesia and a low one in potash compared with that of the tuber. The ash of the tuber is very rich in potash, contains but little lime and magnesia together, but more magnesia than lime and is rich in phosphoric acid. The average phosphoric acid, P_2O_5, in the ash of the potato tuber as found in our literature is 17.33 percent, of potash 60.37 percent. We have stated that nitrates depress the phosphoric acid and increase the potash in the ash of the potato tuber. The averages for all of our samples are, phosphoric acid 13.6 and potash 68.16 percent. The average potash in samples grown with application of nitrates is a little higher than in the case of the checks.

We obtained potatoes from other sections because we found our check plots so richly provided with nitrates that we could not expect very large differences in either the nitrogenous or mineral constituents, nor yet in the growth and characters of the plants, which we found to be the facts. We obtained 12 such samples, mostly grown in mountain sections. These proved to be unsatisfactory and differed as much from one another as from our samples. Some of them were rich in phosphoric acid and others were as poor as our Greeley samples. The average for the three highest in phosphoric acid was 17.4 percent, practically the same as the average given for potatoes in general. There was no nitric nitrogen in these samples. The high phosphoric acid in the ash and the absence of nitric nitrogen are the two respects in which these samples differed from ours. The ashes of ten of the purchased samples were analyzed, the average phosphoric acid of the three highest has been given, the average for the other seven was 12.99 percent. The average potash for all samples was 70.58 percent, nearly the same as for the Greeley samples.

We had a double purpose in following the development of the nitric nitrogen in the soil, to ascertain the supply of nitrates available to the crop, and also as a measure of the bacterial action going on in the soil.

The work of 1924 could not be continued on the same land at Greeley and it was not desirable that it should be so carried on under all of the conditions.

Professor Whipple called my attention to two fields near the town of Delta, Delta County, Colorado, which proved exceedingly favorable for our purposes; namely, to study the effects of large quantities of nitrates upon the potato crop. These conditions were not artificial but were real instances in farm practice to which the order of cropping and the cultivation had given rise, and besides these facts it was land that we have known for many years.

There were two pieces of land each divided in two parts; in one case a part had been planted to grain for two years and the other part had been planted to potatoes; in the second case one part had been in alfalfa for two years and the other part in potatoes or other cultivated crops, partly beets, partly potatoes. The whole of each field was planted to potatoes in 1924. There was a very strong development of nitrates in the cultivated portion of each field, 2100 p. p. m. in one and 2300 p. p. m. in the other in the mealy portion of the crests of the ridges, but there was less than 375 p. p. m. in comparable samples after the alfalfa.

There was a very poor or no stand where these large amounts of nitrates occurred; after the grain the stand was medium and after the alfalfa it was excellent. The yield after potatoes was in one case 20 sacks to the acre; in the other case it was nothing; after the grain, 75 sacks and after the alfalfa, 140 sacks per acre.

The quality of the potatoes was only fair after the alfalfa, poor after the grain and very poor to unuseable after the potatoes. The total nitrogen in the vines was, after grain, 0.4900, after alfalfa, 0.378, after potatoes, 0.5269 and 0.5868 percent respectively; in the tubers after grain, 0.385, after alfalfa, 0.294, and after potatoes, 0.387 and 0.350 percent respectively.

The ash in the vines was high and had the peculiarities of composition shown by the Greeley vines, to wit, low phosphoric acid, low lime for vines, and high potash. All of the tubers were high in ash, one percent or more, and higher after potatoes than after alfalfa. These ashes were very low in phosphoric acid; two samples of ashes from the vines averaging only 2.798 percent and four samples prepared from the tubers averaging 9.656 percent. This included the ash of a sample of small unuseable potatoes. If only the useable potatoes were taken, the average was 9.141 percent.

The starch in the tubers grown after grain was 14.86 and after alfalfa, 16.78 percent, and after potatoes, 15.00 and 12.77 percent respectively.

The samples of Colorado potatoes examined do not compare in their nitrogen content or their starch content, nor in the composition of their ashes either of vines or tubers, with such data as we have found given for other potatoes. Their nitrogen content is higher, their starch content is lower; the ash content is higher and this ash is poorer in phosphoric acid but richer in potash than is given for other potatoes.

We found no standard at all for the comparison of either vines or tubers. Mountain-grown potatoes, generally reputed to be of good quality, are just as aberrant as any others. The low phosphoric acid in the ashes of vines and tubers was not due to any deficiency of this constituent in the soil, but to its suppression by the nitrates developed in the soil.

The high potash was due to the same cause and not to the amount of water-soluble matter present nor to the total amount of potash in the soil.

We found the potato, vine and tuber affected in composition, properties and yield by excessive nitrates very much as the beet and wheat crops were affected.

There has been no outbreak of special trouble with this crop since the period of 1911 to 1914.