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THE FIXATION OF NITROGEN

IN SOME COLORADO SOILS

BY

WM. P. HEADDEN

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THE FIXATION OF NITROGEN IN SOME COLORADO SOILS.

By WM. P. HEADDEN.

It has often been claimed that "black alkali" exists in Colorado. This idea has arisen because of the existence of certain black or brown spots which are met with in some localities. The color of these spots is not due, as has been supposed, to the presence of sodic carbonate, to which the name of black alkali has been applied, but to other causes. This salt, sodic carbonate, constitutes a very small percentage of our alkalis and occurs in but one section in such quantities as to be injurious to vegetation. There are several independent occurrences of this salt in the section alluded to, but they are close together and are within an area of a few hundred acres. This occurrence has nothing in common with that of our alkalis, it is not disseminated through the soil but constitutes lakes of sodic carbonate, small ones, it is true, but real lakes having apparently no connection whatever with the surrounding country. The source of this sodic carbonate is without doubt certain underground waters and has no direct relation to the formation of carbonates in semiarid countries. The soils of Colorado do not contain any deleterious quantities of this salt and the so called alkalis seldom contain any large percentage of it. The composition of Colorado alkalis has been a subject of investigation practically all of the time for the past fourteen years or more and it is pretty well established that there is but one type of alkalis in the State and that this is the white alkali, namely, a mixture of sulfates with some chlorids and carbonates, the latter ranging from nothing to 10 or 11 per cent. We have some variations based on the respective bases which may be predominant. The term alkali is used to designate any and all efflorescent salts which form white coatings on the soil or the grass, sticks, etc., which happen to be present and protrude from the surface. The popular term does not take cognizance of the chemical distinction made between alkalis and alkaline earths and the term is here used in its popular and readily understood sense. In some places, due to easily recognized conditions, we have almost pure calcic sulfate, in others, sodic sulfate, and in one rather large section magnesic sulfate is very abundant. We have no type in which either sodic chlorid or sodic carbonate can be said to be really abundant. We have examined some soils with the express purpose of trying to find out whether it would be reasonable and right to attribute their unproductiveness to the presence of salt, sodic chlorid, but no justification for such a conclusion has been found except possibly in two cases. The soil samples chosen were such as were believed to possibly owe their unproductiveness to this cause.

The areas involved varied greatly in size, some of them were very small. This was the case with both of the samples which might be considered as containing salt enough to be detrimental. The data at my command indicates that about 1.5 per cent of the soil is the superior limit which most plants can endure, though 1.8 per cent is given for some. The highest percentage for water soluble chlorin obtained from any soil is 1.025; the highest percentage of total chlorin is 1.887 per cent. As the highest percentages of chlorin are scarcely above the maximum of tolerance for some plants and these have been obtained from two small spots only, the question of chlorin may be neglected in considering the bigger features of the subject even if applicable to these isolated examples.

It is a fact recognized only by a few persons so far that we have in Colorado some very serious problems. On some of our soils the agricultural results, even under the best of practice, present surprises and disappointments. A well trained and experienced agriculturalist made the remark very recently that the results from an agricultural standpoint grew worse instead of better as the practice of the people approached more nearly to those standards which have been and are recognized as the best. This is no exaggeration but represents a real difficulty. Melon growers have noticed for several years that their old grounds have not been producing the same good grade of melons that they produced in former years. In some sections the quality of the sugar beets has shown a falling off. These are general effects the causes of which may or may not be difficult to trace out. It is in specific cases of injury, in exaggerated cases of the operation of such causes that we may best succeed in tracing them and such is the case in this matter. The diffused action over square miles is not intense enough to make definite recognition or a reasonable interpretation of the facts possible. It is only by the aid of extreme cases that we acquire the data whereby to interpret the ordinary manifestation of the cause. In looking over a field in a high state of cultivation, especially a few days after irrigation, the appearance of broad brownish lines just at the outer edge of the irrigation furrows is not a striking feature and usually would be interpreted that the land had been heavily fertilized, or was rich in humus matter, but under no consideration that it might be indicative of danger. My attention was directed to a melon patch last season, 1909, which was sick, this is the term used. There was no rust, no insects, nothing visible to indicate disease. The melon plants were, however, puny and unthrifty. The soil was in fine condition and had been cultivated for several years and fertilized. A melon patch on adjoining land which had been in alfalfa was healthy and vigorous. These plots were separated by the usual wire fence; the soil was the same; the water used for irrigation the same; the cultivation in both cases was excellent; the men were not new hands at growing melons, the only difference was that the one patch was on a piece of recently broken alfalfa ground and the other on ground that had been cropped for several years. There were no features of either soil which would suggest to anyone not conversant with certain facts, that there was any difference in these fields suggestive of any explanation for the difference in the growth of the plants. It was only after having these certain facts forced on my attention for years that they really became suggestive to me.

The brown lines along the edge of the irrigation furrow might mean heavy fertilization with barnyard manure; it might be due to other perfectly harmless if not beneficient causes, but in these cases they are probably significant of the causes producing the difference in the growth of these young plants. We do not hope in the present bulletin to succeed in tracing out general relations, this is a work for the future concerning which we only promise that it will be prosecuted diligently, with the care and conservatism that its importance demands. It is proper that we should meet the questions presenting themselves in our agricultural practices with only one view, to find out the facts as they obtain at the time without predicting results; though they seem to be already certain and only lack verification. For these reasons no attempt or but little attempt, will be made to more than set forth some facts which have been established, reserving much detail work and the extension of this work in bacteriological lines for the future. Work of this kind is already in progress and some results have been attained, but the work is not ready for publication.

No one can foresee what the problem of the fixation of an excessive amount of nitrogen in our soils may develop into, whether it means the introduction of a new practice or a serious difficulty which we may not be able to control. It may for a while present difficulties because we know but little about such a thing. But if it should prove to be a permanent condition in our soils I am certain that we shall be able to find some remedy perhaps not immediately, but quickly.

Fortunately the trouble expressed itself locally with great violence during May and June of 1909. By fortunately it is not meant that it was a good thing that certain persons suffered loss but simply that the loss was so severe that the people of whole neighborhoods have seen with their own eyes, that something is very seriously wrong, for the sudden death of a large portion of an orchard is convincing proof of this. At this time the foliage of many trees, apple trees mostly, showed a burning, beginning at the apices of the leaves, extending rapidly along the margins until the whole leaf had turned brown and was of course killed. Many trees died from this cause. Plate I shows leaves with burned edges. This trouble was not confined to any one section but was common to several sections of the state. While it, in all probability, depends upon soil conditions, these conditions are met with in so many places that it is necessary to consider the condition rather than the soil itself. It sometimes occurred in light and sandy loams and sometimes in clayey soils. It is sometimes in comparatively low lying lands, again in the lower lying portions of higher lands and again on hillsides. The road side, a ditch bank, and the cultivated fields represent the range of places in which this thing may reveal itself. There is one thing common in all of its occurrences, namely, a brown color in the surface soil. This color is less marked in the sandy soils than in the so-called adobe soils. Perhaps this is due to the presence of deliquescent salts on the surface of the adobe soils, or more probably to the color of azotobacter films.

The preceding gives in a very general way the big features of the question forming the basis of this bulletin. We have certain soils, quite generally distributed throughout the principal sections of the state, which develop what is popularly known as "black alkali" but the popular judgment in regard to the cause of the dark color is wholly wrong because they have adopted the term from California, where it has a fixed and definite meaning, which is not applicable to our case. While it is not advisable to do so we may occasionally use the term because these dark spots are designated by the people as "black alkali." Nitre spots will, however, be used as the equivalent of the popular term "black alkali." We have so far as is now known, no land, unless it is some near a peat bed, to which the term "black alkali" properly applies.

Reports of black spots on which "nothing will grow" have been received at this department quite frequently during the past four years, and occasionally prior to that time. While at work in the San Luis Valley several years ago, my attention was called to what was supposed to be indications of petroleum. We drove through a small section of the country and observed quite a number of round, black spots absolutely devoid of vegetation, the surface was glistening and appeared as though wet. It was frequently the case that these bare areas were occupied by an ant hill but a great many of them were not. I mention this because I thought at first that the ants might have something to do with the color and appearance of these spots, but there were too many spots without ant hills in order that this should hold true.

Samples from the surface of these spots proved to yield 13.1 per cent of their air dried weight to water, and on evaporation this soluble portion proved to be so deliquescent that it could not be evaporated to dryness at 100° C. and was finally dried at 160° C. at which temperature it smelled faintly acid. Incipient decomposition had taken place. This analysis, as all of those given in this bulletin, presented some difficulties, which every chemist will recognize and for this reason moisture, organic matter, etc., have simply been given as loss.

ANALYSIS I.

WATER SOLUBLE PORTION OF SOIL FROM BLACK SPOTS.
Laboratory No. 584.

	Per Cent.
Calcic Sulfate	46.883
Sodic Chlorid	10.032
Calcic Nitrate	12.072
Magnesic Nitrate	17.878
Sodic Nitrate	6.038
Potassic Nitrate	5.871
Silicic Acid	0.365
Loss (water, organic matter, etc.)	0.861
	100.000

The sum of the nitrates is 41.859 or 5.628 per cent of the surface soil.

This analysis represents a spot possibly 12 feet in diameter and almost circular. This is, taken alone, no large area but there were a number of these spots all entirely devoid of vegetation, most of them black and glistening. There were others occurring under different conditions, namely, as round or elliptical, somewhat elevated spots and these, too, were unproductive, but there was a zone about the edges of these spots where oats, barley, and wheat grew luxuriantly. Many other anomalous things were met with in this section of the state. In some places there were no apparent reasons why crops should not, but they did not grow. In others there was some alkali but the amount of it was less than in others where the crops, not necessarily the same crops, were very good. An analysis of this alkali showed it to be essentially sodic sulfate with some sodic chlorid, about 5.5 per cent of the water soluble, and a relatively large amount of potash with some lime and magnesia. Neither the quantity nor the composition of this alkali affords a satisfactory explanation for the very bad condition of the crops. Only the alkali was collected at this place with as little soil as possible, the idea being that it was probably the composition and not the quantity of the alkali that might be producing the trouble. Twenty per cent of it was soluble in water, and ninety per cent of the soluble consisted of sulfates, six per cent of chlorids and about three and a half per cent of silicic acid, etc. The presence of nitrates was not suspected but subsequently it proved that the water soluble portion gave a strong reaction for nitric acid. This is suggestive only and not conclusive that nitrates might have been present in sufficient quantity to have caused the poor growth of the barley.

The explanation for the barren condition of these spots seems plain after the analysis of the surface portion of one of them revealed the presence of a little more than 5.5 per cent of nitrates. The suggestion that nitrates might have injured the barley seemed at first almost absurd but the fact that a few grams of earth taken from the surface of the field contained nitrates enough to give a strong reaction for nitric acid with ferrous sulfate removed the absurdity of the idea and indicated that it might have been the case.

Complaints of brown spots "on which nothing will grow" have been common, more so of late years than formerly. This may mean that the spots are becoming more common or that the land having increased in value more attention is paid to them. The former is probably the case as the complaints are coming from different places and often state that alfalfa, for instance, is dying in spots.

The case of a young orchard of 20 acres presents many interesting points. The trees were first set in 1906, in the spring of 1907 many of them were reset especially in a strip beginning at the N. E. corner and running almost directly southwest through the orchard. These trees likewise died and this strip is in no better condition now than it was then. The surface of the ground was brown, not only had the trees died, but all sorts of vegetation. The ground was bare and has continued in this condition till the present time. The surface presented no other points indicative of any abnormal condition, i. e., than the brown color and its total unproductiveness. Had this soil been plowed and harrowed, no one, however proficient in judging of land, even of alkali lands, would for a moment have suspected that this was other than a very desirable piece of land. I have been on this land and could scarcely believe the things that I knew to be facts. The land had been recently disced and it was only by looking rather closely for the signs which I had recognized as suggestive that I could convince myself that the trouble had not disappeared. The one important fact that remained was the presence of dead trees. The death of these trees was not due to neglect or abuse or the lack of any care that good judgment dictated might be needed to make them grow. There was but little or no efflorescence on the surface. There was in some spots a little incrustation, very slight, but this was brown rather than white. For the sake of convenience the surface soil on which this occurred is designated in my notes as efflorescence on brown spot. This spot was barren. There was no free water at a depth of 2½ feet. But below this point the ground was very wet and one could push an auger down for several feet without turning it. This condition will be described a little later. This sample of surface soil with its incrustation yielded 22.466 per cent soluble in water. We will designate this orchard as No. 1.

ANALYSIS II.

WATER SOLUBLE PORTION OF SURFACE SOIL. Orchard No. 1.

	Per Cent.
Calcic Sulphate	4.462
Potassic Sulphate	2.557
Sodic Sulphate	39.852
Sodic Chlorid	12.626
Sodic Nitrate	29.114
Silicic Acid	0.054
Loss (water, organic matter, etc.)	4.789
	100.000

The sodic nitrate or its equivalent constitutes 6.54 per cent of this surface soil. The first impression, especially in the field, was that salt, sodic chlorid, was the cause of the trouble, but the analysis reveals the presence of another salt which is beyond all question not only more toxic but present in more than double the quantity.

The next sample was taken immediately below the preceding and included the next four inches of soil. The air dried soil yielded 3.4 per cent of salts to water.

ANALYSIS III.

WATER SOLUBLE PORTION OF THE FIRST FOUR INCHES OF SOIL. Orchard No. 1.

	Per Cent.
Calcic Sulphate	11.769
Magnesic Sulphate	3.748
Sodic Sulfate	21.447
Sodic Chlorid	20.797
Sodic Nitrate	32.552
Loss (water, organic matter, etc.)	9.687
	100.000

The organic matter in this sample was very abundant. The nitrates calculated as sodic nitrate equal 1.107 per cent of the air dried soil.

The next sample was collected in a spot occurring in an alfalfa field, belonging to the same party and west of Orchard No. 1. This spot was quite wet, though it had received no irrigation for about five months. The sample was taken in April, 1908, and to the depth of five inches. The air dried material yielded 7.778 per cent of its weight to water. The residue was quite deliquescent. Dried at 110° it smelled faintly acid.

ANALYSIS IV.

WATER SOLUBLE PORTION SOIL FROM ALFALFA FIELD.
West of Orchard No. 1.

	Per Cent.
Calcic Sulfate	21.448
Calcic Chlorid	17.295
Magnesic Chlorid	12.708
Potassic Chlorid	1.641
Sodic Chlorid	6.612
Sodic Nitrate	33.066
Iron and Aluminic Oxid	0.089
Silicic Acid	0.173
Loss (water, organic matter, etc.)	6.968
	100.000

The amount of calcic and magnesic chlorids in this soil is quite surprising. The presence of these salts in a soil extract is quite rare with us. I have met with a few other instances in which these chlorids constitute a considerable portion of the aqueous extract of the soil; in an extreme case it proved that they constituted a little over 55.0 per cent of the aqueous extract; there was in addition to these 25.5 per cent of sodic and 3.8 per cent of potassic chlorid, or a little over 84.3 per cent of chlorids in all. This sample contained a heavy trace of nitric acid but was not collected in Colorado. We will find in this investigation a few samples which carry even larger percentages of calcic and magnesic chlorids than the one whose analysis is given above. The nitrates in this sample constitute 2.571 per cent of the air dried soil. It is remarkable that the surface soil should contain so large an amount of the very soluble nitrates and chlorids considering its wet condition. The alfalfa was dead but the crowns had not yet entirely rotted, indicating that they had died recently and that the present conditions had not obtained for any very long period. The study of conditions in this alfalfa field was not prosecuted further as the orchard presented better conditions for our purposes and it is impossible to study every instance of these conditions which presents itself.

The next sample was taken 60 feet north and west of the first orchard sample, analysis No. II., to a depth of eight inches.

There was no efflorescence or crust on the surface of the soil at this point and also no vegetation. The water soluble portion equalled 1.87 per cent of air dried soil.

ANALYSIS V.

WATER SOLUBLE PORTION, SURFACE EIGHT INCHES.
Orchard No. 1.

	Per Cent.
Calcic Sulfate	14.319
Calcic Nitrate	26.622
Magnesic Nitrate	6.443
Sodic Nitrate	21.277
Sodic Chlorid	25.224
Loss (water, organic matter, etc.)	6.115
	100.000

The nitrates equalled 1.016 per cent of the air dried soil.

Sometimes there is an incrustation, it may be light or heavy, and underneath this there is a mealy mass of soil particles and minute crystals. At other times the surface soil itself is mealy, a peculiar condition which is often expressed by likening the soil to ashes, not always an apt comparison but sometimes an exact description of the condition, especially if the soil is very dry. A sample of mealy soil was taken from this orchard. The soil was slightly incrusted without efflorescence and was mealy beneath the thin crust. The sample was taken to a depth of four inches. The water soluble equalled 5.372 per cent of the air dried soil. The residue was quite deliquescent and smelled acid when dried at 110° for 1 and 3-4 hours.

ANALYSIS VI.

WATER SOLUBLE PORTION MEALY SOIL, FOUR INCHES DEEP.
Orchard No. 1.

	Per Cent.
Calcic Sulfate	19.756
Calcic Chlorid	2.598
Magnesic Chlorid	8.216
Potassic Chlorid	2.117
Sodic Chlorid	27.466
Sodic Nitrate	33.617
Iron and Aluminic Oxid	0.043
Silicic Acid	0.026
Loss (water, organic matter, etc.)	6.161
	100.000

The nitrates constitute 1.706 per cent of the air dried sample.

The next sample represents the foot of soil succeeding the preceding one or from the 5th to 17th inch inclusive. The water soluble equalled 1.161 per cent of the air dried sample.

ANALYSIS VII.

WATER SOLUBLE, 5TH TO 17TH INCH INCLUSIVE.
Orchard No. 1.

	Per Cent.
Calcic Sulfate	27.456
Magnesic Sulfate	11.245
Potassic Sulfate	2.753
Sodic Sulfate	1.688
Sodic Carbonate	2.255
Sodic Chlorid	29.712
Sodic Nitrate	19.431
Iron and Aluminic Oxid	0.089
Silicic Acid	1.052
Loss (water, organic matter, etc.)	3.319
	100.000

The section of this soil showed alternations of light and dark sandy loam. The nitrates constituted 0.226 per cent of the air dried sample.

The next sample represents the succeeding foot or from the

18th to the 29th inch inclusive. The water soluble was 2.11 per cent.

ANALYSIS VIII.

WATER SOLUBLE, 18TH TO 29TH INCH INCLUSIVE.
Orchard No. 1.

	Per Cent.
Calcic Sulfate	49.413
Magnesic Sulfate	20.202
Potassic Sulfate	0.670
Sodic Sulfate	0.923
Sodic Carbonate	2.556
Sodic Chlorid	12.487
Sodic Nitrate	9.375
Sodic Silicate	1.371
Manganic Oxid (br)	0.141
Loss (water, organic matter, etc.)	2.862
	100.000

The nitrates in this sample which represents the lower 3-4 of the second and the first 1-4 of the third foot from the surface constitute 0.198 per cent of the air dried soil. This is the deepest soil sample taken in the orchard.

The ground water in this orchard cannot be said to present a water plane. The soil is very wet at a depth of two and a half feet and forms a real mud from this point downward, but at a depth of six feet the water came in so slowly that in order to fill a two gallon jug we had to let the hole stand open over night. A little water came in at a depth of five feet but this seemed to be an accident, for the next foot below was the same as above, simply mud. I had never seen anything similar to this condition before I began to study this subject. What the relation may be between these facts I do not know; according to what is generally believed they are more or less incompatible but they are simply facts. It is surprising that soil can be so wet and muddy for 3½ feet and we should be unable to find a proper water table within six feet of the surface, but, as stated, we were compelled to let the opening stand over night in order to obtain the sample of ground water. The ground water as obtained was slightly yellow; the total solids held in solution were 1776.95 grains per imperial gallon; loss on ignition 453.42 grains. A part of this loss is due to the presence of nitrates and is more interesting than important, because on ignition the evolution of the brown oxids of nitrogen was quite copious. This water contained 2.0 parts per million of nitrogen as nitrites, ordinary polluted water contains 0.003 parts per million.

ANALYSIS IX.

RESIDUE FROM GROUND WATER. Orchard No. 1.

	Per Cent.
Calcic Sulfate	15.164
Magnesic Sulfate	9.890
Magnesic Cholrid	11.358
Sodic Chlorid	7.225
Sodic Carbonate	1.825
Sodic Nitrate	53.299
Potassic Oxid	Trace
Iron and Aluminic Oxid	0.372
Silicic Acid	0.061
Loss (water, organic matter, etc.)	0.906
	100.000

This residue containing 53.3 per cent of sodic nitrate gives us 941.0 grains of this salt to each imperial gallon. As iodine compounds sometimes occur associated with the nitrates, I tested this residue, using 30 grams, but obtained negative results.

This gives us an idea of the conditions obtaining in this orchard which may be summarized as follows: The surface soil has a brownish color, efflorescent salts are scarcely present. There is some incrusting of the surface soil, beneath which there is sometimes as much as an inch of mealy material, soil particles and fine crystals. At a depth of two to two and a half feet the ground becomes muddy, but there is no free water to a depth of 5½ to 6 feet. There is no vegetation on parts of this ground and the young trees have failed to live. The country is quite flat but is not particularly low; it probably is not less than 50 feet above the river which flows within four miles of it. We find an abundance of nitrates in the uppermost portion of the soil, the maximum being 6.541 per cent of the soil; this soil was incrusted with some efflorescent salts, commonly called alkalis. The next, a sample of very wet soil taken to a depth of five inches, gave 2.571 per cent of nitrates. These percentages are followed by 1.706, 1.107 and 1.016, for what we may consider the first foot of soil, with 0.226 for the upper portion of the second foot and 0.198 for the rest of the soil to the depth of 29 inches.

In the next orchard which I shall designate as Orchard No. 2, we have the same conditions only greatly intensified. This is an older orchard, what is left of it, and we can see the effects more plainly than in Orchard No. 1. What was once an orchard is now absolutely barren, not so much as a weed growing on several acres of this land. See Plate II. There are a few trees remaining in one corner and a few isolated trees on one edge. These will have a great interest for us. The first samples from this orchard were taken in 1907. The soil was glistening, brown and apparently wet on the surface but was really dry. Mr. Whipple who was with me dug a hole close to a small apple tree which was already so good as dead. No water was met with at a depth of three feet; the soil was wet but not sufficiently so to drown the tree; at this place the soil was somewhat sandy. An excavation had been made, but not recently, for the cellar and foundations of a house, this excavation was over three feet deep but contained no water. This was a surprise to us at the time, especially as we had found the soil only a short distance away so wet. Six months later we found the conditions essentially the same; except worse if anything. There were portions of the ground on which there was a crust about 3-16 of an inch thick and beneath this from 1½ to 3 inches of the mealy mixture of soil and crystals. Below this the soil was practically mud, but, as in Orchard No. 1, we had to dig to a depth of six feet in order to obtain a sample of ground water. The crust in this case was not the ordinary crust of effloresced salts accumulated above and easily separated from the soil, but was the soil particles cemented together by the salts present in it. This crust contained 12.523 per cent soluble in water.

ANALYSIS X.

WATER SOLUBLE PORTION OF CRUST. Orchard No. 2.

	Per Cent.
Calcic Sulfate	8.523
Calcic Chlorid	27.388
Magnesic Chlorid	25.875
Potassic Chlorid	1.581
Sodic Chlorid	16.511
Sodic Nitrate	19.822
Iron and Aluminic Oxid	0.223
Silicic Acid	0.077
	100.000

This analysis has been calculated to 100 because on drying the mass I found that I could not heat it above 110° C. without change and at 110° only a part of the water was driven off. It was therefore necessary to analyze the material as it was and calculate the results to 100 as I have done. The nitrates make up 1.482 per cent of the air dried soil.

The next sample was taken to a depth of 1½ to 3 inches below the crust given above. The water soluble portion equalled 8.44 per cent. The following analysis has been computed to 100 for the same reason given for the preceding analysis.

ANALYSIS XI.

WATER SOLUBLE PORTION OF MEALY SOIL. Orchard No. 2.

	Per Cent.
Calcic Sulfate	15.058
Calcic Carbonate	1.755
Calcic Chlorid	23.158
Magnesic Chlorid	25.532
Potassic Chlorid	1.667
Sodic Chlorid	17.014
Sodic Nitrate	15.421
Iron and Aluminic Oxids	0.130
Silicic Acid	0.265
	100.000

The nitrates constitute approximately 1.301 per cent of the air dried mealy soil.

The next sample was taken from another part of the orchard about six months prior to the taking of the two preceding samples and shows in an unusual measure the variability in the character of the salts present in the soil. The area involved is several acres. I suppose that there are 40 acres at least in this piece of land but I do not know how much of it is involved in this trouble. I estimate the portion that I am familiar with at 10 or 12 acres and very much more in adjoining lands. This sample was taken to a depth of one foot. Water soluble equalled 6.51 per cent. The ground is entirely barren where this sample was taken..

ANALYSIS XII.

WATER SOLUBLE PORTION OF FIRST FOOT OF SOIL. Orchard No. 2.

	Per Cent.
Calcic Sulfate	13.072
Magnesic Sulfate	4.928
Sodic Sulfate	7.691
Sodic Chlorid	27.609
Sodic Nitrate	43.578
Loss (water, organic matter, etc.)	3.122
	100.000

The nitrates in this foot of soil amounted to 2.837 per cent of its air dried weight. This indicates the presence of 49.5 tons to the acre foot.

This soil is very wet except the surface portion to a depth of three or four inches, below this point it becomes muddy; even worse if anything than Orchard No. 1. At a depth of about six feet water came into the hole that we dug, very slowly. We were able to get two gallons of water in about an hour. This water contained 2250.01 grains per imperial gallon; the loss on ignition was 375.5 grains.

ANALYSIS XIII.

RESIDUE FROM GROUND WATER. Orchard No. 2.

	Per Cent.
Calcic Sulfate	22.077
Magnesic Sulfate	14.405
Magnesic Chlorid	0.833
Potassic Chlorid	0.441
Sodic Chlorid	44.492
Sodic Carbonate	1.741
Sodic Nitrate	10.545
Iron and Aluminic Oxids	0.256
Silicic Acid	0.067
Loss (water, organic matter, etc.)	5.143
	100.000

Each imperial gallon of this ground water contains 237.0 grains of sodic nitrate. The ground water from Orchard No. 1 contained 941 grains, almost exactly four times as much.

The next place studied included both orchard and non-orchard land, but for the sake of convenience we will designate it as Orchard No. 3.

This is, in some respects, the most interesting case that I have studied because I have been able to obtain its history. The land showed some spots 17 years ago on which there appeared to be too much alkali. Some of the spots grew nothing but at their outer edges things grew well. The owner stated that he had often stood on a barren spot and thrown his hat in the air so that it would fall on the grain at the edge of the spot and lodge on the heads of the grain. This man had tried to wash it off; he had turned a furrow, followed with a subsoil plow and then turned in a hundred inches of water and washed it clean. His farm is beautifully leveled. He had also manured heavily but he has not yet conquered these spots. He states that in the 16 or 17 years past he has set one piece to young trees two or three times and there are no living trees there now. In June, 1908, I took a set of samples from this piece of ground. The top three inches is described as alkali and mealy soil. This three-inch section was removed and taken as one sample. Water soluble equalled 5.04 per cent.

ANALYSIS XIV.

WATER SOLUBLE PORTION OF ALKALI AND MEALY SOIL.
Orchard. No. 3.

	Per Cent.
Calcic Sulfate	14.247
Magnesic Sulfate	4.464
Potassic Sulfate	2.459
Sodic Sulfate	6.849
Sodic Chlorid	33.607
Sodic Nitrate	35.582
Silicic Acid	0.208
Loss (water, organic matter, etc.)	2.584
	100.000

Here the nitrates equalled 1.793 per cent of the air dried weight of the mass.

After removing the three inches of alkali and mealy soil, I took the next 12 inches as a soil sample. The water soluble amounted to 2.97 per cent of the air dried material. This spot had been barren for 16, now 18, years. I saw it a few weeks ago and it is barren still.

ANALYSIS XV.

WATER SOLUBLE, 4TH TO 15TH INCH INCLUSIVE. Orchard No. 3.

	Per Cent.
Calcic Sulfate	15.902
Magnesic Sulfate	2.942
Potassic Sulfate	3.387
Sodic Sulfate	15.264
Sodic Carbonate	4.813
Sodic Chlorid	34.145
Sodic Nitrate	22.781
Silicic Acid	0.252
Loss (water, organic matter, etc.)	0.471
	100.000

The nitrates in this sample equalled 0.676 per cent of the air dried material. I subsequently dug a hole in this piece of ground at the height of the irrigating season, not at this same spot but near it, to see if I could find the water table. I dug to a depth of six feet and found only moist, sandy soil.

The next sample was taken by the owner and sent to me. He stated it was taken from another barren spot and to a depth of one foot. Water soluble equalled 3.33 per cent of air dried soil.

ANALYSIS XVI.

WATER SOLUBLE PORTION OF FIRST FOOT OF SOIL.
Orchard. No. 3.

	Per Cent.
Calcic Sulfate	5.459
Magnesic Sulfate	1.086
Potassic Sulfate	2.557
Sodic Sulfate	49.260
Sodic Carbonate	2.285
Sodic Chlorid	23.897
Sodic Nitrate	11.762
Silicic Acid	0.111
Loss (water, organic matter, etc.)	3.583
	100.000

The nitrates make up 0.392 per cent of the air dried soil in this case. This is one of the spots in which the owner amused himself by standing and casting his hat in the air to see it fall on the grain so rank and stiff-stemmed that it held up the hat.

The next sample is one taken by myself in an alfalfa field on the same ranch. The spot was quite wet and barren. Sample taken three inches deep. Water soluble equalled 10.572 per cent.

ANALYSIS XVII.

WATER SOLUBLE, FROM ALFALFA FIELD. Orchard No. 3.

	Per Cent.
Calcic Sulfate	6.968
Magnesic Sulfate	6.490
Potassic Sulfate	2.526
Sodic Sulfate	45.168
Sodic Carbonate	1.513
Sodic Chlorid	26.116
Sodic Nitrate	4.056
Silicic Acid	0.458
Loss (water, organic matter, etc.)	6.705
	100.000

The next sample is from another orchard, Orchard No. 4. Had the owner not set this land to apple trees the probabilities are that no notice would have been taken of the fact that there was something wrong with the soil. The care bestowed on a young orchard is greater perhaps than that bestowed on ordinary crops. This accounts for the fact that we find these troubles so frequently in apple orchards; it is not that they do not exist elsewhere, for they do. This young orchard contained, it may be, 20 acres, sloping to the south and west. The land is quite high. Some years ago there was a reservoir in the northeast corner of this piece of ground but it had been abandoned for several years, at least four, before the orchard was set. The soil is a clayey loam, but varies somewhat in different parts of the tract. A shale underlies the whole or the greater portion of it at no considerable depth. There is a little draw running southwest and south through the orchard. It begins near the north side and somewhat east of the middle line and extends almost to the southwest corner of the orchard. The area involved in the spring of 1909 was about four acres. By autumn it had increased to nearly double or about eight acres. The land had previously been in alfalfa which, according to my infromant, had ceased to do well in this portion of the field. Up to this time only preliminary work has been done on this particular orchard and it is given for the reason that it presents entirely different conditions from any presented so far. In March, 1908, I found the surface soil a mealy mass. The conditions at the time did not afford opportunity for me to judge of the color of the soil. There was no incrustation; a scuff with the foot would reveal the fact that the dirt which seemed to be ordinary soil was a mixture of soil and crystals of some sort, for they glistened strongly in the light, and clear sunshine was not necessary. I took a sample to a depth of two inches. The water soluble was 8.23 per cent of the air dried mass.

ANALYSIS XVIII

WATER SOLUBLE FROM SURFACE SOIL. Orchard No. 4.

	Per Cent.
Calcic Sulfate	18.986
Magnesic Sufate	29.771
Potassic Sulfate	1.387
Sodic Sulfate	39.914
Sodic Chlorid	1.474
Sodic Nitrate	8.173
Silicic Acid	0.295
	100.000

The nitrates make up 0.673 per cent of the air dried mass. The results of this analysis were what I expected after I had examined the conditions in the orchard.

The next sample is our Laboratory No. 680, and is not from an orchard but from an oat field. The owner had previously written to me concerning this land. I could not go to inspect it at the time but in February, 1908, I was near this place and went to see it. The chief trouble was seepage, but above the seeped area were other conditions, the surface of the ground was puffed up and mealy. I took a sample of the surface soil to a depth of two inches, water soluble equalled 5.42 per cent. I was compelled to dry the residue obtained on evaporating the aqueous extract to dryness at 140° in order to pulverize it; it puffed up, intumesced, and possibly suffered incipient decomposition.

ANALYSIS XIX.

WATER SOLUBLE PORTION. Laboratory No. 680.

	Per Cent.
Calcic Sulfate	9.919
Calcic Nitrate	10.053
Magnesic Nitrate	17.290
Potassic Nitrate	1.159
Sodic Nitrate	21.719
Sodic Chlorid	38.179
Iron and Aluminic Oxids	0.129
Silicic Acid	0.093
Loss (water, organic matter, etc.)	1.459
	100.000

The nitrates in this surface sample equalled 2.722 per cent of the air dried soil; this is a trifle over 50 per cent of the total soluble salts. It may interest someone to learn that I visited this place in the early spring of 1909 and could see no signs of any trouble whatsoever beyond the fact that a portion of the field was undoubtedly seeped. I visited it again later and the present owner who is a stranger to me, was cultivating it preparatory to planting it to beets and there was nothing suspicious, even to one acquainted with the facts, except the seepage. I visited it again when the beets were almost ready to harvest. There were great bare spots surrounded by beet tops of very luxuriant growth. See Plate V. The bare ground was mealy and excessively rich in nitric acid or nitrates. We must defer further statements concerning this till we have done more work.

Our Laboratory No. 588 is a very alkaline soil collected in an old orchard. The soil is a red mesa soil, grows alfalfa, potatoes, wheat, etc., well. The section is in very bad condition and seeped though the mesa is high above the river. The surface of the mesa makes this possible. The water soluble in this soil was 6.65 per cent.

ANALYSIS XX.

WATER SOLUBLE PORTION. Laboratory No. 588.

	Per Cent.
Calcic Sulfate	20.169
Magnesic Sulfate	6.585
Sodic Sulfate	38.872
Sodic Chlorid	23.751
Sodic Nitrate	4.006
Potassic Nitrate	1.740
Sodic Silicate	0.539
Loss (water, organic matter, etc.)	4.338
	100.000

The nitrates correspond to 0.382 per cent of this soil.

The next sample is Laboratory No. 595, and was gathered as a sample of alkali. The spot was quite destitute of vegetation except for the presence of a few greasewood, sarcobatus plants, and a few surviving alfalfa plants. I have visited this place twice since this sample was collected to observe whether the spot is increasing in size. I found this to be the case. Only so much of the soil was taken as was necessary to get a fair sample of the surface alkali, perhaps an inch. This was a new locality for alkali, so far as my record was concerned and the sample was taken without any regard to the presence or absence of nitrates; it was collected in 1907.

ANALYSIS XXI.

ALKALI. Laboratory No. 595.

	Per Cent.
Calcic Sulfate	9.102
Magnesic Sulfate	8.076
Sodic Sulfate	56.254
Sodic Chlorid	22.609
Sodic Silicate	0.308
Sodic Nitrate	2.771
Loss (water, organic matter, etc.)	0.880
	100.000

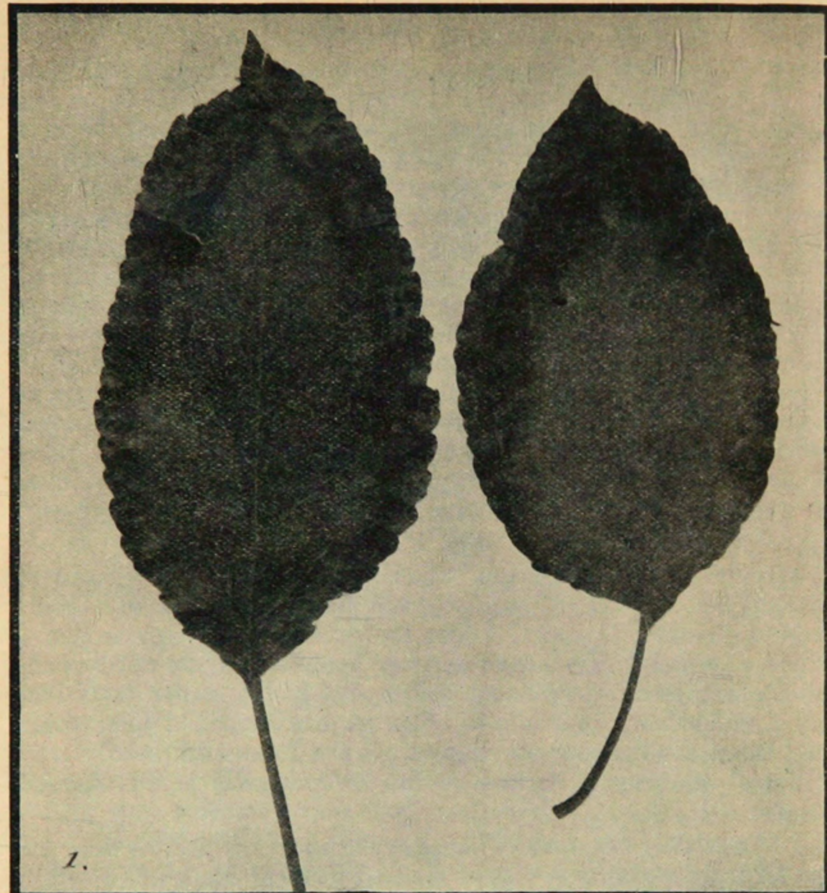
The question of the relation of the greasewood to the alkali question, sodic carbonate in particular, has been discussed somewhat by Prof. Hilgard and others. The association of this plant with the last sample suggests the question whether it might have anything to do with the appearance of the nitric acid in this alkali.

In some cases there is no question about the occurrence of sodic carbonate in dark soils about old clumps of greasewood, but in this case the occurrence of the nitrate in dark, brown soils and the very dark color often noticed in the soil about these old clumps suggests the question whether the greasewood has anything to do with this occurrence. I found a very marked case of a mass of dark soil where such a clump had died and which was evidently very rich in alkali. This was quite near an area where I knew that nitrates occurred in large quantities so I thought it worth while to test the matter. The result was that the soluble salts found to be present were the sulfate 35.248 per cent, carbonate 37.065 per cent, and chlorid of sodium 27.687 per cent, with only a trace of nitric acid. This was the result expected except that the trace of nitric acid was unlooked for under the conditions. Apropos to the occurrence of nitrates in alkalis we have found small quantities of nitrates in others than the one given above but we have not found them always present. Alkalis from these districts may be entirely free from nitrates.

The samples so far given have been of soils or ground waters, the localities of which I have not given and I have purposely avoided giving names. I conceive that the circumstances require that I should do this. I have been requested again and again not to publish the names of owners and places and I believe that it is just that I should not, for while it looks, in many cases, desperate for the future, conditions may change. Some means of remedy may be found whereby what now seems an inevitable result may be avoided.

I have seen instances of these occurrences of nitrates near the southern and within 40 miles of the northern boundary of Colorado and likewise from its eastern to its western boundary. The analyses already given and those to be given, represent many sections, but it is not to be inferred that all or any more than a very small percentage of the agricultural lands of Colorado are in the least endangered. While the matter is serious enough, it by no means amounts to a justification for evil forebodings. I am not at this time prepared to state how we will combat this condition, but I believe that there will be some way. These remedial questions are for the immediate future; the trouble itself has, as yet, only been pointed out.

I will give some cases in a general way but must avoid names and places. A small piece of land, a sandy loam, near and some 12 or 15 feet above the river has a dark brown color and has not been productive for several years. This land has received good cultivation, the application of much barnyard manure, and excessive irrigation in the hope that the "black alkali" would be washed out. This ground is not absolutely barren but some spots in it are nearly



Plates I and II. See Pages 6, 13, 42, 43 and 44.

so. A sample of this soil which was taken by the owner and delivered to me contained 1.262 per cent of water soluble which contained nitric acid equivalent to 11.230 per cent of sodic nitrate, equivalent to 0.142 per cent of the air dried soil. If this sample had been taken to a depth of a foot, which it very probably was, how much would it mean to the average man? Very little so long as it is expressed in tenths of one per cent of the soil. It will mean more to him, perhaps, if we state that this is a piece of very bad land containing 5,680 pounds, 2.84 tons, of sodic nitrate or its equivalent of nitric acid in the top foot of soil. I found on this piece of land an excellent illustration of the mealiness which I have already mentioned several times. The adjoining piece of land on the north is in even worse condition than this, spots in it are barren.

Another case was observed in an alfalfa field under and near a ditch. We are prone to blame seepage for as many of our troubles as possible and I am personally no exception, but I am sometimes conscious that I am trying to give a reason to avoid the labor of finding out a cause. In this spirit I judged the cause of the dead spots in this alfalfa to be due to seepage. The ditch was there; there was water enough; the ditch was higher than the ground. Of course it was simply another case of seepage. I, however, thought it might be well to prove this thing. On examining the ground and digging a hole of some depth my faith in my theory disappeared. I was not at all satisfied about the relation of seepage to the death of the plants. I took a sample of the soil and found that 5.73 per cent of its weight was soluble in water and that this soluble part contained nitric acid corresponding to 27.259 per cent of sodic nitrate or calculated on the air dried soil 1.522 per cent or supposing this soil to have been taken to a depth of four inches it means that there would be 20,290 pounds, 10 1-4 tons, on each acre. If one should spread 10 1-4 tons of Chile-saltpetre on an acre of ground we would not need to appeal to seepage to account for any unproductiveness of the soil which might follow. After a number of such experiences I have concluded that it is not wise to be too certain about the direct and universal effects of seepage. The same remark applies to the effects of alkali. I am quite convinced that I have not seen in Colorado a single instance in which it was even very probable that our ordinary alkali, not this so called "black alkali," has of itself been the cause of the death of any plant. An excess of water in the soil, especially in cases where it continued for a long time, may have been.

These occurrences are not confined to Colorado soils. Two samples of soil received from Brawley, California, were strongly impregnated with alkali and their aqueous extracts reacted for nitric acid with sulfuric acid and ferrous sulfate. Neither the size nor location of the spots relative to the surrounding surface nor the condition of the vegetation was given. The clumps of one of the samples showed distinctly a thin, white incrustation on their upper surfaces. The sample was quite sandy and judging from the clumps of soil had been taken to a depth of from one to two inches. The second sample was quite different in character and described by the sender as being always moist.

The sample numbered one and described as white alkali soil contained 8.886 percent of water soluble salts. The nitric acid in this soluble portion corresponded to 3.939 percent of sodic nitrate or 0.350 percent of sodic nitrate calculated on the air dried soil. This corresponds to 2,333 pounds of sodic nitre in the surface two inches of soil per acre. I do not know anything about the size or location of the areas represented, nor do I know the condition of the vegetation in or about the places where the samples were collected.

One of the samples was a sandy soil and was very probably taken to only a very shallow depth. The sender says that it was scraped up. I would judge from the thickness of the clumps in the sample that from one to two inches of the surface soil had been taken.

We find the nitrates present in soils, where there is a great deal of moisture, but in places where there is too much water, the nitre does not appear. In little valleys and saucer shaped depressions in which the lower portions are too wet there is no visible alkali, then follows a zone where white alkali abounds and above this the nitre is formed. I do not mean to say that there may not be nitre mixed with the white alkali but that the nitre in such cases appears in higher ground than that on which the white alkali usually appears. Furthermore, it is not intended that anyone shall infer that it is only in valleys and depressions that the nitre occurs. Two instances of the occurrence of nitre suggest themselves, one of which is on the side of a hill, and the other on a little reach of rising land at the foot of a hill. It is at least 10 feet higher than land 200 yards away, in short, it is on the gently sloping portion of a hill. These two instances are very far removed from any other occurrences so far mentioned and are nearly 300 miles apart. These occurrences are furthermore very rich in nitrates.

The next sample is an alkali collected from the face of a shale bank from which issued the seep or drainage from an irrigated mesa. The water issuing from this bank contained 176.96 grains total solids per imperial gallon, ignition 21.42 grains. There are no carbonates present. The efflorescent alkalis on this shale bank were white and consisted essentially of magnesic and sodic sulfates, but carried about 2.3 per cent nitrates.

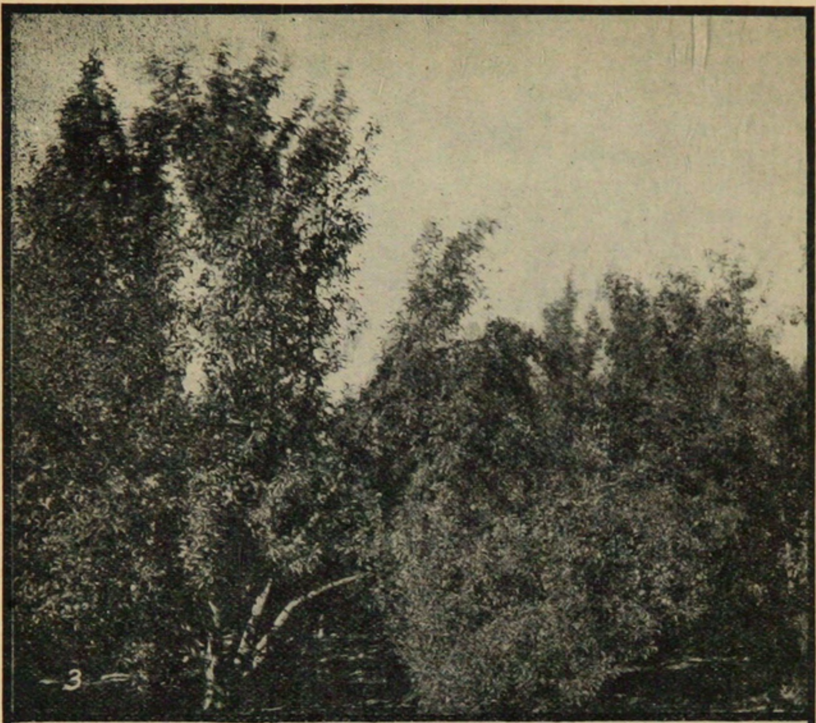
The last sample naturally suggested the examination of other waters issuing from the shales underlying irrigated mesas. The same point had been reached, starting from an entirely different point of departure, i. e., the search for an answer to the question, how much alkali may an irrigation water contain without detriment to the land to which it is applied? No attempt is made to answer this question at this time; it suffices that no one has yet complained with good cause that he has reached the injurious limit. An inspection of the next two analyses will indicate clearly why they are given in this place. The land was planted to corn and rye. It had passed into the hands of a man who had no experience with irrigation; the water was handy and plentiful, the people on the mesa above had only a moderate supply of water or there would have been more. The corn had been rather deeply furrowed for the purposes of irrigation. There was a band of efflorescent alkalis at least two inches wide on the side of each furrow. My curiosity was excited to find some reason why the corn should grow at all and not die. The rye was dying, but the corn was in pretty fair condition, which was a matter of surprise. Inquiry elicited the fact that small stuff had been a failure on this ground. I took a sample of the worst of this surface soil where even the corn, which seemed to have endured better than anything else, had almost failed. The irrigation was very excessive. The sample of soil yielded 4.67 per cent of water soluble, which gave me the following analysis: The determination of NO was made four times, because at the end of the reaction there was a rather copious evolution of CO_2, more than the sodic hydrate in the measuring tube could readily absorb.

ANALYSIS XXII.

WATER SOLUBLE PORTION. Laboratory No. 589.

	Per Cent.
Calcic Sulfate	16.645
Magnesic Sulfate	14.518
Potassic Sulfate	2.360
Sodic Sulfate	35.731
Sodic Chlorid	19.914
Sodic Nitrate	7.352
Sodic Silicate	0.328
Loss (water, organic matter, etc.)	3.152
	100.000

The nitrate according to this analysis is 0.342 per cent in this portion of the soil. This can only be considered as an approximate result. The big fact is that nitrates were present in notable quantities. This land was irrigated with the seepage water which issued from or above the shale underlying the mesa. This water contained 418.2 grains per imperial gallon or 5,975.7 parts per million. No nitrites were present.



Plates III and IV. See Pages 42 and 44.

ANALYSIS XXIII.

RESIDUE FROM SEEPAGE WATER. Laboratory No. 766.

	Per Cent.
Calcic Sulfate	27.397
Magnesic Sulfate	27.697
Potassic Sulfate	1.389
Sodic Sulfate	21.749
Sodic Carbonate	4.026
Sodic Chlorid	5.391
Sodic Nitrate	2.986
Sodic Silicate	0.401
Loss (water, organic matter, etc.)	8.944
	100.000

These two samples are more interesting in connection with this work than in connection with the purpose for which they were collected. Results like the foregoing are very disconcerting when one is seeking the limit of alkalis present in an irrigation water which may be injurious to the land or crops. The same is true in regard to the soil. It is true that this sample represented what I believed to be the worst and what according to the growth of the corn, was the worst, but the whole patch was so bad that it appeared useless to continue that study with great hope of success. The only encouragement that one could find in the case was that some things had died and that the rye was dying, but the question whether this was due to excessive salts or excessive water was impossible to determine. This digression may serve to show that our problems are far from simple and that an acquaintance with a large range of facts pertaining to our conditions does not lead to very firmly fixed convictions concerning what the facts really may be. I will add one more statement relative to this piece of ground and that is, that I saw the wheat grown on it two years later, 1900, and it yielded at the rate of 60 bushels per acre. All of which was extremely perverse from the standpoint of the theorist but very good from that of the owner.

The question of the presence of nitrates in seepage water issuing from the shales seemed to be of sufficient interest to justify further analyses. Another place was selected 80 feet below the top of the bank which was the level of the mesa. The sample was taken in the irrigating season. The water contained 557.9 grains per imperial gallon or 7,970.0 parts per million of total solids; ignition expelled 84.9 grains or 121.3 parts per million. This water was tested for free ammonia and 0.12 part per million was found. The following analysis has been calculated to one hundred.

ANALYSIS XXIV.

RESIDUE FROM SEEPAGE WATER. Laboratory No. 739.

	Per Cent.
Calcic Sulfate	31.102
Magnesic Sulfate	26.487
Potassic Sulfate	1.210
Sodic Sulfate	21.305
Sodic Carbonate	6.101
Sodic Chlorid	8.531
Sodic Nitrate	4.972
Sodic Silicate	0.292
	100.000

The aggregate volume of water issuing from a long stretch of this shale is large and according to this analysis each gallon of 70,000 grains carries 27.75 grains of nitrates.

In looking for a place to take a sample of shale to see whether the shale itself carried nitrates a brick yard offered the best opportunity for here a face, which had been recently opened, was accessible. The overlying strata are thin but the mesa country above and back of this opening is very extensive and quite well watered. It was observed that the brick in the drying sheds were covered with an efflorescence. This consisted essentially of sodic sulfate about 88.0 per cent; nitric acid was present but was not determined. A sample of the shale 1,280 grams was extracted with water and yielded 1.4 per cent of material soluble in water.

ANALYSIS XXV.

WATER SOLUBLE PORTION OF SHALE. Laboratory No. 645.

	Per Cent.
Calcic Sulfate	32.198
Magnesic Sulfate	13.705
Potassic Sulfate	1.930
Sodic Sulfate	42.990
Sodic Carbonate	0.716
Sodic Chlorid	2.477
Sodic Nitrate	1.711
Sodic Silicate	1.081
Loss (water, organic matter, etc.)	3.192
	100.000

The nitrates calculated on the air dried shale gives 0.03 per cent. The shale presents but little of interest. The amount of nitric acid found is so small that it would escape detection in the ordinary course of analysis. Still the analysis of this shale was made and shows that there is nothing in the character of the shale itself to indicate anything unusual.

ANALYSIS XXVI.

ANALYSIS OF SHALE. Laboratory No. 645.

	Per Cent.
Carbon	1.587
Silicic acid	47.292
Sulfuric acid	1.457
Carbonic acid	11.466
Chlorin	0.053
Titanic acid	0.500
Calcic oxid	16.129
Magnesic oxid	2.271
Potassic oxid	2.389
Sodic oxid	2.884
Ferric oxid	4.052
Aluminic oxid	7.957
Water at 108°	1.699
Water at 200°	0.656
	100.392

This shale is fossiliferous, is low in silicic acid and carries a large amount of lime, but no organic matter or other source of nitric acid.

We have presented by a considerable number of samples, the question of the nitrates in the soil, in the ground waters and in some of our seepage waters. There yet remains the question of our drain waters. We have but two of these to present. One is from a water course constituting the natural drainage of the section in which it is located, the second is from a box drain laid 4½ feet deep.

The water course constitutes what is locally called a "wash." The sample was collected in October, 1907, and was made up of a mixture of water from the irrigating canal, of off flow water from irrigated fields, and of seepage or drain water. The total solids were 359.52 grains per imperial gallon or 5,164.5 parts per million; ignition expelled 115.08 grains. This wash runs through the first mesa counting from the river and the mesa back of this has not yet been brought under irrigation. The depth of soil over the shale is not great, in some places it is very shallow.

ANALYSIS XXVII.

RESIDUE FROM WASTE WATER. Laboratory No. 605.

	Per Cent.
Calcic Sulfate	20.283
Magnesic Sulfate	33.573
Sodic Sulfate	20.749
Sodic Carbonate	5.351
Sodic Chlorid	8.528
Sodic Nitrate	4.159
Sodic Silicate	0.631
Sodic oxid (excess)	0.161
Loss (water, organic matter, etc.)	5.346
	100.000

Plates V and VI. See Pages 20, 43, 44 and 45.

I do not know how much water was flowing in this stream at the time the sample was taken. Nor do I know how much the average flow of this stream may amount to. I imagine that the flow varies greatly from time to time.

The next sample is one of a drain water taken in Oct., 1907. This drain was one of the main branches of a system put in 6½ years prior to the taking of the sample for the purpose of improving a piece of ground lying to the east and south and partly to the west of a rather large orchard. In spite of the drain the bad soil conditions have encroached upon the orchard area necessitating the removal of trees till the orchard is much smaller than it was six years ago. The case of this orchard is rather peculiar. There is on the north and west sides of the orchard a wash ranging from 6 to 10 feet deep and on the east, south and part of the west side is this system of drains and yet in June of this year I saw some of the few remaining trees in the extreme southern portion of the orchard very badly burned by nitre. The drain is a box one, seven by six inches laid 4½ feet deep. The land above the orchard was boggy at the time the drain was laid. It has been unwatered to the extent that grain can be grown on the greater portion of the land. The yield on some parts of this land is excellent. The condition of the orchard as suggested is gradually becoming worse and is at this time a promising subject for study. Total solids 637.3 grains per imperial gallon.

The analysis has been calculated to one hundred.

ANALYSIS XXVIII.

RESIDUE FROM DRAIN WATER. Laboratory No. 610.

	Per Cent.
Calcic Sulfate	23.203
Magnesic Sulfate	36.662
Potassic Sulfate	0.705
Sodic Sulfate	29.991
Sodic Chlorid	2.863
Sodic Carbonate	4.093
Sodic Nitrate	2.275
Silicic Acid	0.209
	100.000

The residue gave off water and red fumes when heated in a test tube. A sample of this drain water taken in June, 1909, about 20 months later, showed the presence of 622.65 grains of total solids per imperial gallon. Loss on ignition was 99.26 grains per imperial gallon. The ammonia was found to be 0.56 part per million. The analysis has been calculated to one hundred.

ANALYSIS XXIX.

RESIDUE FROM DRAIN WATER. Laboratory No. 792.

	Per Cent.
Calcic Sulfate	22.352
Magnesic Sulfate	31.586
Potassic Sulfate	1.502
Sodic Sulfate	24.775
Sodic Chlorid	9.050
Sodic Carbonate	4.120
Sodic Nitrate	6.500
Silicic Acid	0.115
	100.000

These results show what is pretty well demonstrated by the other samples, i. e., that the presence of the nitrates in the waters is not an accidental but a regular occurrence.

I have now presented all of the analytical data which I propose to present in this bulletin to show the occurrence of excessive amounts of nitrates in certain of our soils. These occurrences are not confined to one section of the state; the samples given represent widely separated sections.

There are no data that I have been able to find relative to the amount of nitric acid, respectively nitric nitrogen, in soils in general. The most satisfactory statements have been found in the latest edition of Storer's "Agriculture." These statements are largely based on the Rothamsted experiments and give aggregate results which are very difficult to apply to our lands, or to use in answering the questions suggesting themselves. We, therefore, collected a number of samples, representing the surface portion of our soils, because it is only with the upper layers that we are concerned. The percentages of nitrates given in the preceding analyses varying from 0.2 to upwards of 5.0 per cent of the air dried samples will not appeal to some readers as large quantities, therefore we wish to know and present what some other surface soils in Colorado contain. We are aware that the content of nitric nitrogen in a soil varies from time to time and that the nitrates may be carried down to considerable depths by rain water, etc.; all of these things have but little bearing on the object had in view. We wanted to know how much nitric nitrogen we might expect in the soil to a depth of 2½ feet, for our samples have mostly been taken at less depths, in fact the most remarkable quantities have been found practically within the first half inch of soil, though some very large percentages have been found at as great depths as three inches. We determined on sampling different sections of the College farm. The samples were taken in October during a period of fine weather and no irrigation water had been applied for some weeks. Other detailed data of this character are not at my disposal. This study was entrusted to Mr. Douglass and the following is his report:

SAMPLES TAKEN TWO INCHES DEEP.

	Per Cent Nitric Nitrogen Oct. 4	Oct. 6	Oct. 16
S. of Agr'l Hall near N. end of grain field	0.00045	0.00040	0.00035
S. of Agr'l Hall near S. end of grain field	0.00085	0.00120	0.00035
S. of Agr'l Hall near W. side of grain field	0.00050	0.00040	0.00010
Beet field, Experimental Farm	0.00005	0.00005	0.00005
Unused roadway, near beet field	0.00500	0.00350	0.00100
Alfalfa plot, fallow place		0.00225	......
Beet field, fallow place		0.00120	......

SAMPLES TAKEN THREE INCHES DEEP.

October 7, 1909.

	Per Cent Nitric Nitrogen In the row	Between rows
Near a fallow spot	0.000075	0.000100
In the fallow spot		0.002800
In the row nex to the fallow spot	0.000400	....
First full row on north side near west end	0.000150	0.000050
Nineteenth row from N. side near W. end	0.000150	0.000200
Thirty-fifth row from N. side near W. end	0.000300	0.000075
First row on north side near east end	0.000500	0.000100
Forty-seventh row from N. side near E. end	0.000300	0.000150
Midway between ditch and fallow spot	0.000500	0.000150
Fifth row south of fallow strip	0.000200	0.000500
One hundred feet from S. and E. sides	0.000200	0.000100
One hundred feet from west side between ditch and fallow spot	0.000200	0.000300
One hundred feet from W. and S. sides	0.000250	0.000250
The middle of the field	0.000200	0.000075
Twenty feet south and east of fallow spot	0.000100	0.000075
Near the fallow spot	0.000150	0.000100

These samples were taken between the beets in the rows and between the rows to see whether any difference in the percentage of nitric nitrogen could be detected.

SAMPLES TAKEN TO A DEPTH OF 2½ FEET.

October 18, 1909.

	Per Cent of Nitric Nitrogen
South of Agr'l Hall near N. end of grain field	0.000070
South of Agr'l Hall near the S end of grain field	0.000350
South of Agr'l Hall near the W. side, alfalfa 1908	0.000100
Unused roadway next to the beet plot	0.001600
Between plants, alfalfa plot Expt Farm	0.000800
In the beet plot, among the beets	0.000075

Plates VII and VIII. See Page 43.

SAMPLES TAKEN OCTOBER 18, 1909.

	Per Cent Nitric Nitrogen Top 2 in.	From 2 in. to 6 in.	From 6 in. to 12 in.
South of Agr'l Hall near N. end	0.000350	0.000300	0.000200
South of Agr'l Hall near S. end	0.000250	0.000250	0.000500
South of Agr'l Hall near W. side	0.000300	0.000070	0.000100
S. Agr'l Hall 50 ft. from Col. Ave. E. side	0.000800	0.000800	0.000800
South of Agr'l Hall, middle of field	0.000500	0.000150	0.000250
South of Agr'l Hall S. W. portion of field	trace	none	trace
*Alfalfa plot, Expt. Farm	0.002000	0.000700	0|001000
Alfalfa plots Expt. Farm between plots	0.001000	0.000600	0.000800
Alfalfa plots, Expt. Farm between healthy plants	0.001000	0.000200	0.000300
Alfalfa plots, Expt. Farm stand poor	0.000600	0.000600	0.000600
Cornfield S. of alfalfa plot	0.000800	0.000250	0.000100
Unused roadway next to beet plot	0.001000	0.001000	0.001800
Beet plot, among the beets, between ditch and fallow spot	0.000400	0.000075	0.000050
Beet plot, fallow strip 150 ft. from W side	0.000800	0.000400	0.000400
Beet plot, middle of patch among beets	0.000050	0.000025	0.000025
Beet plot, S. W. corner among beets	0.000175	0.000100	0.000100
Beet field, fallow spot	0.000400	0.000300	0.000200
Beet field, southeast portion among beets	0.000250	0.000025	0.000025
Beet field, fallow strip near east end	0.003500	0.001200	0.000800
Beet field, among beets near east end	0.000150	0.000025	0.000025
Beet field, among beets N. W. corner	0.000300	trace	0.000050
Beet field, among beets middle N. side	0.000100	trace	0.000050
Beet field, among beets W. side	0.000100	0.000025	0.000050
Grain field, south of beet field	0.000500	0.000450	0.000250
Oat field, north of beet field	0.000100	0.000025	0.000050
Virgin soil Sec. 4, T. 6, R. 59 W., top 6 in		0.000800	....
Virgin soil Sec. 34, T 6, R 59 W., top 6 in		0.000800	......
Virgin soil, Yuma County, Colo		0.000120	....
Soil Lab. No. 869, Rocky Ford, Oct. 11, 1909		0.006400	....

According to these results we find rather large amounts of nitric nitrogen in our surface soils. For instance the unused road way at the edge of the beet field gave in the top two inches on October 4, 0.005 per cent nitric nitrogen. This is equivalent to 0.03 per cent of sodic nitrate, 200 pounds per acre in the surface two inches of this soil. The roadway is really only a driveway between two plots of ground and has not been used, so that there was scarcely any more probability of the results having been influenced by the voidings of animals than any spot in the beet plot itself. The sample taken two days later gave nitric nitrogen equivalent to 0.020 per cent of sodic nitrate. This would give 140 pounds in the surface two inches. I am using 6 as the factor for converting nitrogen into sodic nitrate. The more exact factor is 6.0534. On October 16, we obtained much less, 40 pounds in the same depth of soil per acre. The alfalfa plot mentioned in these notes is a young nursery, the plants are small and set, I think 3x3 feet.

*This is a young nursery; the plants are very small and occupy only a small portion of the ground.

It is almost fallow ground. The beet field was a cropped field with the beets well grown and the ground well shaded. Here we find an average of 0.0000975 per cent of nitric nitrogen not including the fallow strip for the depth of from 2 to 6 inches. This is equivalent to 7.8 pounds of sodic nitrate in these four inches of soil per acre. These examples include our extremes but these are small quantities compared with the nitrate content of the first foot of soil of Orchard No. 2, 49.5 tons, or with the soil from the 5th to the 17th inch inclusive from Orchard No. 1, 6.5 tons per acre foot. While the nitric nitrogen in the soil of the College farm is probably normally high, it is simply not comparable to the samples of soils from these orchards. The Rothamsted experiments showed that during a period of from 14 to 15 months nitric acid equivalent to 553 and 572 pounds of commercial sodic nitrate was formed in the first 27 inches of soil per acre. This included the amount removed by drainage. This would give us 0.00625 per cent sodic nitrate counting the weight of an acre foot of soil as 4,000,000 or 0.00726 per cent counting it as 3,500,000 pounds.

The general character of these soils is given by the following analyses.

ANALYSES XXX, XXXI, XXXII AND XXXIII.

	No. 724 per cent.	No. 725 per cent.	No. 697 per cent.	No. 785 per cent.
Insoluble	54.653	57.068	76.500 (Insoluble and Silicic Acid)	64.820
Silicic Acid	19.805	12.754		5.650
Sulfuric Acid	0.047	0.049	0.320	0.810
Chlorin	0.032	0.059	3.090	0.890
Phosphoric Acid	0.120	0.127	0.120	0.180
Carbonic Acid	3.048	6.312	3.470	7.040
Lime	6.100	8.465	3.490	7.180
Magnesia	1.355	1.448	2.080	2.190
Sodic Oxid	0.290	0.432	0.840	0.840
Potassic Oxid	0.872	0.742	0.590	0.690
Ferric Oxid	5.601	3.499	3.040	3.110
Aluminic Oxid	3.738	5.397	4.020	2.250
Manganic Oxid (br)	0.118	0.026	.....	.....
Moisture	.....	.....	1.370	1.470
Ignition	5.072	3.887	1.760	2.970
Sum	100.851	100.265	100.690	100.090
O equiv. to Chlorin	0.007	0.013	0.690	0.200
	100.844	100.252	100.000	99.890
Total Nitrogen	0.147	0.069	0 080	0.072
Humus	0.426	.....	.....	0.248

Samples 724 and 725 represent the soil and subsoil of the Experiment Station plots. The surface soil has a depth of one foot and the subsoil was taken to a like depth, so the samples represent the first two feet of the plot. Samples 697 and 785 represent soils of orchards which have suffered severely from the effects of excessive quantities of nitre. These four soils differ principally in the amount of silicic acid set free upon digestion with hydrochloric acid. The carbonic acid may be considered as existing wholly as calcic carbonate which is essentially correct, for the calcic carbonate can be detected in most of the soils by simple physical examination. The humus in our soils is usually low in percentage and though apt to be richer in nitrogen than the humus of states with a higher rainfall it is not always so. The total nitrogen content of our soils as indicated by a fairly large number of analyses is not far from 0.10 per cent. It follows that a great many of them are below this amount. The four samples given illustrate this and show that there is no excessively large quantities of nitrogen present in the soil. The nitrogen determinations were made by the plain Kjeldahl, as it was not supposed that the nitrates were present in sufficient quantities to influence the results, assuming that this is correct it would appear that about one half the nitrogen in number 697 was present in the form of nitrates for we found 0.037 per cent of nitrogen calculated on the air dried soil in the aqueous extract as nitrates. The amount of nitrates present in the soil at a given time seems never to have been made the subject of study, probably because they are very small. The Rothamsted experiments lead to the conclusion that in good agricultural land cultivated as bare fallow about 80 pounds of nitrogen were transformed into nitrates in 14 or 15 months between the removal of the preceding crop and the taking of the samples. This includes the nitrates carried out of the land by drainage. The source of these nitrates is not considered. They may have been and probably were largely formed partly by nitrifying processes, partly by fixation. Storer further states "In three fields at Rothamsted 56.5, 58.8 and 59.9 pounds of nitrogen in the form of nitrates were found in September and October taking the soil to a depth of 27 inches. In one of these fields 49 pounds of nitric nitrogen occurred in the uppermost 18 inches. This result was due to the richness of the soil in nitrifiable matter. The other two fields in less favorable agricultural conditions contained only 33.7 and 36.3 pounds of nitrate nitrogen in the uppermost 18 inches of soil." Lipman states that "The determinations of nitrates, at Rothamsted, in the drainage waters of land that had been kept fallow, showed an annual removal of 40.2 pounds of nitrate nitrogen per acre." The maximum of nitric nitrogen here given, 59.9 pounds, gives only 359.4 pounds of nitrate of soda per acre taken to the depth of 27 inches; while we found in number 697, 9,040 pounds in an acre foot after the rich surface portion had been removed. This surface portion contained in the uppermost four inches of soil 22,747 pounds of sodic nitrate. It is understood that sodic nitrate is used simply as a convenient form of expression and is not intended as a definite statement that there were no magnesic or calcic nitrates present. The fact is that in some samples we have had to combine the nitric acid with these bases because there were no other acids with which to combine them. Another consideration will give an idea of the amount of nitrates in our samples, especially of the surface samples, i. e., that the India saltpetre earth carries a total of nitrates varying from 1.6 to 12 per cent and that the caliche worked in Chile carries from 21 to 51 per cent while these samples carry from about two tenths to more than six per cent of the air dried soils.

It may be thought that the amounts of nitric nitrogen given for our good agricultural soils are exceptional, even for Colorado, in order to answer any such misgiving which some may entertain, I append tables containing 100 determinations representing 64 different fields.

The following 46 samples represent as many different beet patches. The samples were taken to a depth of six inches, October 1-15, 1909.

NITRIC NITROGEN IN FORTY-SIX SAMPLES OF BEET SOILS.

Results Given in Per Cent of Air-Dried Soil.

1.	0.001250	24.	0.000200
2.	0.000050	25.	0.000075
3.	0.006000	26.	0.000100
4.	0.008000	27.	Trace
5.	0.000120	28.	0.000050
6.	0.002000	29.	0.000025
7.	0.000075	30.	0.000800
8.	0.000800	31.	0.000025
9.	0.003500	32.	0.010000
10.	0.000050	33.	0.007000
11.	0.000800	34.	Trace
12.	0.004000	35.	0.000050
13.	0.000600	36.	Trace
14.	0.000600	37.	0.000100
15.	0.000100	38.	0.002500
16.	0.002000	39.	0.000150
17.	0.000075	40.	0.001250
18.	0.000100	41.	0.004000
19.	0.000200	42.	Trace
20.	0.000200	43.	0.001500
21.	0.012000	44.	0.016000
22.	0.003500	45.	0.001500
23.	0.000800	46.	0.000075

The above samples represent a variety of soils on which beets are grown. Some of the land is low and heavy, some of it high, light and well drained. The table shows that the amount of nitrates represented in these soils varies from a trace to 1,920 pounds in the top six inches of soil.

The following 54 samples from 18 different beet fields collected Jan. 26-31, 1910, show the amount of nitric nitrogen in the top six inches of the soil at this date.

NITRIC NITROGEN IN EIGHTEEN BEET FIELDS.

Results Given in Per Cent of Air-Dried Soil.

Number	In the Beet Row	In the Furrow	In the Turning Row
1.	0.000625	0.001375	0.000625
2.	0.001	0.0015	0.003
3.	0.000375	0.0002	0.000375
4.	0.0015	0.003	0.008
5.	0.0002	0.000375	0.0015
6.	0.001125	0.0005	0.00175
7.	0.0004	0.0001	0.0005
8.	0.0005	0.001	0.002
9.	0.000125	0.0005	0.00025
10.	0.005	0.000875	0.0005
11.	0.00075	0.000625	0.0005
12.	0.0001	0.0002	0.000375
13.	0.00025	0.00075	0.000375
14.	0.0015	0.00075	0.0005
15.	0.000875	0.0005	0.014
16.	0.00006	0.00008	0.0002
17.	0.000875	0.00125	0.001
18.	0.001	0.00075	0.001

The preceding table gives us an idea of the amount of nitric nitrogen in our cultivated soils. All of the samples were tkaen to a depth of six inches. The activity of the azotobacter is assumed to have been moderate not only at the time the samples were collected but also for a rather long period before, as the ground had been frozen at least two months prior to this date, and had remained frozen for some time. The rains and snows during the autumn had tended to wash the nitrates deeper into the soil. The amount of rain fall during the months preceding the taking of these samples or practically from September 1st to February 1st, was 3.83 inches of which 3.36 inches fell between September 12th and December 1st.

The samples were taken, as we see, in mid-winter from fields which had been in beets and after a season with heavy rain or snow falls in late autumn and severe freezing. The crops would naturally be supposed to remove considerable quantities of nitrates, the rains and snows would be expected to wash them into the deeper portions of the soil, and the freezing weather should have retarded the activity of the azotobacter. Still the table reveals the presence of nitric acid equivalent to 180 pounds of sodic nitrate in the surface six inches of two of these fields and 600 pounds in another. These samples were taken between beets in the rows. The samples taken in the furrow between the rows give us a maximum corrsponding to 360 pounds of sodic nitrate in the top six inches of soil. The turning row, however, gives us an idea of the amount of nitric acid that may be present and at the same time some idea of the difference in the amount of nitric acid or its corresponding nitrate due to the presence of beets. We have for the fourth farm nitric acid between the beets corresponding to 180 pounds of sodic nitrate, Chile saltpetre, in the upper six inches of the soil, and in the soil of the turning row there is five times as much, 900 pounds. We sometimes find less nitric acid in the middle between the rows than between the beets in the rows, though we usually find more. The presence of larger quantities of nitric acid in the fallow ground of the turning row is a fact which one would expect as the sunshine, air and soil conditions are favorable for its production. The same is true for even small spots within the beet field which for some reason or other may chance to be fallow. The percentages of nitric nitrogen found in the beet plots at this station may be used to show this; in a fallow, i. e., a bare spot 0.002800 per cent; between the beets in the row next to it 0.00040 per cent. Again in the beet field among the beets 0.0001; in an oat field 0.0001; in a fallow strip 0.0035; in another fallow spot in the field, 0.0004 per cent.

The significance of the analytical data may be presented by the following averages representing the College farm at Fort Collins:

	Per Cent of Nitric Nitrogen
71 Samples 2 and 3 inches deep, Oct. 4-18, 1909	0.000626
28 Samples 3 to 6 inches inclusive, Oct. 18, 1909	0.000515
25 Samples 7 to 12 inches inclusive, Oct. 18, 1909	0.000323
6 Samples 2 1-2 feet deep, Oct. 18, 1909	0.000499

The following samples represent other farms, sixty-four in number:

	Per Cent of Nitric Nitrogen
46 Samples 6 inches deep, Oct. 1-15, 1909	0.002005
54 Samples 6 inches deep, Jan. 26-31, 1910	0.001271

The College land contained in October less than one-third as much nitric nitrogen as the other 46 farms sampled at the same time, and about one-half as much as 18 other farms sampled in January, 1910. This is very striking as the samples from the College farm were taken to a maximum depth of three inches while the others were all taken to a depth of six inches.

That there has been a decided deterioration in the quality of our beets within the past six years cannot ,I think, be doubted. Many causes may have attributed to this, but the discussion of these at this time would be out of place. Suffice it, for the present purpose, to state, that there are many fields of good beets every year, but that in spite of this the average quality has been deteriorating. The past few seasons seem to have been especially favorable for the production of nitrates in the soil, and I am of the opinion that there is a direct and intimate relation between these facts.

The amount of nitric acid present in the sugar beet is usually assumed to be small, more in the French beet than in the German. but the amount is always small. Further the nitrates are usually considered as molasses formers. We have examined our beets qualitatively for nitric acid and find it present in quantities, which are easily detected. I have been kindly furnished with samples of Steffens waste water from several factories in this state and find them uniformly rich enough in nitrates to give a strong reaction without one's going to any particular trouble to prepare the waste water. There is nothing new in the occurrence of nitric acid or nitrates in beets. It has been shown that the leaves have contained as much as 0.16 per cent of their green weight, which is stated to be exceptional in plants. Stock beets have been found to contain 0.126 per cent and sugar beets 0.164 per cent of their green weight. The last percentage was found in beets which had been heavily manured with saltpetre or other highly nitrogenous manures. No information is given concerning their deportment in the factory. The nitrates have been considered as exercising a prejudicial influence on the working qualities of the beets if applied alone, in considerable quantities and after the plant has attained to some size. It seems possible that we may have in these facts the explanation for the deterioration of our beets. The nitrates are being continuously formed in our soils. In the turn row of field fifteen, we find nitric acid equivalent to 1,680 pounds of sodic nitrate in the surface six inches per acre whereas we find the equivalent of only 120 pounds in the furrow between the rows. We must be careful about drawing extreme conclusions in regard to the amount of nitrates used by the crop. The quantity was almost certainly materially less than the difference between 1,680 and 120 pounds because the ground had been shaded by the beets during most of the season and this would make some difference; further, the row had been washed out by the irrigation water applied, etc., but the possible supply for the beets grown on this field was as much as 1,680 pounds in the top six inches of soil per acre. This determination was repeated and checked by the determination of the nitric acid in the aqueous extract of the soil by a different method.

The soils here considered are such as were planted to beets last season, 1909. The extreme cases given in other portions of this bulletin are soils in which this process of fixation has proceeded so far that they are now barren, due to the excessive amounts of nitrates.

The past season may have been an exceptionally favorable one for the azotobacter and we may not have the recurrence of such serious results for years; there is, however, no assurance that this may be the case. In fact we have no data relative to the effects of the season upon the activity of the bacteria.

One question has undoubtedly suggested itself in regard to the origin of these nitrates, i. e., whether the popular idea that the irrigation water brings them to the surface may not be correct. Some at least will deem this question as deserving a definite answer especially as I have found that the waters issuing from the shales underlying the mesas carry significant quantities of nitrates. The shales themselves when a sufficient quantity of them, 1,280 grams, were extracted with water actually showed the presence of a trace of nitric acid. There are two samples of waters and one of shale They represent three different localities, two of them within three miles of one another while the third is more than 50 miles from either of the other two. This might mean that the shale area is very large and though it contains but a trace of nitric acid it might suffice to furnish all of the nitric acid which has been found, especially as this water has been issuing from these shales and filling up the lower portions of the country for a very long period. This can all be answered very easily by stating the following facts. The mesas above these shales are cultivated and bad nitre spots occur on top of them, in one case 80 feet above the level at which the water was taken. Second, that nitre spots occur in entirely different geological formations where these shales do not occur, in alluvial deposits and under our ordinary prairie conditions, in other words the shales considered as a source of the nitre would not be adequate for the explanation of the greater number of occurrences and independent of any other reason than their insufficiency, we must seek for a more general source or a cause sufficient to account for all of the occurrences assuming that they have a common cause, which is reasonable, at least, until we are sure that they have different causes.

The occurrence of nitrates in the waters and apparently in the shale is susceptible of an easy explanation, i. e., the nitre spots which are only exaggerated instances of a general condition, occur in the lands above the shales. The water that falls or is put upon these lands washes the nitrates down into the shales. The soil has no power to retain these salts and this seepage water is simply washing the nitrates out of the land. The shale from the brick yard was saturated with this water and the same water was used in making the brick. A trace should be present in the aqueous extract of the shale as we find was the fact.

The effect of the nitre on vegetation has been alluded to; the spots where the soil is rich in nitrates is entirely barren. See Plate II. The most serious manifestation with which we have yet met was the rather sudden death of a large number of apple trees mostly in June 1909. See Plate III. Plate IV is a view of the same rows outside of the affected area. The leaves began turning brown at the apices, then along the margins until the whole leaf was involved. See Plate I. Sometimes it did not affect the whole tree, only a few limbs being attacked. Other trees, beside apple trees were attacked. A number of cottonwoods were affected in this way. As elsewhere stated the condition of the soil in regard to excessive water was immediately investigated but we could not find any reason for attributing the trouble to this cause. One case in particular was instructive, it was in the remnant of the orchard designated Orchard No. 2. See Plates II, VI and VII. Plate VII gives a good idea of the size of this barren area as well as the killing of the remaining trees. The trees in the background are of the same age as those in the foreground. The dead tree in the middle of the background is the same tree that appears in the foreground of Plate II.

There are a few trees on the east side of the orchard which had up to that time remained in very good condition, in fact, were quite thrifty trees. These trees are shown in the background of Plate VI. These trees died suddenly. Plate VIII shows a tree killed late in the summer. The crowns and roots of these trees were apparently healthy. The roots were followed for six or eight feet from the trunk of the tree, nothing could be found to indicate any cause for the deportment of the tree. I had known for three years that this ground was very rich in nitrates and locally in chlorids. This determined me to make some experiments with nitre and salt. The nitre in this soil amounts to many tons per acre foot, 56.7 tons in the surface foot. It was evident that I had to deal with large quantities so I applied nitre to some young trees in an experimental orchard and irrigated them to bring the nitre solution in contact with the feeding roots. The amounts applied were from 5 to 20 pounds per tree. The results were that in those trees, about which I buried five pounds of nitre each, some of the limbs were reached and others were not, in other words in applying the nitre, (Chile saltpetre was used in this experiment), I had reached some of the feeding roots but the others had escaped. With the application of 20 pounds I succeeded in reaching all of the roots, at least I killed the tree in about four days. Judging from the deportment of these trees, I can conceive of ones failing in an experiment of this sort, even though he applied large quantities of nitre or other poison provided the poison was not put within the feeding area of the roots for the effects produced on different trees was by no means proportional to the amounts applied to the soil, the application of five pounds produced just as pronounced results as the application of 10 pounds. This of course depended upon the root system of the tree and the location of the nitre. The effects were in all respects similar to those produced in the other orchards, the beginning and progress of the effects, the killing of the leaves, the deportment of the tree in throwing out a few whitish-yellow leaves and the appearance of the bark and wood after death, were identical. An application of large quantities of salt proved injurious but did not produce these effects. Prof. C. S. Crandall of the University of Illinois, also experimented on the effects of nitre but he introduced the solution under the bark by properly attaching a vessel filled with a solution of nitre to the tree. He wrote me that the result was the same as on the trees which I had shown him. There is no doubt but that the nitre in the soil is capable of producing these effects. The more observant and intelligent orchardists also blame the "black alkali" which in this case is nitre, it may be calcic, magnesic, or sodic nitrate and is probably usually a mixture of the three. A very simple explanation for the death of the trees suggests itself. The nitrates accumulated in the surface soil were probably carried down to the roots by a rain fall or an irrigation at a time when they were very active and enough of the nitre was gathered to do the injury. I am convinced that this simple explanation is the correct one. It matters not that there is arsenic in this soil. These trees are not affected in the least as those are which are injured by arsenic. These may grow thriftily until the time of their being killed. This trouble is not scattered through hundreds of orchards or even through one orchard, a tree here and there, but is confined to areas. See Plates II, IV and V. The orchards designated as Nos. 2 and 3 have been totally destroyed in parts, these parts of the orchards constituting an irregular but continuous area. Other orchards present similar conditions. Both old and young trees have been killed during the past season, nineteen hundred and nine.

This is the only effect of this soil condition that I wish to present at this time though there are other serious agricultural conditions which I believe we will find attributable to this cause, i. e., to an excess of nitre in the soil. Sometimes too much at one time as is attested by the death of apple and also other kinds of trees, sometimes to too great an aggregate supply during the season. The following may illustrate what I mean by the latter statement. It is generally conceded that the application of nitrates to the sugar beet except in the earlier stages of its growth is detrimental to the quality of the beet. The following recommendation has been made in regard to the application of nitrates to this crop. One hundred and seventy pounds per acre applied in conjunction with farmyard manure in the fall and 245 pounds also with manure in the spring, a total of 415 pounds. This is applied either on the surface or near it and the crop is not supposed to receive further application of nitrates during the season. But what will be the condition of the crop if it should receive a continuous supply amounting during the season to, say, 600 or 800 pounds or is planted in soil which already contains several times this amount per acre. If the assumption that nitrates injuriously affect the quality of the beet when present in large quantities, then beets grown in such soils ought to be very poor, not necessarily in crop but in quality. I have seen beets planted in ground so rich in nitrates that when the water soluble residue, amounting to 4.6 per cent of the air dried soil, was treated with ferrous sulfate and sulfuric acid the red brown vapors of NO_2 could be seen filling and even flowing out of the test tube. This sample of soil was taken October 11, 1909. There was only here and there a straggling beet in this portion of the field. Adjoining this was an area of big green tops with medium sized, white, brittle beets. The sugar content and coefficient of purity were not determined. This study has probably only been begun.

Plate V illustrates a beet field, not the one referred to above. The amount of nitric acid in this soil is very high, as high as that of some of our orchard soils in which it is measured by the ton per acre foot of soil. I have tried to give facts enough to place the occurrence of these very large quantities of nitrates in our soils beyond question. I have endeavored to give reasons for believing that the nitrates are not derived from the shales which are often popularly assumed to be the source of this "black alkali" or nitre. I have given one instance of its serious effect upon orchard trees but hold back other features of its influence upon our agriculture for further study.

Unaided by bacteriological investigation, until within the past year, I had to content myself with a theory in regard to the source of these nitrates. I found a few things common to these occurrences. They were all so situated that while the water was not excessive there was an adequate and constant supply of it. The soils are almost uniformly comparatively poor in nitrogenous matter and there is always an abundance of carbonate of lime. We have some occurrences of these nitrates in the northern parts of the state but they are always in places where we have comparatively even, high temperatures for goodly periods at a time. These are favorable conditions for the development of a bacterial flora. I believed that in these places the flora was a nitrogen fixing one. I presented these views to Professor Sackett and have been fortunate enough to obtain his aid in carrying the investigation further on bacteriological lines. Considerable preliminary work has already been done and we purpose to continue the work in the field and in the laboratories even beyond the limits which we now see and there is much work within these limits. Professor Sackett and I have already gathered samples from several sections of the state. All of the samples so far examined are from localities that I have known for several years and in one sense are from promising places, i. e., from sections rich in nitrates. Some of the samples are unfortunately so rich in nitrates that the nitrogen fixing flora has practically perished. One thing is characteristic of them all, i. e., the brown color of the soil, hence the common term "black alkali." This is most striking along the roadsides where we sometimes can observe the dark color continuous for as much as a mile at a time. No samples were taken from such places. The dark color is possibly due to the bacterial flora itself as the azotobacter form yellow brown or dark brown films. The following numbers are simply laboratory numbers for a preliminary series and may not again be presented, this of course is entirely in Professor Sackett's hands. Professor Sackett found that these samples were comparatively rich in nitrogen fixing bacteria of which he finds a considerable variety. It is not time to state any conclusion even tentatively held. Professor Sackett has given me the following results which may suffice for the present purpose, i. e., to place the source of these nitrates beyond a reasonable doubt. The nine samples represent five localities.

Number 1.—A surface soil very rich in nitrates.
Number 2.—This sample is from the same locality taken to a depth of 6 inches.
Number 3.—Same locality 12-14 inches deep.
Number 4.—Taken as normal soil for this locality, 2-6 inches deep, no water at a depth of five feet.
Number 5.—Another locality from 2-6 inches deep.
Number 6.—Another from 2-6 inches deep.
Number 7.—Another locality from 2-6 inches deep.
Number 8.—Normal soil near No. 7.
Number 9.—A normal mesa soil in an alfalfa field with no apparent trouble.

NITROGEN FIXATION.

Milligrams Nitrogen Fixed in 100 CC. Mannite Solution, Infusion of 10 Grams of Soil Added.

	10 Days	20 Days	30 Days
Number 1	0.00000	0.00000	1.05075
Number 2	0.00000	1.19085	0.56040
Number 3	1.78627	3.08220	3.43245
Number 4	3.92780	6.16440	12.46890
Number 5	0.63045	0.84060	3.08220
Number 6	0.07213	0.77055	3.57265
Number 7	1.72130	3.50250	3.01215
Number 8	1.87562	2.38170	2.87205
Number 9	4.13431	13.02930	10.15725

All questions of technique and further detail will be presented by Professor Sackett in due time.

The great variety of soils in which I have observed this trouble and the variety of differences in the appearances of these places make one hopeful of very interesting results.

We may be pardoned for adding the following consideration, possibly of some geological interest. The source of the nitrogen present in the Chile saltpetre beds has been the cause of much speculation. The source of the nitrogen in the India saltpetre earth is considered as evident and the formation of the nitrates is sufficiently accounted for by the action of nitrifying bacteria, which convert the nitrogen of the liquid excreta of the households into nitric acid which may be recovered in the form of potassic nitrate.

In the case of the Chile saltpetre we have no definite evidence regarding the source of the nitrogen and as a result we have a variety of theories to account for its presence in such extremely large quantities in the form of nitrates. Almost every conceivable source, the droppings of great herds of animals, guano or the droppings of birds, marine vegetation, etc., have been suggested. These sources attribute the formation of the nitrates to the action of nitrifying bacteria on nitrogen of animal or vegetable origin. I know that this has not always been stated in just this way. Another source which has been suggested is the atmosphere. It has been claimed that the hydrated oxid of iron has the power to induce the oxidation of ammonia salts and that other basic compounds, the alkaline carbonates, for instance, have the power under certain conditions of inducing the oxidation of atmospheric nitrogen. Again the electric discharge has been suggested as the cause of the union of the oxygen and nitrogen of the atmosphere to form nitric acid, which falling to the earth as a dilute solution of ammonic nitrate in rain water may have reacted with the carbonates of the alkalis or alkaline earths which would then be carried with the waters to natural basins from which the waters have subsequently evaporated leaving the nitrates in their present form and place.

The facts which I have found obtaining in such large districts in Colorado suggest the possibility that the atmosphere is the source of the nitrogen in these nitrates but that the agency which has transferred it from the atmosphere to the fixed form of the nitrates is not the electric discharge nor the action of alkaline carbonates on the nitrogen of the air in the presence of oxidizable matter, but to that of those micro-organisms, the azotobacter, which have the power of converting atmospheric nitrogen into nitric acid, respectively into nitrates, especially if there be enough calcic or other carbonate present to prevent the soil from becoming acid.

We have in miniature a great many analogies to the occurrences of Chile. In the lower parts of small basins we have deposits of sulfate of soda, above this zone we have one rich in nitrates. I have been told that in Chile they sometimes find calcic chlorid but usually sodic chlorid. We find samples in which calcic and magnesic chlorid together constitute 48.5 per cent of the water soluble portion. Others in which sodic chlorid constitutes 44.5 per cent of the water soluble. The amount of nitrates, dealt with in this bulletin, is surprisingly large. We have as the highest percentages of nitrates found, 5.628 and 6.541 per cent of the air dried samples. These samples were gathered from the surface soil and were not taken to any depth, perhaps the one showing 5.628 per cent may have reached a depth of two inches, but the area involved was small. The other sample may have reached a depth of an inch but the area involved was large, some eight or ten acres. In the case of another sample taken to the depth of five inches we find the nitrates equal to 2.571 per cent of the air dried soil. This sample was taken to a medium depth and the area involved is at least eight acres and we would have 344,000 pounds or 172 tons of sodic nitrate in the top five inches of this land. In another sample taken to a depth of four inches we find that 1.706 per cent of the air dried sample is sodic nitrate. The area involved represented by this sample is certainly as large, i. e., eight acres, and we would have 189,971 pounds or practically 95 tons in the top four inches of this land. The largest amount of nitrates indicated by the analysis of any sample taken to a depth greater than four inches was in the case of a sample taken to the depth of one foot which contained 2.837 per cent of sodic nitrate corresponding to 113,480 pounds or 56.74 tons per acre in the surface foot. These figures are given to show the large aggregate amount of nitrogen which is being taken from the air and converted into nitrates in these semi-arid soils usually fairly rich in sulfate of soda and containing large amounts of calcic carbonate.

The aggregate area involved in this active fixation of nitrogen would be difficult to estimate accurately but as stated elsewhere in this bulletin it is present in widely separated sections of the state. In some places only a small area may be involved, in others it is almost continuous for miles.

SUMMARY.

The cause of the barren spots in some sections of Colorado which is popularly, though incorrectly, called "black alkali" is the presence of excessive quantities of nitrates.

These nitrates do not come from the soil nor from the shale as frequently assumed but are formed in the soil.

The death of many apple trees, some poplars and other shade trees during the season of 1909 was caused by excessive amounts of nitrates in the soil.

These nitrates were carried down within the feeding area of the roots by the spring rains and irrigation.

The amount of these nitrates accumulated in some of these soils is already very large, amounting to many tons per acre foot of soil, 100 tons per acre foot having been indicated by some samples.

The agency by which the nitrogen of the air is converted into these nitrates in the soil is a group of micro-organisms possessing the power of converting the nitrogen of the air into nitric acid.

These organisms have a very wide distribution in our soils and are not always hurtful, but when the conditions of the soil, including moisture, temperature, and the presence of much alkaline earth carbonate, become very favorable they develop so vigorously that they produce the effects recorded in this bulletin.

These organisms thrive in some of our best cultivated lands, and some of the anomalies of our agriculture are probably due to them.

The very considerable amounts of nitrates found in some of our soils, together with the large areas so enriched, and their wide distribution suggest the probability that the formation of the nitrates of Chile and Peru may have been due to the agency of these organisms.