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THE FIXATION OF NITROGEN

IN SOME COLORADO SOILS

A Further Study

BY

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INTRODUCTION.

In Bulletin 155, of this station, I endeavored to demonstrate the occurrence of large quantities of nitrates in some of our Colorado soils by giving a number of analyses showing the presence of phenomenal quantities of these salts. So far as I have been able to learn it will undoubtedly be wise to lay emphasis upon this fact as its importance is fundamental; therefore, I shall give further examples of this occurrence though it seems that it ought to be a superfluous task.

A second point which I endeavored to make perfectly plain was that I was writing not only of an extreme degree of concentration of nitrates in the soil but that this concentration pertained to large areas. Though I endeavored to write very conservatively I mentioned areas of eight, ten and twelve acres, as having been rendered barren by the accumulation of this salt, nitre, which term was used to designate any nitrate, calcic, magnesic, sodic or potassic nitrate, the essential point being the presence of nitric acid.

Again I endeavored to show that any transportation, leaching and subsequent concentration was inadequate to account for the occurrences of these salts, because they occur on high mesas where there is no wash or transportation from higher lands as well as in low lands. In writing of the presence of nitrates in the waters issuing from the shales, I recognized the fact that it might suggest these shales as the source of the nitrates and endeavored to show that such a conclusion would be unwarranted, for the shales in question contain only 0.03 percent of nitrates and the presence of this small amount was probably due to the water from the higher lying mesas where nitrates occur rather abundantly, which fact is stated in Bulletin 155, p. 42, as follows: "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." Further, that nitre spots occur in 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 nitre, would not be available for the explanation of the greater part of the occurrences and we are compelled, on account of their insufficiency, to seek for a more generally occurring source or a cause sufficient to account for all the occurrences, assuming that they have a common cause, which is reasonable, at least, until we are sure that they have different causes in different places.

The relation of seepage to these occurrences of nitre was also discussed and the statement was made that the nitre is associated with a rather uniform and abundant supply of moisture but that in really wet soils it does not appear; on the other hand, at least one instance of its occurrence in well drained land was specifically mentioned and described, as follows: "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." In describing Orchard No. 4, I stated that this land is quite high and slopes to the west and south. Again I mention its occurring on hillsides, which was done to convey to the mind of the reader that the locations in which we meet these occurrences are so varied that it would be doing violence to the facts to attribute it to seepage. I mentioned the muddy condition of the soil in three cases which I discussed and gave the height of the water table, if it could properly be called such, as five and one-half or six feet, a perfectly safe depth for all ordinary vegetation. This question was investigated at various seasons of the year without results, materially contributing toward a solution of the problem. The very first question suggesting itself in connection with the troubles described in Bulletin 155, and one which every intelligent ranchman investigates, is the question of water and if the solution of the difficulties were to be found in an excess of water in the soil the ranchmen themselves would long since have found it out, but even in cases in which I have thought it possible or even probable that the soil water might be too abundant, I have been informed by persons of very different character that the water plane varied from 12 to 16 or more feet throughout a whole section of country. These people had dug cisterns and wells and made other excavations, and their information on this subject is fairly reliable. I am convinced that the muddy condition of the three soils described is rather a result of the presence of the nitre than a cause of the trouble.

Bulletin 160 is more than a popular restatement of the facts of Bulletin 155, in that it gives our observations upon the orchards from September of 1909 till May of 1910, which gave us no reason for modifying any view expressed in Bulletin 155, except to intimate rather strongly, that the seriousness of the problem was even greater than had been suggested in Bulletin 155.

In describing the condition of the land I again state more strongly than before: "This condition then is not restricted to low lands; is not dependent upon the variety of the soil unless it be within very wide limits, and is not due to bad drainage though it is often observed in low, moist places." In order to convey a definite measure of its effects it was stated: "I know of one orchard from which 110 trees have been removed this—the spring of 1910—another from which 200, and still another from which more than 200 trees have been removed or are dead."

I gave what appeared to me a justifying reason for considering orchard trees rather than some other crop. My reason was essentially this, that the effect, in the case of the apple tree in particular, is so wide-spread and disastrous that no one conversant with the facts can doubt the existence of a very serious evil, and inasmuch as our orchards both old and young received almost constant attention and care, I wanted to appeal to both the knowledge and interests of the people, as I realized that I was setting forth rather startling facts, and if the people did not believe in the existence of the evil any explanation of the cause would be nothing more than an appeal to their imaginations. That I was justified in this course is fully shown by the doubts entertained by persons who are not ranchmen and orchardists but men of education, experience and mature judgment, some of whom when asked for an opinion have reserved their judgment on the ground that they had never seen such conditions as were described.

It was not my intention in either of the bulletins previously issued on this subject to venture upon the question pertaining to the possible influence of the excessive formation of nitre in the soil upon any of the general crops but it seemed wise to make some tentative statements regarding this feature of the question and the beet crop was mentioned as one which had, possibly, already shown the effects of a continuous and, in the aggregate, excessive supply of this salt. Of course, such a bold suggestion would meet with doubt if not with less kindly treatment. I purposely held close to demonstrable facts, i. e., the presence of unprecedented quantities of nitrates, sometimes confined to small areas but often extending so as to involve eight, ten, twenty or even forty acres, or the death of many apple trees scattered over a large territory, all attacked and dying in a similar manner, or the increasing nonproductiveness of the land till total barrenness ensued. I suggested as a cause for the accumulation of these nitrates the action of certain groups of bacteria only after I had considered every other source which might prove sufficient to explain all of the facts. While the facts adduced as the basis of this claim may be open to some objections, I believe that we shall be able to show that it is a fact that the nitrates are formed in situ, but I shall leave the explanation of this fact and the questions, whence comes the energy; are the azotobacter species alone responsible for the fixation and nitrification or do other groups of bacteria play a more important part than the azotobacter in converting the nitrogen into nitric acid, for others to solve.

The task which I set myself is to show that the nitrate *is* formed in situ, but this is only a part of the purpose of the present bulletin. It is intended to extend the discussion of the occurrences of these nitre spots and to describe further the effects of this nitre on the soil and plants. In a subsequent bulletin I intend to take up, in some degree of fullness, its effect upon the growth and quality of the sugar beet, more especially upon its composition.

Case No. 5—The orchards and localities described in Bulletin 155 will not be treated of in this bulletin except as further observations made since Bulletin 155 was published may seem to justify, when they will be referred to by the number under which they were described in that bulletin. We will continue the numbers beginning with orchard or case No. 5. I visited this orchard, quite a large one, on the 12th of June, 1909. I did not obtain the age of the trees but they were probably not less than 15 years old. They had been sprayed heavily, especially in 1903, 1904 and 1905. There were a few trees in the orchard with corroded crowns, very probably due to arsenic, but arsenic had nothing to do with the trouble that we went to investigate. The condition of the orchard was, in the main, good; we, however, found twelve large trees in a group, with brown leaves and the trees appeared to be dead. The rest of the orchard was in good condition, the foliage was of full size and healthy in color. We learned from the owner that these trees had appeared perfectly healthy until within a fortnight or less. The orchard had not been irrigated as I inferred from the appearance of the surface of the ground in parts of the orchard, but this was due to the overflow of a waste ditch some weeks previous to this time. The soil about these trees was mealy on the surface and felt soft under the foot. We dug a hole near to one of these dead trees, five and a half feet deep. The soil was moist but there was no free water at this depth. I took a sample of soil from a place near to one of the very badly affected trees to a depth of one foot. The water-soluble in this sample amounted to 0.57 percent. It was rich in nitric acid but owing to the small amount of residue at our disposal no analysis of it was attempted.

It was evident that these trees were not drowned by the rising of ground water nor killed by an excessive amount of ordinary alkali. I next visited this orchard on September 21, 1909. More trees were affected and there was no improvement in the condition of any trees previously observed. On November 3 I again visited it and dug a hole five and a half feet deep near a tree which was dying. The soil was wet but there was no free water, and this was at the season when the fall irrigation of adjoining lands was being applied. A sample of soil was taken from the surface of this ground to a depth of two inches. The surface was slightly incrusted and mealy underneath but there was no efflorescence. In places the surface appeared wet, evidently due to the presence of deliquescent salts. The sample of surface soil taken on this date contained 5.91 percent soluble in water.

ANALYSIS*	I Water-Soluble Laboratory No. 873 Nov. 23, 1909 Percent
Calcic sulfate	20.360
Magnesic sulfate	6.655
Magnesic chlorid	0.459
Potassic chlorid	1.292
Sodic chlorid	45.229
Sodic nitrate	25.843
Iron and Aluminic oxid	Trace
Manganic oxid	0.032
Silicic acid	0.130
	100.000

This analysis shows the presence of five tons of nitrates, calculated as sodic nitrate in the top two inches of soil or a trifle over thirty tons calculated on an acre-foot.

I again visited this orchard for the purpose of further investigating the question of the water table on December 3. It has been stated that on June 12 we dug a hole five and a half feet deep near a tree which had recently died. On this date, December 3, we dug another hole at the same place six and a half feet deep. The ground was quite wet at this depth but there was no free water. It has already been stated that the soil is a sandy loam, and it was sandier at this depth. Another hole was dug seven and a

*In this bulletin all of the analyses have been calculated to one hundred. This has been done because we believe that the reader will be able to compare the results more easily, as they are all reduced to a common basis, i. e., parts per hundred of the dry residue—also to save space. Many of the samples presented difficulties, mostly owing to the presence of very deliquescent and easily decomposed salts such as the chlorids and nitrates of calcium and magnesium—and in a few cases of large quantities of organic matter.

The nitric acid determination in a few samples is undoubtedly too low because of the presence of magnesic nitrate and the continued drying necessary to obtain a manageable residue. Some of these samples intumesced badly and emitted an acid odor, during which some loss of nitric and hydrochloric acids probably took place. The nitric acid was determined in duplicate in every case as NO, and the NO absorbed by means of a recently boiled $FeCl_2$ solution. I believe that the results as presented in the analyses represent the composition of the water-soluble portion of the soils in a water-free condition with a very fair degree of accuracy. It is not, however, intended to assert that the nitric acid is all combined with one base, as appears in the greater number of the analyses, as for instance as sodic nitrate. This is simply a convenient manner of combining it and may in some cases be correct, but in many of these residues it is probably not correct.

There is almost uniformly a trace of manganese in these aqueous extracts, but it has been disregarded for the most part as it seldom exceeds two or three hundredths of one percent.

half feet deep at the same place, where we dug to the depth of five and a half feet on November 3. At this depth the ground was very wet, even muddy. We waited a short time to see whether any free water would flow in but it did not. On May 14, 1910, I again visited this orchard. The condition of the orchard was very bad, many trees had been removed and many more were dying. On June 11, 1910, almost exactly a year subsequent to the first observations made on these dying trees, I visited it again. The orchard was ruined; most of the trees were dead; and worse yet, the land, so far as we can now see, is as thoroughly ruined as the orchard. A large portion of this orchard—six to eight acres—has been dug up.

The orchard immediately south of this one is in a very bad condition; it is, for the most part, dead. No samples of either the soil or the ground water were taken at this place. The owner, a man of considerable education, is fully convinced that the trouble is not due to excessive water in the soil.

The following samples of surface soil from Orchard No. 5 will convey a better idea of the conditions existing in this soil than any words describing them. In No. 947-a the water-soluble equalled 11.6; in No. 959, 3.4; in No. 995, 12.79, and in No. 1013, 7.20 percent of the air-dried soil.

ANALYSES	II	III	IV	V
	Water-Soluble Laboratory No. 947a May 14, 1910	Water-Soluble Laboratory No. 159 June 11, 1910	Water-Soluble Laboratory No. 995 Aug. 25, 1910	Water-Soluble Laboratory No. 1013 Sept. 13, 1910
	Percent	Percent	Percent	Percent
Calcic sulfate	18.437	20.437	8.219	9.123
Calcic chlorid	14.778	———	17.005	20.415
Magnesic sulfate	———	5.999	———	———
Magnesic chlorid	10.474	———	12.295	10.658
Potassic sulfate	———	1.447	———	———
Potassic chlorid	2.273	———	1.434	1.575
Sodic sulfate	———	15.104	———	———
Sodic chlorid	13.726	35.416	8.747	27.708
Sodic nitrate	39.790	21.303	52.071	30.350
Iron and Aluminic oxids	0.132	0.149	0.090	0.051
Silicic acid	0.210	0.235	0.139	0.111
	100.000	100.000	100.000	100.000

The dates on which the various samples were taken, extending over two years and representing the months of May, June, August, September and November, show that the condition is a persistent one, and while it may vary from month to month there was a very dangerous quantity of nitrates in this soil throughout the whole period.

In 1909 I produced decided injury to four-year-old trees by the addition of five pounds of nitre to the soil, within a radius of about twenty inches around the trunk of the tree. No one has to my knowledge demonstrated how small an amount of nitrates may do injury to an apple tree if placed within reach of its feeding roots, especially at the period of its most rapid growth. My experiments were made to see whether this amount would produce any effect upon the trees and to observe how this effect expressed itself and not with the idea of determining the tolerance of the apple tree for this particular salt, sodic nitrate.

The trees in this orchard, especially the first ones attacked, twelve or more in number, did not turn yellow, dwindle and gradually succumb, but, though they were in full leaf and appeared vigorous and healthy, the leaves suddenly turned brown and drooped and the trees died outright within ten days or a fortnight. As the trees in this orchard continued to die throughout the season of 1910 it may serve a purpose to calculate the amount of nitrate available to an ordinary-sized tree, fifteen years of age. The roots of such a tree will occupy an area represented by a circle forty feet in diameter, at least; this will give approximately 1,200 square feet of surface. All of the feeding roots in this orchard were found to be within two feet of the surface. The sample of soil was taken to a depth of two inches or one-sixth of a foot and there would be two hundred cubic feet of such dirt to furnish nitrates to the tree. Assuming a cubic foot of this sandy soil to weigh ninety pounds, we have 18,000 pounds of nitre-rich soil, 11.6 percent of which is soluble in water, or 2,088 pounds, four-tenths of which (39.97 percent) or 835 pounds consists of sodic nitrate or its equivalent in other nitrates.

In this calculation I have assumed that the soil below a depth of two inches furnished no nitrates—which is altogether contrary to the facts. It may, however, serve to convey a clear idea of the large amount of nitrates present within the feeding areas of these trees, 832 pounds in this case, ready to be moved downward and supplied to the feeding roots, all of which are within two feet of the surface, by a rain or irrigation or any other agent, possibly even by cultivation of the soil. This was in May when the trees were feeding actively. Our sample taken in August is still worse, 12.8 percent soluble in water, placing 2,304 pounds of salts above the roots of the tree with 1,178 pounds of sodic nitrate or its equivalent. When we incorporated five pounds of sodic nitrate with the soil about a four-year-old tree and watered it, we injured some of the branches; when we incorporated twenty-five pounds and irrigated it we killed the tree in four days. It is not probable that every tree in this orchard had either 1,178 or even 832 pounds of sodic nitrate at its disposal but all of the trees in this area, some eight acres or more, died and were dug up between May 1909 and March 1911. Another way to convey an idea of the large quantities of nitrates with which we are dealing is to express it in tons per acre-foot as was done in Bulletin 155 or in the surface two inches of soil. The figures obtained for the August sample gave us 22.1 tons in the top two inches of soil for each acre of land or practically 133 tons per acre-foot which corresponds to 6.66 percent of the weight of the air-dried soil. These trees had lived and grown healthily, some of them I would say vigorously, for fourteen or fifteen years, till May, 1909, when twelve or more of them died within a fortnight without previously having shown any distress and within the next eighteen months eight acres or more of this orchard died.

Case No. 6—My first observations on this orchard were made in 1908. Some trees scattered throughout the orchard had already died and been removed. While I was satisfied that arsenic had caused the death of some of them, it evidently had had nothing to do with the death of others. At first I had considered seepage to be the possible cause of the trouble. The water plane, however, was stated to be from seven to ten feet below the surface. Subsequent investigation indicated that this statement was correct, besides my knowledge of this section of the country would lead me to expect the water plane to be not less than six feet below the surface. I do not believe that the water plane rises and falls through any great distance, at least I have found no indications of such a fact. The owner stated that the ground turned brown and then things died. The aspect of the land is to the south with a slight depression running northeast and southwest through the orchard. There are some differences of level in different parts of the orchard. I have no notes in regard to the amount of these differences but they are not great, possibly a maximum of twelve feet. A cellar is located near the middle of the east side of the orchard and it is five feet deep with a hole dug about the middle of it. This hole had some water in it in the spring of 1909. More trees, eighteen of them, died during the latter part of the season of 1908 and these were removed in the spring of 1909 after which the orchard was plowed and this portion of it sowed to wheat. The wheat was a total failure as almost none of it came up. The owner attributed this to his failure to irrigate the land. My opinion is that it was not his fault. By July 1, 1909, the orchard was very badly burned and by October a portion of it was dead and leafless. Photographs of this orchard were used as illustrations in Bulletin 155, Plates III and IV, page 26. As Plate III shows the healthy condition of that portion of the orchard which formed the background of Plate IV, which gives an excellent idea of how the orchard had suffered, they are reproduced in this connection as Plate I. This represents the destruction wrought in a single season. These trees, 110 of them, were removed in the spring of 1910, and on July 14, the date of my next visit, the affected area had been extended very noticeably and many more trees were dying.

A set of soil samples was taken from this orchard May 14, 1909, representing the surface soil, also the first, second and third foot. In taking these samples we dug a hole about four and one-half feet deep. No water was met with but we filled up the hole as soon as we had procured the samples and did not wait to see whether any water would run in or not. These samples were extracted with water and gave as follows, the surface soil 4.68, the first foot 1.86, and second foot 2.09 and the third foot 1.509 percent soluble in water.

ANALYSES	VI	VII	VIII	IX
	Water-Soluble Laboratory No. 784 Surface Soil May, 1909	Water-Soluble Laboratory No. 785 First Foot of Soil	Water-Soluble Laboratory No. 736 Second Foot May, 1909	Water-Soluble Laboratory No. 787 Third Foot May, 1909
	Percent	Percent	Percent	Percent
Calcic sulfate	29.607	69.830	57.250	37.344
Calcic carbonate	9.679	——	——	——
Calcic chlorid	6.686	——	——	——
Magnesic sulfate	——	5.071	13.249	15.311
Magnesic chlorid	9.729	3.203	3.442	0.670
Potassic chlorid	3.549	1.736	1.265	1.229
Sodic chlorid	32.834	18.780	22.601	41.448
Sodic nitrate	7.239	0.709	1.591	3.402
Iron and Aluminic oxid	0.145	——	——	——
Manganic oxid	0.234	——	——	0.282
Silicic acid	0.298	0.671	0.602	0.314
	100.000	100.000	100.000	100.000

ANALYSES	X	XI	XII
	Soil Laboratory No. 785 First Foot	Soil Laboratory No. 786 Second Foot	Soil Laboratory No. 787 Third Foot
	Percent	Percent	Percent
Insoluble	64.820	66.674	68.027
Silicic acid, soluble	5.650	2.927	2.131
Sulfuric acid	0.810	1.282	0.503
Chlorin	0.890	0.333	0.308
Phosphoric acid	0.180	0.242	0.267
Carbonic acid	7.040	7.370	6.636
Lime	7.180	7.730	6.590
Magnesia	2.190	2.967	2.961
Sodic oxid	0.840	0.402	0.494
Potassic oxid	0.690	0.595	0.661
Ferric oxid	3.110	2.890	3.170
Aluminic oxid	2.250	1.354	2.030
Manganic oxid (br)	——	0.210	0.220
Moisture at 100°	1.470	1.260	1.498
Ignition	2.970	(3.838)	(4.573)
Sum	100.090	100.074	100.069
O equiv. to chlorin	0.200	0.074	0.069
Total	99.890	100.000	100.000
Humus	0.248	——	——
Humus ash	0.194	——	——
Total nitrogen	0.072	0.056	0.055

There is nothing in the results obtained by the ordinary agricultural analyses of this soil to indicate anything unusual unless it be the small amount of total nitrogen present. The method followed in these analyses was the conventional one, digestion with hydric chlorid sp. g. 1.115, etc., and the nitrogen determined by the Kjeldahl method modified for the determination of nitric acid. No. 785 is the first foot of soil from which the surface portion was scraped off in order to obtain the soil without incrustation of effloresced salts, and we have, as shown by the aqueous extract of this sample, a remarkably small amount of nitrates while the second and third foot show decidedly increased quantities. The third foot contains only a little less than the top two inches but is relatively only one-sixth as rich. We have for the top two inches 2,257 pounds, for the next foot 528 pounds, for the second foot 1,332 pounds and for the third foot 2,053 pounds per acre. I do not believe that the nitre in the third foot of soil participates largely in doing injury to the trees unless it be brought nearer to the surface, say within two feet of the surface, by capillarity or some other agent, so that we cannot take this third foot into our reckoning except as a possible source of nitrates. The top twenty-six inches of this soil, however, contained at the time the samples were taken, in May, a little better than two tons of sodic nitrate, a comparatively moderate quantity, provided that these salts were not concentrated within the feeding zone of the roots. But, even as the case stands, there is, assuming 80 trees to the acre, fifty pounds of sodic nitrate to the tree, taking the soil to the depth of twenty-six inches and supposing that the succeeding foot with twenty-five pounds more for each tree does not in any way enter into the problem. I do not know how the amount of nitrates varied during the ensuing season, but, if they increased in this soil as they were observed to do in some others, the aggregate amount present during the season must have been at least twice as great as that given but, be this as it may, 110 trees occupying a continuous area about the point where these samples were taken died within the next four months in the same manner as that in which the trees we poisoned with sodic nitrate and as thousands of others, in lands richer in nitrates, died. The question of the amount of nitrates necessary to kill apple trees would be an interesting one to answer but it is not the object of this bulletin. There are also other questions involved, for instance, to determine the maximum quantity of nitrates available to trees in such lands at any one time, for, it is evident, that if a fatal quantity were available for only a few days, perhaps one day, it might suffice to kill them. We killed a tree in four days. Again it would be interesting to know whether a tree, say 15 years of age, would tolerate more saltpetre in September than in April, May or June, owing to its different vegetative activity. But none of these questions fall within the scope of this bulletin.

Fortunately we can, in part, answer a question suggested above in regard to whether the nitrates have increased, as we have a sample of the surface soil taken very nearly from the same point at which the surface sample was taken May 9, 1909. The second sample was taken May 3, 1911.

This land is, at this writing, planted to winter wheat. The plants are largely confined to the bottoms of the creases or irrigating furrows. The crests of the creases or spaces between the furrows are mostly bare. The owner thinks that this may possibly be due to the lack of a sufficient amount of moisture to germinate the seed. I do not think that this was the case, as the irrigating furrows are rather close together and as he gave it a fair irrigation, it is not probable that there was so great a lack of moisture as to cause a general failure of germination between the furrows. I think it much more probable that the water flowing in the furrows removed the nitrates far enough from the seed to permit their germination and the establishment of the young plant.

The condition of these plants at this time, May 3, 1911, was very interesting; the plants were large and vigorous, and had an intensely green color, but so many of them were burning that the tips, already browned back on the leaf for three or four, or even more inches, presented a marked contrast to the otherwise luxuriant looking wheat, and it is a question whether even these thoroughly well established plants will endure it to mature their grain.

ANALYSIS	XIII Water-Soluble Laboratory No. 1069 May 3, 1911
	Percent
Calcic sulfate	14.155
Calcic chlorid	20.275
Magnesic chlorid	12.885
Potassic chlorid	1.360
Sodic chlorid	38.496
Sodic nitrate	12.621
Iron and Alumina	Trace
	100.000

Sample 784 was taken in May of 1909. Sample No. 1069 was taken in May, 1911. The ground from which No. 1069 was gathered, in 1911, was occupied by healthy trees in 1908 and the early part of 1909, but these trees died in 1909 and were removed in the spring of 1910. Stated otherwise, this land prior to the summer of 1909 had never contained enough nitrates to injure the trees which had been growing in it for fifteen or more years, but the accumulation of the nitrates in 1909 passed the limits of tolerance for the apple trees and they died. By May 3, 1911, this land, which showed no nitrate at this place in 1909, was brown and mealy and wheat was not able to grow healthily in it and on a great deal of the ground not at all. A surface sample, taken in May, 1909, from a part of this orchard where the trees had died, gave 4.68 percent soluble in water which contained nitric acid corresponding to 7.239 percent of sodic nitrate. A similar sample, taken in May, 1911, from ground which did not show this trouble in 1909, gave 6.80 percent soluble in water containing nitric acid equal to 12.621 percent of sodic nitrate. As these samples represent the surface portion, approximately to a depth of two inches, we will compare them; in 1909 the surface two inches of a portion of this land where the trees had died contained 2,258.8 pounds of sodic nitrate per acre, whereas a portion of the same land which did not contain enough nitrates in May, 1909 to kill the trees contained in May, 1911, 3,433 pounds, a gain of 1,174 pounds per acre in the surface two inches in two years on the supposition that this soil was really as rich in 1909 as the ground in which the trees had already died, which is not true, so the gain actually exceeds 1,174 pounds of nitrate in two years. Evaporation of ground waters from the surface of this soil is wholly inadequate to account for such an accumulation as this. I will give figures and statements showing that it is very liberal to assume the presence of 0.3 p. p. m. of nitric nitrogen in the ground water and I will support this with further figures in subsequent paragraphs. But 0.3 p. p. m. of nitric nitrogen is equivalent to 1.8 p. p. m. of sodic nitrate equal to 4.896 pounds per acre foot. On the assumption that this nitrate has been brought to this land by the ground waters and deposited by its evaporation we would have to evaporate 239.8 acre-feet in two years or 119.9 acre-feet per annum—whereas our actual evaporation from a free water surface is forty-one inches or it would take 70 years to effect the evaporation from a free water surface required by our supposition in two years from a soil surface. There is another feature of which we cannot lose sight; our ground waters are rich in other dissolved salts and these must be accounted for in some way. Our ground waters seldom carry less than 100 grains per imperial gallon or 1,429 p. p. m. or 3,858 pounds per acre-foot of water according to which we would have to account for 925,920 pounds or 463 tons of alkalis on every acre of this ground which, assuming the alkalis to be as dense as the soil itself, would cover the soil one-quarter foot deep every two years which is evidently contrary to the facts. Our soils are rich in soluble salts, that is salts soluble in water, but they are not covered nor even mixed with any such quantities as this supposition shows must be present. This particular soil is quite rich but we found in the surface soil, two inches deep, in 1909, 4.68 percent and in the first foot 1.86, in the second 2.09 and in the third 1.509 percent—which the analyses show to be very largely calcic sulfate.

These statements, as well as the following considerations, apply to every individual case considered in this bulletin. The ground waters are wholly inadequate to transport the nitrate, for we have no 120 acre-feet of ground water per annum nor is there any land surface from which to obtain the nitrates. The whole of the irrigated lands in some sections are more or less affected and it is wholly gratuitous to even suggest our native prairies and mountain sides as a source of these nitrates. Our river waters, even those used for irrigation, contain very little nitric nitrogen from 0.00 to 0.4 p. p. m. Our virgin soils show only 8.000 p. p. m. of nitric nitrogen as a maximum—and even this is subject to appropriation by plants and reduction in the soil, so that even though very large areas were to be leached out or washed off this source could scarcely be soberly appealed to as the source of these nitrates.

Case No. 7—This orchard showed the first bad burning about the middle of May, 1909, shortly after the orchard had been heated to protect the crop against frost, about April 27. The trees had continued to grow steadily worse and the owner at first feared that the injury was due either wholly or in part to the gases given off during the combustion of the coal used in heating the orchard. To this question there was a very direct answer, i. e., the water sprouts which had grown since the heating were burning badly.

This orchard presents, in regard to soil conditions, a strong contrast to the last one mentioned, and to all others heretofore mentioned, except Orchard No. 5. The soil is sandy, inclining in some parts of the orchard to a clayey loam. The attack began a little to the east of the center of the orchard. This part of the orchard is not lower than the rest of it. The owner has sprayed very heavily some seasons and is still a heavy sprayer. There were some girdled trees in the orchard but the arsenic had nothing to do with the burning. This burning is quite distinct from a spray burn. We dug a hole near to one of the burned trees five and one-half feet deep. The orchard had been recently irrigated but we found no more than a desirable degree of moisture at this depth. A sample of soil was taken at this time. The depth to which it was taken is not stated in my notes. The water-soluble equaled 0.187 percent. No analysis was made of this material beyond a nitric acid determination which showed an amount corresponding to 5.412 percent of sodic nitrate or 0.01 percent of the air-dried soil, a small amount, still it equals about 22 pounds to a tree taking the soil to a depth of two feet. The family is supplied with water stored in a cistern which is 10 feet deep. I was informed that they did not strike water in digging it. The age of this orchard was 18 years. The owner stated that he had observed a Lawver tree about three years previous to this time which turned brown on one side but recovered so that it grew healthily the following year. Some of these burned trees put forth a few new leaves which had a whitish yellow color and soon died. We visited this orchard again on November 3, when we found a number of the trees evidently dead, and again on December 3, 1909, when with the help of the owner we dug out a number of the roots and again sought to ascertain the depth of the water table. We followed the roots from the trunk of the tree as far as possible. In one case this proved to be 21 feet at which point we lost it because it had turned abruptly toward the surface and had been cut off by the plow. The root had become so small at this point and other roots were so numerous that we could not identify it with certainty. We attempted to follow other roots but we found it very difficult to do, owing to the presence of such a number of other roots and the smallness of the extreme ends. The greatest depth attained by those that we followed was two feet below the surface. All of the little roots that we encountered in this attempt seemed to be perfectly healthy even to the minute fibrous roots. Th greatest distance that we followed any root was 23 feet. There were only a very few fibrous roots as deep as 30 inches, almost all of them being within 24 inches of the surface. These roots which we dug out belonged to the trees which had been badly burned. Not only were the roots of the trees apparently healthy but the crowns and larger roots near the trunk were also apparently perfect. The owner suggested that we dig up one of these trees but as the root system seemed to be in such good condition I suggested that it would be better to let it and the rest of them stand till the next spring, 1910, and see whether they would recover or not. The trees were left standing, but they did not recover—they had already been killed.

Wishing to dispel, if possible, all doubts in regard to the part played by the ground water in the death of these trees, we dug another hole near one of the trees just described. The orchard had received a heavy irrigation on September 25, and the next few days following. The ditch, 120 feet east of where we dug this second hole, had stood full of water for three or more weeks in September. It had overflowed and formed a small pond at the edge of the orchard. The soil at the place where we dug this hole was sandy and we encountered the water plane at five and one-half feet, or two and three-quarters feet below the deepest roots that we observed. On May 14, 1910, four days after the orchard had been irrigated, I found the leaves on some trees burning. There seemed to be so good as no recovery from the injury of 1909. On June 11 the condition of this orchard was very bad indeed, and

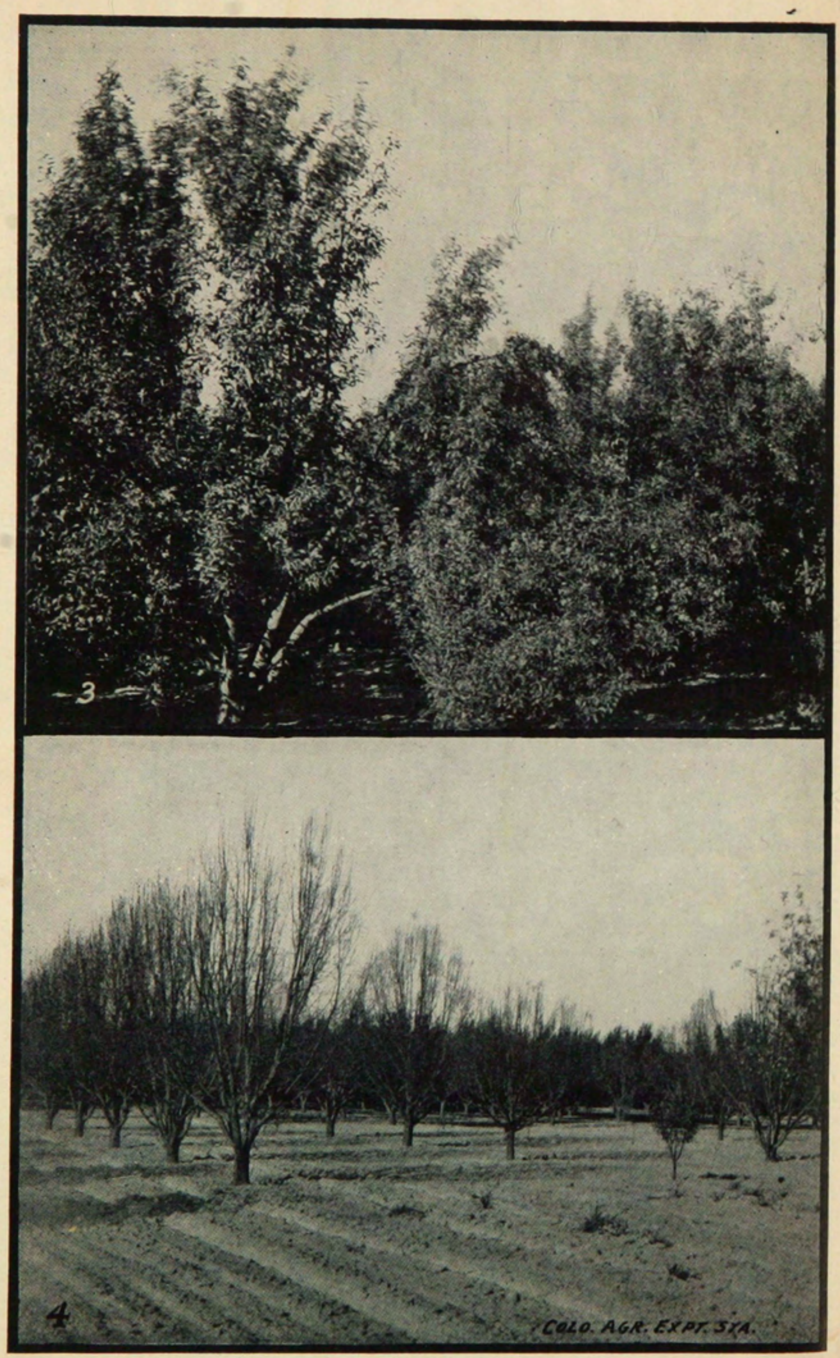

PLATE I.—See page 10.

evidently growing worse. It was evident that a considerable number of trees would succumb, indeed some were already dead and conditions were not improving in the least. The water table was not within five feet of the surface in an adjoining orchard though recently irrigated. The affected area had extended so as to embrace nearly the whole of this old orchard. There is a young orchard on still higher land which is not yet affected. By September 13, 1910, the old part of the orchard was practically ruined. The water table at that time was not within five and a half feet of the surface. In this orchard we have a decidedly sandy soil, inclining to a clayey loam in places, and not an adobe soil which often becomes muddy at comparatively shallow depths as described in Bulletin 155. At no time have we found the water table less than five and a quarter feet below the surface and practically no roots at a greater depth than two and a half feet, and but few below two feet. The surface of this soil is brown and mealy, and is rich in nitrates and the orchard is in very bad condition.

The orchard immediately east of this presents the same conditions of soil with the water plane deeper than five and a half feet below the surface. The top soil is brown and mealy and many of the trees are dead, some having died in 1909 and others in 1910.

The orchard immediately to the south is worse than either of these as the trees are practically all gone.

This orchard, No. 7, has been given in such detail because it is the first old orchard planted on this type of soil with the water table well below the surface, to which we have made so many visits, and in which we have been able to watch the progress of the trouble. Orchard No. 5 went rather more rapidly, as did also No. 6. The soil of Orchard No. 5 is likewise a sandy loam and the water table is likewise low, but the land itself is possibly a little less favorably located than that of Orchard No. 7.

I will give but two analyses of soil from Orchard No. 7, or rather I will give analyses of the water-soluble portions of surface samples, one taken from near a young tree, seven or eight years old, which was burned but slightly at the close of the season, September 13, 1910, No. 1014; the other No. 1071, taken in May, 1911. The water-soluble of No. 1014 equalled 2.974, and of No. 1071 equalled 6.276 percent.

ANALYSES	XIV Water-Soluble Laboratory No. 1014 Percent	XV Water-Soluble Laboratory No. 1071 Percent
Calcic sulfate	23.270	25.022
Calcic chlorid	17.550	24.160
Magnesic chlorid	15.930	17.420
Potassic chlorid	4.044	4.023
Sodic chlorid	35.432	24.268
Sodic nitrate	1.420	4.686
Iron and Aluminic oxid	2.069	0.162
Silicic acid	0.285	0.258
	100.000	100.000

This orchard was beginning to burn in the early part of June, 1911, earlier than in preceding years.

Case No. 8—This is a young orchard set in 1908. The history of the ground as given to me is as follows: Prior to 1904 the whole piece of land was productive; in this year a brown patch appeared and the land became unproductive. It was covered thickly with manure in 1904 and again in 1906. The conditions were not improved. In 1908 it was set to orchard and planted to beets. The trees did not do at all well in this area and some of them died. The beets came up very poorly; they were replanted twice and the stand was still very poor, the beets produced being over-grown and having large tops. My information is that the quality was poor. In my field notes mention is made of the fact that the land outside of this area appears as heavily charged with alkali as the area itself, but the owner asserted that this land was very productive and subsequent observations lead me to believe that the statement is correct. This land was irrigated ten or twelve times during the season, each time excessively in the hope that the "black alkali" might thereby be removed—to use the owner's language: "I washed it till the soil was white." I took a set of samples from this land in April, 1909. The soil is sandy loam with a more sandy subsoil. I dug to a depth of five feet, without further change in the soil and without striking the water table. This place is practically on the river bank where the soil section is sand lying on top of coarse gravel. The river bed is now from twelve to fifteen feet below the level of this land and the brown mealy soil occurs within fifty feet of the edge of the bank. It is scarcely possible to obtain better drainage conditions than these. This is, in fact, the reason for my making particular mention of this place. At first I thought that this condition was in general largely due to an excess of moisture, such an excess as to be of itself injurious to vegetation, but I do not find such to be the case. Orchards No. 5 and No. 7 are also on sandy loam soils and not adobe soils which retain water persistently. They are, however, not drained so well as this land, lying as it does on the river bank, the most remote part of it being scarcely more than three hundred feet from the river, and twelve or fifteen feet above its bed. The trees that had died in 1908 were replaced in the spring of 1909. On May 6, I have noted that the brown area appears in good condition but that the trees are not doing well. November 2, same year, I visited this place again and noted that the apple trees in this bad spot had died. The ground had been recently disced and seemed in good condition, but those spots which had escaped being stirred were brown and mealy. Some one attempted to conduct a truck garden immediately north of and contiguous to this ground, beginning in 1907. At this time, November, 1909, it was almost black in color, encrusted a little and mealy underneath.

In July, 1910, the condition of the land was worse than I had ever seen it, not only the trees but also corn and peas showing the effects of the nitre.

One sample of soil was sent to me in February, 1908, presumably taken to a depth of from eight to twelve inches according to directions. This sample yielded 1.262 percent of salts soluble in water, containing nitric acid equivalent to 11.230 percent of the soluble salts or 0.142 percent of the air-dried soil, or 5,680 pounds, nearly three tons per acre-foot. Other samples of soil were collected at this place at subsequent times, April 21, 1908, April 6, 1909 and November 2, 1909.

Further back from the river we have seepage beyond a question. We found the water table at from two to eleven feet, but the water at the latter depth was under considerable hydrostatic pressure and rose in the holes dug to within two and a half feet of the surface. The party who procured some of the water samples for me described this fact as follows: "It kept getting wetter until I struck gravel, at four feet, when the water rushed in and bubbled up as if under pressure. The water rose sixteen inches in thirty minutes, and finally stood at two and one half feet below the surface." The gravel here referred to is very probably the natural drainage into the river and this water passes beneath the land which we have just described.

These general conditions are given only because they contribute to a better understanding of the question. I have been repeatedly asked whether the seepage water does not bring these nitrates into these localities. This question has been raised by the character of the samples of drain and ground waters whose analyses are given in Bulletin 155, p. 27 *et seq.* I stated in connection with them that the presence of nitrates in the seepage water issuing from the shales, for instance, was easily accounted for by the cultivation of the higher lying mesas, on which these nitre spots occur and in some cases are even prevalent. If the seepage water from any section were wholly derived from such a source there would be nitre introduced into the seeped lands with the water unless the nitrates were reduced or otherwise removed. This, however, is not the case. The seepage in almost every case is made up of the leakage from irrigating canals and ditches or from excessive irrigation. The lands before being brought under irrigation do not contain nitrates or even nitrogen in quantities worthy of note, in fact the supply of this element is quite limited. The waters used for irrigation are taken from our rivers and lesser streams which are supplied by the snows which fall in our mountain sections. While there may be a few exceptions to this statement, it is in the main correct, and no exception of any weight, so far as I can recall, applies in any measure to any of the lands treated of in Bulletin 155 or which will be considered in this.

I know of no lands anywhere which would be more likely to be affected in such a manner than land immediately north and a little east of this particular tract, and concerning the seeped or water-logged condition of which no question can fairly be entertained. As already stated we encountered water as close as two and a half feet of the surface, which fact alone does not prove that the ground is necessarily unproductive; but this ground was nearly barren. It had been in alfalfa, a little of which was still living at the time of which I am writing. The soil was wet and heavily charged with the ordinary alkali of the section. Three samples of this ground water were taken in November and December of 1907. The alkali in this immediate section is higher in chlorin than is usual. This is one of the places referred to in Bulletin 155 as especially rich, so rich in chlorin that the salt, sodic chlorid, present may possibly be injurious to vegetation. Inasmuch as this question has been suggested and as I know of no place more unfavorable to my views regarding the subject, I will give analyses of soils, of samples of alkali and of the three samples of ground waters from this section. They are not from the same spot but were taken from places near one another, within one quarter of a mile and not more than one half mile from Orchard No. 8. The alkali and the soil were taken from land that had at one time been cultivated. The rows were still visible and the manure in the rows had not yet rotted. The ground was at this time bare but not brown and greasy in appearance. I do not know whether anything could have been made to grow on it or not. No attempt to do so has been made at any time during the past three years. The surface portion of this soil was extremely rich in alkali. I observed, at the time these samples were taken, in some depressions in this field, crystals of sodic sulfate from one and a half to two and a half inches long. The soil sample, taken to a depth of one foot, yielded 2.45 percent soluble in water. The second and third foot were taken as one sample and gave 4.27 percent soluble in water.

ANALYSES	XVI Water-Soluble Labratory No. 632 First Foot Percent	XVII Water-Soluble Labratory No. 633 Second and Third Foot Percent
Calcic sulfate	41.882	42.122
Magnesic sulfate	8.747	18.397
Sodic sulfate	10.847	5.747
Sodic chlorid	34.014	28.019
Sodic silicate	1.276	1.479
Manganic oxid	——	0.070
Ignition	3.234	4.184
	100.000	100.000

These water-soluble portions were tested for nitric acid and there was not enough present to give a reaction with ferrous sulfate and sulfuric acid. That the water-soluble should be made up so largely of calcic sulfate is what one would expect, because this salt, as the mineral gypsum, can be seen forming veinlets and small aggregations throughout the mass of the soil. This is the case to a greater extent in the second and third than in the first foot. The quantity of sodic chlorid is larger than usual but is still within the limits of tolerance for almost all plants.

ANALYSES	XVIII Soil Laboratory No. 632 First Foot Percent	XIX Soil Laboratory No. 633 Second and Third Foot Percent
Sand	48.951	47.747
Silicic acid (sol.)	22.377	17.945
Sulfuric acid	0.708	3.194
Chlorin	0.387	0.599
Phosphoric acid	0.156	0.217
Carbonic acid	3.968	3.709
Lime	4.624	5.877
Magnesia	2.650	2.864
Sodic oxid	0.740	1.033
Potassic oxid	1.082	1.356
Ferric oxid	4.344	3.374
Aluminic oxid	5.286	7.405
Manganic oxid	0.168	0.675
Water expelled at 100°	1.707	2.933
Ignition	2.986	(1.207)
Sum	100.134	100.135
Oxygen equiv. to chlorin	0.087	0.135
Total	100.047	100.000

Another soil in which the conditions were worse even than in the preceding is represented by the next sample. This ground had been an alfalfa field and a few of the plants were not yet entirely dead. The crowns and roots showed that it had recently been a good stand and that the plants had been large. The water table was in this case within two and a half feet of the surface.

ANALYSIS	XX Soil Laboratory No. 625 Percent
Sand	66.822
Silicic acid (sol.)	11.303
Sulfuric acid	0.042
Chlorin	0.703
Phosphoric acid	0.042
Carbonic acid	4.458
Lime	4.294
Magnesia	2.339
Sodic oxid	0.653
Potassic oxid	0.660
Ferric oxid	3.089
Aluminic oxid	2.005
Manganic oxid	0.051
Water at 100°	1.250
Ignition	2.192
Sum	100.663
Oxygen equiv. chlorin	0.159
Total	100.504

ANALYSIS	XXI Alkali Laboratory No. 622 Percent
Calcic sulfate	6.893
Magnesic sulfate	17.373
Sodic sulfate	27.868
Sodic chlorid	43.466
Sodic silicate	0.316
Ignition, etc.	(4.384)
	100.000

The following three samples are ground waters taken within the area under consideration, all of them taken in November and December of 1907.

ANALYSES	XXII Ground Water Laboratory No. 647	XXIII Ground Water Laboratory No. 668	XXIV Ground Water Laboratory No. 669
Total solids in grains per Imp. Gal.	883.54	1052.29	1076.81
	Percent	Percent	Percent
Calcic sulfate	19.726	14.318	10.976
Magnesic sulfate	22.618	24.687	30.105
Magnesic carbonate	———	———	1.827
Potassic sulfate	0.700	0.967	———
Potassic carbonate	———	———	0.715
Potassic chlorid	———	———	0.308
Sodic sulfate	5.744	11.060	———
Sodic carbonate	2.431	3.872	———
Sodic chlorid	44.670	40.405	49.732
Sodic silicate	0.869	0.841	0.149
Manganic oxid (br)	0.097	———	0.059
Ignition	(3.143)	(3.850)	(6.129)
	100.000	100.000	100.000

There is not enough nitric acid in this alkali or in any of these soil extracts or water residues to give, when as much as one-half to one gram of the dry residue is taken, a satisfactory test with ferrous sulfate and sulfuric acid, and some of them give no reaction with diphenylamine and sulfuric acid.

There is not another instance of the occurrence of nitre within this state which is so favorably located for justifying the theory of concentration from adjoining lands as this one and it is for this reason that I have set forth these facts pertaining to the composition of the alkali, the soils to a depth of three feet, the aqueous extracts made from these soils, and the solids held in solution by the ground waters. The results of the analyses show that even if the soil of Orchard No. 8 had been saturated with the ground waters which had drained through this area it would not, at this time, have become impregnated with nitrates but with sulfates and chlorids. These ground waters, however, do not saturate the nitre soil and it is a question whether they ever rise or in any other manner find their way into it and consequently cannot possibly account for the nitrates for two reasons; first, there was so good as no nitrates in either the soil lying to the north of this orchard or in the alkali which, in places, was abundant on its surface, or in the ground waters, which came near to the surface in parts of the area; second, because these ground waters do no find their way into this orchard soil which is underlaid by gravel and is well drained.

A great deal has been said and somewhat written about alkali and seepage. I will remark in passing that while seepage and alkali usually accompany one another they constitute two distinct subjects. We have many examples of lands rich in alkali which are not now wet enough to be objectionable, and I shall in a subsequent bulletin give specific data which are the basis for the statement that both water and alkali may be quite abundant and the land still be productive. These are very undesirable conditions but they alone are not so fatal as some people would have us think. In all events they constitute problems distinctly different from the nitre problem, and are not so closely related to it as even I at first thought. My original description of these occurrences of nitre showed that I considered it as dependent upon a constant, optimum supply of moisture. This condition is met with near the outer edges of wet places. The nitrates do not appear where there is a great excess of water. On the other hand they are not confined to places which are seeped, of which fact the orchard in question, No. 8, is a good example, as is also Orchard No. 7. In fact, Orchards 1 and 2, Bulletin 155, are the only cases given in which an excessively wet condition of the soil was observed but no proper water table was found in these at a depth of six to six and a half feet. Such, then, are the conditions surrounding this orchard No. 8, and the little garden tract immediately north of it. I have already stated that the soil is sandy and the section at the river bank, which practically forms the southern boundary of the field, shows a section of twelve to fifteen feet, the upper six or seven feet of which is sand while the lower portion is a coarse river gravel. A sample of surface soil, taken two inches deep in April, 1909, gave 4.42 percent of the air-dried soil as soluble in water. Sample No. 875 contained 10.86 percent of salts soluble in water.

ANALYSES	XXV	XXVI
	Water-Soluble Laboratory No. 772 April, 1909	Water Soluble Laboratory No. 875 Nov, 1909
	Percent	Percent
Calcic sulfate	35.266	24.810
Magnesic sulfate	3.197	3.238
Magnesic chlorid	14.673	15.235
Potassic chlorid	2.109	1.911
Sodic chlorid	33.841	50.704
Sodic nitrate	10.508	3.944
Iron and Aluminic oxid	——	0.158
Sodic silicate	0.406	——
	100.000	100.000

We have in No. 772 the nitrates equivalent to 0.464 percent of the top two inches of the soil, equal to 3,096 pounds or one and one-half tons of nitrates per acre taken to a depth of two inches or at the rate of nine tons per acre-foot. In No. 875 we find the sodic nitrate equal to 0.424 percent of the surface soil, giving us practically the same amount of nitrates per acre as No. 772.

ANALYSES	XXVII Water-Soluble Laboratory No. 877 Surface Soil	XXVIII Water-Soluble Laboratory No. 778 Sample taken 8 inches deep top 2 inches, removed April, 1909
	Percent	Percent
Calcic sulfate	15.345	38.643
Calcic chlorid	3.521	———
Magnesic chlorid	14.611	———
Magnesic sulfate	———	11.082
Potassic chlorid	2.215	———
Potassic sulfate	———	9.500
Sodic sulfate	———	2.473
Sodic chlorid	51.474	33.854
Sodic nitrate	12.596	3.784
Iron and Aluminic oxid	Trace	0.100
Manganic oxid	0.094	0.042
Silicic acid	0.144	0.522
	100.000	100.000

In this case we find in April, 1909, that the top two inches of this soil showed the presence of one and a half tons of sodic nitrate. Another sample taken in November of the same year, and perhaps one hundred and fifty feet north of where the sample was taken in April, gives us essentially the same amount, one and a half tons in the top two inches. But the same depth of soil taken November 2, the same year and very nearly at the same point where the April sample had been taken, showed the presence of almost four tons, 3.978 tons, of nitrate in the top two inches per acre. A sample of this soil taken from the third to the tenth inch inclusive in April, 1909, or eight inches of the soil, after the top two inches had been removed, showed the presence of 2,306 pounds, a little over one ton to the acre taken to this depth, eight inches. This land had been excessively irrigated ten or twelve times during the season of 1908 with the idea of washing out the alkali. There were no signs of trouble in this land prior to 1904 according to the statement of its former owner.

Sample No. 875 was taken from ground which had been used as a truck garden in 1908. I scarcely need to state that the truck garden was a failure. This young orchard, Case No. 8, is used for the same purpose, i. e., gardening, and with excellent results except in this brown area. Analyses XV to XXVII inclusive are analyses of the alkali, the soil, and the ground waters which lie to the north and east of this land, not quite surrounding it but including the land through which the ground waters would have to move in order to reach this orchard. These samples were taken in 1907 and contained no nitrates—or only such traces as may be found by extracting any soil. I may state, though it is very evident, that neither Bulletin 155 nor this one deals at all with such quantities of nitric acid or nitrates as are usually understood when nitrates in the soil are spoken of, but of the occurrence of such unusual quantities as to be fatal or injurious to vegetation. I shall endeavor to deal with the general condition, of which only extreme cases are presented in this bulletin, in a subsequent one.

The analyses of the adjacent, almost circumjacent soils, the alkalis and the ground waters have been given to show that they have nothing to do with the conditions in this orchard soil, and especially nothing to do with the nitrates. Apropos to the influence of the drainage and the character of the soil upon this question, we have chosen one sample of dark brown surface soil from this orchard collected within fifty feet of the edge of the river bank, and a second one, also a dark brown surface soil from another piece of land of which no other mention is made. Both of these pieces of land are naturally well drained but in addition to this there are four tile drains in the second piece which contains only thirteen acres. One of these drains was carrying about two inches of water while the other two that I saw were not running at all. There is still another drain on the land adjoining this on the east, which was carrying a large flow of water. The owner of the land stated that all of the drains carry water after he irrigates the land, showing conclusively that the land drains freely. The soil is sandy, very similar to that of Case 8, with which we have joined it. I was informed that some of the drains have been laid four years. Laboratory No. 1067 is a sample from Case 8, collected March 27, 1911, fifty feet from the river bank. We give two analyses of this sample, one of the water-soluble portion, the other a mechanical analysis of the soil. The water-soluble in this sample equaled 8.165 percent of the air-dried soil. Laboratory No. 1076 is a similar sample collected from the drained land and also within fifty feet of the river bank and not less than twelve feet above the river bed. These soils are so similar that the mechanical analysis of the one faithfully represents the other. The water-soluble in No. 1076 equalled 9.882 percent of the air-dried sample.

ANALYSES	XXIX Water-Soluble Laboratory No. 1067 March 27, 1911 Percent	XXX Water-Soluble Laboratory No. 1076 May 2, 1911 Percent
Calcic sulfate	21.826	19.494
Calcic chlorid	23.971	1.647
Magnesic chlorid	20.534	16.435
Potassic chlorid	2.880	1.716
Sodic chlorid	26.846	57.106
Sodic nitrate	3.807	3.374
Iron and Aluminic oxid	——	0.101
Silicic acid	0.136	0.127
	100.000	100.000

ANALYSES	XXXI Mechanical Analysis Laboratory No. 1067 Percent
Above 1.0 mm. dia.	0.708
1.0 mm.-0.5 mm. ..	1.222
0.5 mm.-0.25 mm. ..	9.851
0.25 mm.-0.05 mm. ..	47.582
0.05 mm.-0.01 mm. ..	21.021
0.01 mm.-Clay	8.419
Clay, by diff.	11.197
	100.000

	XXXII Drain Water Labratory No. 1201 Percent
Calcic sulfate	21.380
Magnesic sulfate	25.249
Potassic sulfate	0.695
Sodic sulfate	5.119
Sodic chlorid	42.874
Sodic carbonate	4.683
	100.000

	p. p. m.
Total solids	8489.00000
Ammonia	0.01800
Nitrogen as nitrites...	0.00003
Nitrogen as nitrates...	0.10000

The two pieces of land discussed at this time differ only in this, that one of them has been drained for four years and the other is not artificially drained at all. We observe that the soil consists of 47 percent of fine and very fine sand, further that there is 21 percent of silt and a fair amount of clay. The samples 1067 and 1076 are alike in location so that they are perfectly comparable in every respect except that the land represented by No. 1076 has been drained for four years; some of the drains having been put in recently, others of them at earlier dates. The samples are both surface samples, that from the undrained land contains 8.165 and the drained land 9.882 percent of water-soluble salts which in both cases consist of sulfates, chlorids and nitrates. The amounts of nitrates contained in the samples give us for No. 1067, 2,072 pounds calculated for the top two inches, while No. 1076 gives us 2,223 pounds calculated for a like depth, or calculated for the acre-foot of soil, we have 12,432 and 13,336 pounds respectively.

The drain water was collected from an east and west drain crossing the northern end, while the sample of soil, No. 1076, was collected from the southeastern corner of this land. It may be further stated that there are two other east and west drains between the drain from which the water sample was taken and the point where we took the soil sample and in addition to this there is a north and south drain running within a few feet east of this latter point which is itself not more than fifty feet north of the river bank.

I may also add that the soil on top of and along the side of this north and south drain is in the same condition as the sample actually taken.

The object in stating these details is evident, i. e., to show that these conditions are independent of the seepage question and that drainage is not of itself and necessarily a cure, and still further to show that these nitrates are not deposited by the evaporation of ground water coming from other lands. The owner explained to me that the depth of the drains vary—which is evident without statement—but he added that the gravel below the soil is very irregular in its surface so that the depth of gravel penetrated by the drains is quite different. We will not consider any greater depth of soil than is represented by our samples, i. e., two inches, but we will calculate how much of this drain water would be required to furnish the nitrate which we actually find in these two inches of soil, and we will take this as 2,150 pounds. The samples of soil and drain water were taken in May, 1911. The drain water contains 0.1 part per million of nitric nitrogen equivalent to 0.6 part per million sodic nitrate; taking an acre-foot of water at 2.7 million pounds it gives us 1.62 pounds of nitrates per acre-foot of water and we would have to evaporate 1,327 acre-feet of this drain water to obtain this 2,150 pounds of nitrates which we find present at this time. The evaporation of this amount of water would require, assuming that the annual evaporation amounted to sixty inches (at Ft. Collins it is only 41 inches) two hundred and sixty-five years. This drain water carries 8,489 parts of total solids per million which, calculated on the 1,327 acre-feet of water necessary to yield the 2,150 pounds of nitrates, would yield 30,414,840 pounds of salts, a quantity sufficient to cover the land more than seven feet deep, if we suppose them to have the same density as the soil itself.

The changes in the conditions of these soils have taken place within the past few, say six, years, and these conclusions to which we are forced if we suppose that these nitrates have their origin in the evaporation of the ground waters are evidently false. We know that no 1,327 acre-feet of water have evaporated to dryness on this land in this time and it is evident that our country is not covered nearly eight feet deep with calcic chlorid and other salts and we are likewise quite as sure that land which up to six years ago, and this assumed period is from three to six times as long as the facts indicate, has not been two hundred and sixty-five years in going to the bad.

I have described the condition of the land north and east of north of this orchard, designated No. 8, and from one-fourth to one-half mile distant, as having the natural color of ordinary adobe soil, in 1907 and 1908, with an abundance of ordinary white alkali in its surface portions, and stated that sulfate of soda crystals up to two and a half inches long occurred in the lower portions of this land, especially in depressions in the surface soil. In the spring of 1911 practically the whole surface in this land is dark brown in color and greasy in appearance. I dug a hole four and a half feet deep in a low spot in the field, and while the ground was wet, there was no free water. It is very probable that the water table in this land varies exceedingly from place to place, indeed it is very probable that one might choose a place and dig a hole twelve or more feet deep and find no portion of it wetter than the top six inches, possibly not as wet, and at another point encounter water within three feet or less of the surface; further, these points may be close together in the field. A sample of surface soil with its alkali was taken at the point where I dug the hole four and a half feet deep; this was mixed with samples of like soil from other parts of the field. This sample is so rich in nitrates that the aqueous extract from two grams of it gives a strong reaction for nitric acid. In 1907 the extract of the soil gave none. There are many square miles of such lands. The following analysis is to be compared with analyses of Laboratory Nos. 622 and 632. This land was already seeped in 1907, almost if not quite as badly then as now. The water-soluble in sample No. 1070 equalled 18.176 percent.

ANALYSIS XXXIII

	Water-Soluble Laboratory No. 1070 Surface Soil May 2, 1911 Percent
Calcic sulfate	21.104
Magnesic sulfate	15.766
Potassic sulfate	2.391
Sodic sulfate	1.676
Sodic chlorid	58.263
Sodic nitrate	0.518
Iron and Aluminic oxid	0.052
Silicic acid	0.230
	100.000

The percentage of sodic nitrate in this analysis is not large compared with some of our samples, but compared with the quantities present in 1907 it is quite as striking as the changes in the appearance of the land itself which was then the uniform gray of our adobe soils, now it looks as though it had been irregularly moistened with a heavy crude oil and though the large quantities of salts present are not favorable to an abundant development of nitrates we now find nitrates present at the rate of one and nine-tenths tons per acre-foot where, four years before, we found none.

Case No. 9—I visited this orchard for the first time May 18, 1910. The age of the trees still living was twenty-eight years. No disease had appeared in the orchard till the season of 1909. During this season about two and one-half acres of the orchard, two hundred trees, showed serious trouble and died in about six weeks. These trees had been removed from the orchard at this time, May 18, 1910, and used to stop the washing away of the river bank. The trees were not only old, they were also large, some of them measuring fifteen inches in diameter, and the owner stated that he had gathered from them crops of fifty boxes to the tree. The soil is a light sandy loam with a decidedly sandy subsoil, underlaid by gravel at a depth of from six to eight feet. We dug a hole five feet deep eight days after irrigation and found the ground only fairly moist. The drainage of this land is so free that when the northern part of it is irrigated freely a well in the southern part will show a rise of water within a few hours, less than twenty-four, and falls quickly.

After the dead trees were removed the land was prepared for planting to some crop. It appeared to be in the most excellent condition. Corn was subsquently planted but the stand obtained was very poor indeed. The owner attributed this to the quality of the seed which he said appeared to be good but it did not come up. I dug up samples of the seed corn which were thoroughly preserved, the grains were full, plump, fine-looking ones and there was an abundance of moisture to permit germination. This soil was brown and mealy on the surface. A sample was taken at this place where the corn had failed to come up and an analysis of it will be given later. This land continued to become more and more mealy and the remaining portion of the orchard became involved to a greater extent as the season passed, till, by the middle of September, at least one-half of the total area, five acres or more, was decidedly brown, and a further number of these old apple trees were affected. The corn crop was a complete failure. The sample taken, 989, represented the surface soil of a considerable area and was made by taking portions at various places, mixing as thoroughly as possible and then cutting it down to a manageable size; the depth of the soil represented is four and a half inches. The water-soluble equalled in No. 989, 2.884; in No. 892, 2.398; in No. 1074, 3.909, and in No. 989a, 6.96 percent of the air-dried soil.

ANALYSES	XXXIV Water-Soluble Laboratory No. 982 July 19, 1910 Percent	XXXV Water-Soluble Laboratory No. 989 July 11, 1910 Percent	XXXVI Water-Soluble Laboratory No. 989a Sept. 12, 1910 Percent	XXXVII Water-Soluble Laboratory No. 1074 May 7, 1911 Percent
Calcic sulfate	30.263	24.664	8.756	37.982
Calcic chlorid	5.888	9.298	14.117	—
Magnesic sulfate	—	—	—	1.726
Magnesic chlorid	14.930	15.217	9.217	10.817
Potassic chlorid	3.190	2.861	1.632	3.898
Sodic chlorid	41.757	43.832	60.219	35.135
Sodic nitrate	3.605	3.033	5.906	9.889
Iron and Aluminic oxids	0.152	0.138	0.084	0.087
Silicic acid	0.215	0.232	0.069	0.466
Carbon	—	0.725	—	—
	100.000	100.000	100.000	100.000

The soil designated as Laboratory No. 989a, was very brown on its surface, and when exposed to the atmosphere, after drying at 100°, absorbed enough moisture to cause it to adhere so tenaciously that one could press it into clumps in the hand which retained the form of the fingers. The aqueous extract had a brownish yellow color which became decidedly brown on evaporation. This color continued to go into solution even after the chlorids and sulfates had been completely washed out. The color could scarcely have been due to humus in the presence of such quantities of lime salts, besides the soil is poor in humus and the strong brown color on the surface of this soil is not due to this cause. It would have been difficult to have obtained a sample of this soil entirely free from the azotobacter pigments in which to determine the humus. Prof. Sackett has obtained cultures showing that the azotobacter pigments are soluble in water. This accounts for the deportment of this sample.

The mechanical analysis given for Laboratory No. 1067 is quite as applicable to the sample No. 989 as to the one of which it was made and likewise the agricultural chemical analysis is quite as applicable to 1067. The localities are probably as much as two miles apart but the soils are similar in location and character.

ANALYSIS	XXXVIII Soil, top four inches Laboratory No. 989 Percent
Sand	59.993
Silicic acid (sol.)	15.000
Sulfuric acid	0.430
Carbonic acid	3.450
Chlorin	1.561
Phosphoric acid	0.220
Lime	4.890
Magnesia	1.783
Potash	0.794
Soda	1.557
Ferric oxid	3.542
Aluminic oxid	2.189
Manganic oxid	0.370
Water at 100° C.	0.500
Ignition	(4.072)
Sum	100.351
O. equivalent to chlorin	0.351
Total	100.000
Total nitrogen	0.118

The ordinary agricultural analysis of this sample indicates that it is an excellent soil, which inference would be further justified by the mechanical analysis of No. 1067. While these inferences are fully justified by the analytical results and even further by the fact that all that was said of the preceding case,

Case No. 8, in regard to the drainage or water conditions, the simple fact remains that the twenty-eight-year-old apple trees, beginning in 1909, have practically all died, and the corn planted in 1910 was a total failure as a crop. When we consider samples 982, 989 and 989a, we see that the surface five inches of the soil contains from 1,440 to 1,660 pounds of sodic or other nitrate per acre. Approximately this depth was taken because these samples were taken after the corn had failed to come up and it was thought that the results obtained would give us an idea of the lower limits of nitrates which would prohibit germination. We knew perfectly well that this would not establish anything beyond giving us an idea of what quantity will prohibit the germination of corn. The quantity which effects this is less than 0.09 percent of the soil. Sample No. 1074 is a surface sample from the place where oats, pofatoes, etc., will not grow but pear trees continue to do quite well. We find that the top two inches of this land carries 2,578 pounds of nitrates per acre—I surmise that the pear trees endure this apparently better than apple trees and the other plants because they feed at greater depths and it may be true, as it actually seemed to be, that they are more tolerant of these salts than the other plants, but they are not immune for I have seen pear trees that have been killed just as the apple trees were killed. I repeat that the facts adduced pertaining to the two pieces of land mentioned under Case No. 8 apply with full force to Case No. 9, in fact these cases might have been discussed as a single one if the distance between them and the age of the orchard in Case 9 had not made it ill advised to do so.

Case No. 10—This is a peach orchard and the part referred to in this paragraph has been reset a number of times, the last time to pear trees, but without success. The part very badly affected is about one-third of an acre in extent, but there is probably three acres in all that is damaged by these conditions. This soil is a sandy loam three feet deep, underlaid by a coarse granitic gravel. The surface is brown and there is no vegetation. The land is no lower than the surrounding country. There was no excessive water in this or in adjacent lands. Two samples of soil were taken, one to a depth of one foot, No. 874; this sample showed the presence of 1.127 percent soluble in water; the other, No. 880, was a surface sample taken to a depth of one and one-half inches which showed the presence of 5.528 percent of the air-dried sample soluble in water.

ANALYSES	XXXIX Water-Soluble Laboratory No. 880 Nov. 2, 1909 Percent	XL Water-Soluble Laboratory No. 874 Nov. 2, 1909 Percent
Calcic sulfate	30.513	52.204
Calcic chlorid	2.412	——
Magnesic sulfate	——	6.991
Magnesic chlorid	13.990	10.594
Magnesic nitrate	5.210	——
Potassic chlorid	——	5.199
Potassic nitrate	6.809	——
Sodic chlorid	——	1.276
Sodic nitrate	40.841	22.981
Iron and Aluminic oxid	0.092	0.393
Manganic oxid	Trace	Trace
Silicic acid	0.133	——
Loss	——	0.362
	100.000	100.000

This is perhaps the most surprising occurrence of this difficulty that I have to record. This land is most favorably located, but it is not the only piece of land affected in this manner in this section. The owner told me that he had removed an old orchard principally because the varieties were poor, and that he had not been able to get the young trees to live. In the case of No. 880 we have been compelled to unite a part of the nitric acid with magnesium and potassium and we have 52.86 percent of the total soluble salts composed of nitrates, giving us the top inch and a half, the depth to which the sample was taken, 14,610 pounds to the acre—7.3 tons, or 116,880 pounds of nitrates to the acre-foot of such soil—58.4 tons.

Sample No. 874 represents the next succeeding foot with 5.7 tons per acre-foot. We actually have in the top thirteen and one-half inches of this land 13 tons of nitrates, principally nitrate of soda. This land is wholly barren. There is a cellar at the edge of this piece of land, six feet deep, the bottom of which is in the coarse gravel previously mentioned. In March, 1911, the bottom of this cellar was not only dry but actually dusty when stirred.

Most of the pear trees set in the spring of 1910 died before mid-summer and but few survived till the spring of 1911. The pear tree seems to be very tolerant of these salts, especially so when once established.

Case No. 11—This orchard is located near a ditch. The trees were attacked in July or August and died outright. The land had been heavily manured and when I visited it, it had just been irrigated and was, of course, wet on the surface. We dug a hole five and a half feet deep and found no signs of any excess of water. The soil is a sandy loam. I took two samples, one of them one and a half inches deep; this gave 1.45 percent soluble in water and showed very little nitric acid. The other sample was taken to a greater depth, eight inches, and showed the presence of 1.762 percent water-soluble and a very decided quantity of nitric acid.

ANALYSES	XLI Water-Soluble Laboratory No. 876 Percent	XLII Water-Soluble Laboratory No. 877a Percent
Calcic sulfate	80.355	43.457
Magnesic sulfate	8.591	19.658
Potassic sulfate	2.998	10.206
Potassic chlorid	4.458	———
Sodic sulfate	———	1.030
Sodic chlorid	2.302	13.494
Sodic nitrate	———	11.373
Iron and Aluminic oxid	0.193	0.147
Silicic acid	1.103	0.635
	100.000	100.000

It is seldom that we have so great a difference in the character of the soluble salts in samples of soil from the same place. This is probably due to the heavy irrigation that this land had just received. It had apparently moved the whole of the nitric acid down into the soil to a greater depth than one and a half inches and most of the sodic and potassic salts with it. In this respect these two analyses are quite interesting. The eight-inch sample shows the presence of 5,344 pounds per acre in this section of soil, or a little over four tons to the acre-foot.

Case No. 12—This is one of the worst cases that I have observed. The soil is sandy and the orchard is contiguous to Orchard No. 11 and west of it. In June, 1910, I observed the beginning of a very general burning in the orchard and a few trees, perhaps twelve to twenty, were already dead or in a bad condition. I spoke to the owner in regard to the matter but he thought that it was a case of spray burning and attributed the trouble to a faultily prepared lead arsenate. He was very positive in regard to the matter. I saw this orchard in September when it was in a very bad condition, probably upwards of six acres being involved and very many of the trees will not survive the season. The conditions of this orchard are the same as in Orchard No. 11, and there is no question of drainage or alkali. Both orchards are fairly old ones, the oldest trees being probably not less than sixteen years and the youngest twelve to fourteen years old. When the owner of Orchard No. 12 became convinced that something more serious than spray burning had happened to his trees he manured the land and irrigated heavily. The development of this orchard in 1911 would have been interesting to watch, if the owner had not removed the six-or-eight-acre block of trees.

Cases Nos. 13 and 14 — These orchards have suffered greatly, especially No. 14, during the past seasons; fifty acres or more in the two orchards have been seriously affected, and many trees have died. The soil conditions vary considerably in different portions of these properties; some of the land, a small portion, is low, but the most of it is well located. I have joined these properties because they are close together but not adjoining and because they present, in the main, essentially the same problems. They are both pretty well protected against seepage, being nearly if not the highest ground under irrigation in that section. One of them has a very deep wash on the north and west sides of it and a system of drains running through the lower land. The questions pertaining to Orchard No. 13 may be more involved than any which I have heretofore described, but this is not the case with No. 14. I gave the analyses of two samples of drain water from Orchard No. 13 in Bulletin 155. They were as follows:

ANALYSES	XLIII Residue from Drain Water Laboratory No. 610	XLIV Residue from Drain Water Laboratory No. 792
	Percent	Percent
Calcic sulfate	23.202	22.352
Magnesic sulfate	36.662	31.586
Potassic sulfate	0.705	1.502
Sodic sulfate	29.991	24.775
Sodic chlorid	2.863	9.050
Sodic carbonate	4.093	4.120
Sodic nitrate	2.275	6.500
Silicic acid	0.209	0.115
	100.000	100.000

The solids in these waters are essentially sulfates. The small amount of carbonates indicates the amount of this salt to be expected in the soil. We find in the drain waters from soils more favorably conditioned than this one, from seven to twenty-three percent of the total solids held in solution consisting of this salt, carbonate. I unfortunately do not know the amount of water discharged by the respective drains at the time the samples were taken but the total solids varied only slightly. No. 610 contained 637.3 grains of total solids per imperial gallon; No. 792, 622.65 grains. A drain water flowing from a piece of strongly alkalized ground contained 113.8 grains, sample taken in April. Another sample from the same ground, taken in July, contained 72.8 grains, and another in February three years later contained 160.5 grains. Another drain water flowing from a somewhat alkalized area, but by no means a very bad one, contained 62.2 grains per imperial gallon.

The nitric nitrogen was determined in two of these samples, one containing 0.24 part, the other 0.48 part per million, whereas No. 610 carried 34.5 parts and No. 792 carried 96.37 parts nitric nitrogen per million, or No. 610 carried 143.8 times as much as the first drain water and No. 792 carried 200 times as much as the second drain water. While the percentage of sodic carbonate in the residue obtained from these waters varies greatly, the actual amount of sodic carbonate per million of water is nearly the same, for instance, 323, 355, and 364 parts per million, which serves to show how very high the nitrates in these two waters are in comparison with the amounts present in drain waters from ordinary alkali land.

The flow from these drains undoubtedly varies with the irrigating season. I do not know whether the drains are stopped up or not but they discharged no water for several months during the spring of 1911.

The land included in Orchard No. 13, as stated before, presents involved conditions. A portion of it was seeped and badly so, ten or twelve years ago, and was drained a little over ten years ago. This land in the meantime has been benefited to such an extent that good crops of wheat, forty-five bushels per acre, have been harvested from it. There are portions of this area through which the drain passes and which one would think should receive the full benefit of the drainage which, though not wetter than other portions, are unproductive. I took samples from such places several years ago. In taking these samples I recognized three conditions, a thin crust on the surface, of which 8.317 percent was soluble in water; a portion immediately underneath this crust, of which 7.680 percent was soluble, and the soil proper, the first foot of which after the two preceding portions had been removed, gave me 1.330 percent soluble in water.

ANALYSES	XLV Water-Soluble Laboratory No. 819 Crust on surface Percent	XLVI Water-Soluble Laboratory No. 818 Portion under the crust Percent	XLVII Water-Soluble Laboratory No. 816 Soil one foot deep Percent
Calcic sulfate	13.926	51.858	19.863
Magnesic sulfate	20.841	11.043	14.511
Potassic sulfate	2.027	2.084	2.611
Sodic sulfate	44.021	16.734	52.334
Sodic carbonate	———	0.872	———
Sodic chlorid	16.427	16.793	8.795
Sodic nitrate	2.525	2.435	1.646
Iron and Aluminic oxid	0.067	0.032	0.098
Silicic acid	0.166	0.149	0.142
	100.000	100.000	100.000

A very large portion of this orchard, at least thirty-five acres, has been removed. Some of the trees may have been killed by an excess of water. I am fully prepared to accept this as an adequate and very probable cause in some cases and yet the question presents itself why they should have lived to be fourteen or sixteen years old and die several, eight or ten, years after the drains were put in and the water had been removed. I realize that it is exceedingly difficult to present all of the facts and the questions which arise in this connection so that persons who have never seen these conditions can apprehend them. But though the facts may be perplexing and it may be difficult to give a satisfactory reason why seepage should kill these trees, I am still thoroughly convinced that excessive water injured some of them. This, however, does not apply to the greater part of this orchard. Almost, but not quite, the highest portion of this orchard with the deep wash, previously referred to, bounding the section on two sides, has suffered severely, in fact, several acres of it, ten or more, have been entirely destroyed. The trees have not been killed by winter injury, nor by arsenic, so far as I have been able to detect and I have tried to determine this point, but a great many of them have been burned and have died just as in the other orchards described. In the summer of 1909 and again in 1910 I watched the progress of the destruction of this orchard, marking trees in May and June to see them dead in August and September.

Samples of the surface soil from the higher sandy portion of the orchard, where the destruction of the trees has been complete, gave the following results: the water-soluble equalled in 815, 0.985, in 1061, 1.467, and in 1075, 8.590 percent of the air-dried sample.

ANALYSES	XLVIII	XLIX	L
	Water-Soluble Laboratory No. 815 June 3, 1909	Water-Soluble Laboratory No. 1061 March 28, 1911	Water-Soluble Laboratory No. 1075 May 2, 1911
	Percent	Percent	Percent
Calcic sulfate	17.521	59.460	28.162
Magnesic sulfate	27.166	15.714	9.470
Magnesic chlorid	———	———	9.141
Potassic sulfate	3.768	3.466	———
Potassic chlorid	———	3.264	3.932
Sodic sulfate	11.925	———	———
Sodic chlorid	18.683	4.540	5.086
Sodic nitrate	20.367	13.057	44.035
Iron and Aluminic oxid	0.065	———	Trace
Silicic acid	0.505	0.499	0.174
	100.000	100.000	100.000

Sample No. 1075 is the surface, mealy portion formed in the irrigating furrows after the last irrigation. This land has been sown to oats this year, 1911, but they are not in good condition.

The water-soluble in this sample equalled 8.590 percent and the nitrates equaled 44.0 percent of this, or 3.78 percent of the sample as it was gathered, showing that the surface soil is now very rich in nitrates. Sample No. 1061 is an actual sample of this soil taken to a depth of from four to six inches; the sample is a composite one from ten different points in the field. We see that it contains practically 1.5 percent of the water-soluble salts of which 13.0 percent was sodic nitrate which gives us 3,900 pounds of nitrates in the top six inches of the soil. This land lies on and above the wash alluded to which is eleven feet ten inches deep and is actually encroaching upon this land on both the north and west sides, which ought to secure excellent drainage especially as the land is not a heavy adobe soil, still it will puddle and retain water more persistently than one would think. The presence of the nitric acid in the first sample of soil, No. 815, taken at the base of one of these trees was a surprise to me, though I knew of its occurrence in adjoining portions of the land where the trees had already died. This whole section of trees, probably ten acres, has been dug up.

It is useless to attempt to present to oneself any questions in regard to what would have been the condition of this orchard and land had it not been drained, as it was a little over ten years ago. I am satisfied that the drainage system carries off the excessive water whether it is from the irrigation applied or from other sources and establishes a zone and certain areas where there is a comparatively uniform and moderate, but still an abundant supply of moisture which renders possible the development of the nitrates, if other conditions are favorable. What the optimum degree of moisture may be I do not know but my observation leads me to believe that a constant supply amounting, near the surface, to 18 or 20 percent, is sufficient for a rapid development of the trouble. After this is thoroughly established it seems to modify the moisture conditions of the soil as has been indicated by direct assertion of this fact and further by describing the ground as a veritable mud.

Orchard No. 14 is also a large orchard, but has quite a different soil. The burning has been very general and serious, at least twenty acres being involved, some of it on rather high and sloping land, some of it on lower and level land. The developments in this orchard during the season of 1910 were sufficient to cause the manager and the owners the gravest anxiety, while the developments in the past month, May, 1911, are extremely serious.

In this case we probably have an illustration of the effect of the irrigating water washing the nitrates down into the feeding area of the roots, and thus causing the damage, for some of the soil, while it is stained brown, is not at all in a bad condition. The former manager of this property kept the orchard well cultivated and the soil was in fine condition throughout the season of

1910, so that there was no good opportunity to observe the formation of crusts and mealy portions. The irrigating furrows, however, showed the brown lines very strongly in places. A sample of the soil taken from the northeastern section of the orchard to a depth of one foot showed only 0.062 percent of the matter soluble in water, but this soluble portion reacted like a pure nitrate solution. The trees were burning in this section of the orchard at the time the sample was taken. I had known for several years that a small part, possibly one-quarter of an acre, of this orchard, close to a deep wash, was affected with this trouble, but in the early part of June, 1910, I found the trouble more general and it grew quite rapidly in severity and extent till there was scarcely a tree in a large portion of the orchard but that showed more or less burning, and the present outlook is very bad.

ANALYSES	LI	LII
	Water-Soluble Laboratory No. 1063 March 28, 1811	Water-Soluble Laboratory No. 1072 May 2, 1911
	Percent	Percent
Calcic sulfate	10.388	31.808
Calcic chlorid	36.807	12.813
Magnesic chlorid	5.312	14.940
Magnesic nitrate	9.946	———
Potassic chlorid	———	2.329
Potassic nitrate	1.727	———
Sodic chlorid	———	1.983
Sodic nitrate	35.560	35.556
Iron and Aluminic oxid	0.066	0.267
Silicic acid	0.194	0.304
	100.000	100.000

Sample No. 1063 was taken in March and No. 1072 in May, 1911, from the southwestern section of the orchard. The total area of this orchard is ninety acres. A few trees died in this section of the orchard in 1910 but the death rate in May, 1911, is most alarming. Many trees that leafed out fully in the early part of the month, May, 1911, were killed outright by the 30th, as many as six or eight consecutive trees in a row, all succumbing in exactly the same manner. The water plane of the lowest portion of this land was at this time four and three-quarters feet below the surface. I wish to emphasize the following two facts; first, that apple trees in our country do not root deeper than two and a half feet as a rule; second, that it is very improbable that even the oldest reader of this bulletin has ever seen anything in any way comparable to the facts here presented, and I am fully convinced that they are so entirely beyond his observation and knowledge that he can neither conceive of nor justly pass judgment upon them for he does not know the facts.

I have at all times avoided anything approaching a dissertation upon the facts believing that no statement of them can be more forceful than the facts themselves, but men who may have seen many things and never seen the like of this and others also judge such things to be impossible because they have not seen them and no one has, heretofore, described anything comparable to them. In these facts lies my only justification for the following statement relative to this case. Some five or six years ago I found in the southeast corner of this orchard a few dead trees, killed, as I then believed, by nitre. The ground was mealy and had that softness under the foot which we have learned to be peculiar to the earlier stages of this condition and sometimes persistent throughout the course of its development, even to the utter ruination of the land. No further trouble seemed to develop in this orchard for several years except that this bad area extended slowly from year to year. I visited this orchard but once or twice in 1909, and if there was any general burning of the orchard I neither saw it nor was it called to my attention. That there was some burning is understood, especially in the southeastern section. In 1910, however, the burning was very general throughout the ninety acres. A portion of the orchard was decidedly bad and many trees, the actual number I do not know, died and were removed.

In the northeastern section of the orchard many trees that so far as was known, were in good condition in 1909, were in bad condition and the leaves were burning in July, 1910. Even I had difficulty in pursuading myself that much of the injury was not due to freezing dry. The fact remains, however, that the leaves were burning in just the manner that nitre burns them; further, the sides and crests of the irrigating furrows were streaked with brown, which we have learned to be an almost infallible sign of the presence of nitrates. Holes were dug in this section of the orchard without striking water but the trees were being injured. In the spring of 1911 a party kindly bored a hole at my suggestion to determine the depth of the water plane; he found the soil dry at a depth of six and a half feet. At the time of my last visit to this orchard, May 30, 1911, the trees at this point had not yet begun to burn. The leaves were large and deep green in color. One would infer from the conditions as they presented themselves that too little water had been applied to this section. I have no contour map of this orchard but this northeastern section is patently the highest portion of it and the slope is to the south. A little way down in the orchard we found the leaves of the water sprouts burning to such an extent that there could be no possible question concerning the cause. This season, 1911, is the first time that I have seen burning to any noticeable extent before the middle of June, but this year it is very common at this date, May 30.

In 1910 almost every tree throughout the central portion of

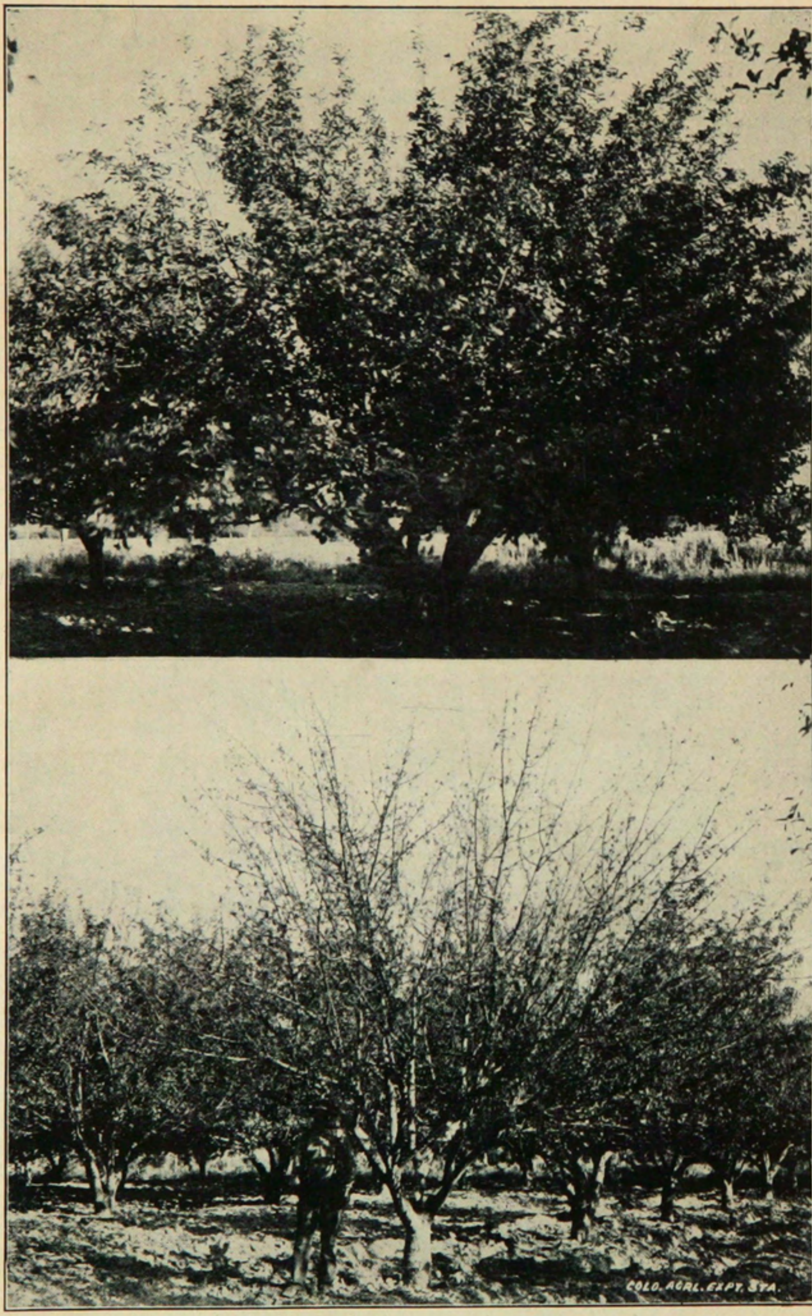

PLATE II.—See page 41.

No. 1 is the upper figure

this orchard showed in August and September more or less burning and here and there a tree wholly succumbed. Many trees, however, were only severely injured, either by having one or more limbs entirely killed or the extremities of the branches killed back varying distances. As yet this section of the orchard does not show the burning badly at all; it is too early and the trees have not had a liberal supply of water.

The western part of this orchard was rather bad, and many trees showed burning last year, but the burning did not take place till the latter part of the season, from mid-summer till autumn. This year, however, many trees that came into full leaf in early May had already been killed by the thirtieth of the month. I visited this orchard on the second and again on the thirtieth of this month and while I have seen other orchards destroyed quickly I have nowhere seen anything surpassing this in the extent of the injury and the rate of its accomplishment. The ground water was four and three-quarters feet below the surface. The surface soil was dry but brown and mealy. The disc had cut about three inches deep and the sides and bottom of the cut looked as though crude oil had been uniformly distributed over them. Sample No. 1063 was gathered from the surface of this ground on March 28, and was taken to a depth of two or more inches. It was a composite sample made up of smaller samples from several places. Sample 1072 was likewise a composite sample taken from the sides and bottom of the cut made by the disc. These samples represent the salts soluble in water and contained in the top two inches of the soil, where the trees are now dying very rapidly, and we see that they agree in showing 6.158 and 6.197 percent of such salts, 47.233 percent of the former and 35.556 percent of the latter being composed of nitrates. Calculating the nitrates present in the top two inches of this soil, we obtain 9.6 tons per acre for the sample taken in March from the surface soil and 7.6 tons for the sample taken in May from the sides and bottom of the disc cuts or furrows, or calculated on the acre-foot, 58 and 44 tons respectively. The ground where the samples were taken is lower than a portion of the orchard but the ground is still so sloping that we cannot explain the presence of this large quantity of nitrates by supposing them to represent the washings from the rest of the orchard.

Plate II shows the condition of some of the trees in this orchard on June 23, 1911. The upper photograph, Fig. 1, represents a tree which at this time showed no effects of the nitrates. The lower one, Fig. 2, represents a tree which developed a full foliage in May and was dead at the time the photograph was taken, June 23, 1911. These two trees do not stand more than fifty or sixty feet from one another. The only reason why trees even this far apart, were chosen was because we could not get a good view of an unaffected tree standing in the next row and contiguous to the dead tree represented by the lower photograph.

In a preceding paragraph I stated that on May 30, 1911 the trees were burning badly in the southwestern portion of the orchard, as many as six or eight consecutive trees in a row being attacked and dying in the same manner. On June 23 I counted thirty-five consecutive trees in one row which were all attacked to a greater or less extent. Of these thirty-five trees not less than twenty-five were already dead and of the remaining ten five were already so badly injured that there was no hope of their recovery.

Case No. 15—Under this number I shall present two adjacent orchards, without going into any details. I first noticed one of these orchards about four years ago. At that time about one and a half acres of the land was bare; the few trees that were still standing were dead. The surface of the soil was brown. I visited this orchard in 1909 and took a sample of the soil to a depth of one foot. The condition of the land did not appear to be very bad but it had been recently cultivated which operation effectually conceals this condition if carefully done. This sample yielded 3.580 percent of water-soluble which afforded the following results:

ANALYSIS LIII

	Water-Soluble Laboratory No. 779 Percent
Calcic sulfate	30.528
Magnesic sulfate	19.901
Potassic sulfate	1.878
Sodic sulfate	23.006
Sodic chlorid	12.951
Sodic nitrate	18.307
Manganic oxid	0.267
Silicic acid	0.162
	100.000

This analysis indicates the presence of a little more than 13 tons of sodic nitrate to the acre-foot.

There is another orchard immediately to the north and east of this to which my attention was directed in the spring of 1911. Drains were laid in this land in the autumn of 1910 with the idea of washing the soil by heavy irrigation and depending upon the drains to carry off the leachings of the soil with the excessive water which might be added or which might possibly accumulate from other sources. The soil is a sandy loam passing into a clayey loam in places. The water plane, determined by means of a series of wells, was four and a half feet below the surface. Some of the trees at this time, May 1, 1911, were burning quite badly though the leaves were not yet fully developed. It is unusual to observe this burning of the leaves in any degree so early in the season and very much more so to meet with such marked cases of it as these trees presented. Unfortunately I do not know how high the water plane rose during the season of 1910, but information elicited by specific inquiry in regard to this point did not suggest an undue amount of water as the cause of the trouble or as the probable source of the nitrates. I visited this orchard again on May 30, 1911, at which time the destruction of the orchard not only seemed a certainty but was already far advanced. The following analyses represent the surface soil and the water from a well located near by a burning tree. This sample of water was sent by the owner.

ANALYSES	LIV Water-Soluble Laboratory No. 1073 March 28, 1911 Percent	LV Water Residue Laboratory No. 1200 May 12, 1911 Percent
Calcic sulfate	24.275	36.596
Calcic chlorid	8.658	———
Magnesic sulfate	———	2.194
Magnesic chlorid	8.577	11.654
Potassic chlorid	1.951	2.107
Sodic carbonate	———	5.040
Sodic chlorid	39.187	41.992
Sodic nitrate	17.075	Minute trace
Iron and Aluminic oxid	0.088	0.078
Silicic acid	0.189	———
	100.000	100.000

Sample No. 1073 represents the surface soil, an inch and a half or at most two inches deep, taken beneath a tree which was already burning. This sample yielded 5.768 percent of salts to water, of which a little over 17.00 percent, 17.075, was nitrates, giving us 6,500 pounds, three and a quarter tons, of nitrates in the top two inches of this soil per acre. Sample No. 1200 is the ground water taken from a well near to another burning tree which has since died. This water contained 10,094 p. p. m. of total solids, but contained so little nitric acid that five grams of the residue gave with hydric and ferrous chlorids only a minute trace of nitric oxid. This test, like all of the nitric acid determinations, was done in duplicate. It is a striking fact that this ground water within four and a half feet of the surface on which an abundance of nitrates occur should be so nearly destitute of even a trace of nitric acid, but this is the second case; we have already given one case in which this is so and we have still another which will indicate the same thing. In the case of sample 1201, a drain water, we have given even fuller data, showing the presence of 8,489 parts of salts per million with only 0.018 p. p. m. of ammonia, 0.00003

p. p. m. nitrogen as nitrites and 0.1 p. p. m. of nitrogen as nitrates, which could scarcely be possible if the surface salts were washed down into this ground water to any extent, and contrariwise all of these samples agree in leading us to most extremely improbable conclusions if we consider them to be the source of the nitrates. While this is not yet an extreme case the results are most striking and most evidently false, for if this ground water were the source of the nitrates and it were as rich as this drain water we would have to assert that 40,122 acre-feet of it had been evaporated to dryness on each acre of this orchard which would mean a mass of water 7.5 miles deep. This amount of water would deposit 541,670.6 tons of salt on each acre of which only 3.25 tons, the amount now present in the top two inches of this soil, would be nitrates, and the time required to effect this, assuming the evaporation to take place from a free water surface at the rate of five feet per annum, would be 48,128 years. The facts, on the contrary, are that these apple trees grew healthily for ten years or more until within the last two or three years which is conclusive proof that these nitrates were not present previous to this time, say three years ago, in sufficient quantities to do any damage, but within this time the limit of tolerance has been passed and this orchard has been destroyed.

It is evident from the results in all the cases of ground waters given that it is not water derived from the surface of the land which has passed through the soil and now forms a sheet of water beneath this soil but probably represents, in large measure, the leakage from the irrigating ditches and other similar sources, for we have already given samples of such waters as have without any reasonable doubt come from the soil, i. e., passed through the soil of nitrate areas, and they are rich in nitrates. Further, this ground water, especially the drain water previously given owes its immediate origin to the gravel which underlies the sand, and which, as elsewhere stated, constitutes the natural drainage of this section. I do not know whether the section where the well is located is underlaid by gravel or not, but the water agrees with the others here given in containing so good as no nitrates. Another point is the absence of ammonia and nitrites from this drain water, which can only be interpreted as indicating that no reduction of nitrates can have taken place in the areas from which this water came. The reader is referred to Analysis IX, Colorado Experiment Station Bulletin 155, pp. 12 and 13, for the description and composition of a water derived from a nitre soil. We cannot extend the consideration of this subject at this time.

Case No. 16—Orchard No. 3, described in Bulletin 155, pp. 16-18, has grown worse and many trees, not previously described, have shown burning to a very serious extent. A little to the east of this place is a piece of ground which some one has tried to bring under cultivation. The piece of land is not very large and lies between two ridges and beside the public road. An open drain was run north and south through the center of it, from the north end of which another open drain was run parallel to an irrigating ditch across the north and northeast end of the east half, to intercept leakage from the ditch. These ditches were not well cared for and their efficiency was greatly reduced owing to the indifference of the owner. A large irrigating canal runs on the east side of the public road and is six or more feet below it, while this piece of land lies on the west side of the road.

The west half of this land was planted to oats last spring, 1910. The condition of the field on September 13, is shown in the upper figures, Plates III and IV. That of Plate IV shows the oats that survived. The photograph conveys a good idea of the size and sharp delimitation of the piece, also of the rank growth made by the plants, they being well above the waist of a medium sized person. The photograph, however, does not convey any idea of the extremely dark green color of the plants. The other figure, Plate III, shows the condition of the rest of the field, the western portion, and the irrigating creases, also that the land was entirely bare, there being only a very few Russian thistles that had survived. These photographs show in a most excellent manner the brown stained margins on the spaces between the creases, even the slight encrusting and puffed up condition which is very characteristic of extreme cases of this trouble, can be recognized in Plate III. These pictures show that the ground immediately back of this, north of it, is higher and some of it is uncultivated, while other portions of it support old and healthy orchards. The pictures also convey a fairly good idea of the length of the field, as the public road runs only a few feet, perhaps thirty, this side of the picture. The length may be four hundred feet. I did not measure it but I think that it cannot be more than this. The north and south ditch runs a little to the east of Plate IV, and the irrigating ditch at least six feet deeper than the lower end of this field runs within forty or fifty feet of its south side. I have already given too many details relative to this piece of ground. The growth of the oats on ground which is neither higher nor lower, neither wetter nor drier than the rest, indicates that it is really not a question of seepage and drainage. This ground was not very wet at any time that I have seen it. It was wet enough to justify the ditching, and the results have been disappointingly small. I interpret this as being in harmony with many other observations, that while this land would be considered as seeped land the chief difficulty is not the water but the bacterial flora of the soil.

A sample of the surface soil was taken from that portion of the field represented in Plate III immediately in front of the person who is actually holding the sample. This sample was taken only to a very shallow depth, scarcely more than one inch; it yielded to water 8.83 percent after being thoroughly well air-dried.

ANALYSIS	LVI Water-Soluble Laboratory No. 1012 Percent
Calcic sulfate	5.941
Calcic chlorid	26.566
Magnesic chlorid	4.469
Magnesic nitrate	21.527
Potassic nitrate	4.107
Sodic nitrate	37.269
Silicic acid	0.121
	100.000

Case No. 17—The trouble in this orchard came to my notice for the first time in July, 1910. Inquiry elicited no satisfactory information relative to the presence of any burning of the leaves during the preceding year. I, however, became fully convinced of one thing, namely, that while it is very probable that the trouble was present in 1909, even to the extent of killing a few trees, it was not so general as it became during the early part of the season of 1910. The location of this orchard is very favorable; the soil is of the best quality and the drainage is excellent. The red mesa-soil is uniform in appearance and texture for a depth of four and a half feet, when it changes to a gravel as shown by a hole dug by a badly burnt tree. The land had been irrigated probably a week prior to the date on which I dug this hole and took my samples. We found, however, no excess of water in the soil. The irrigating water, if it had at any time made a portion of the soil excessively wet, had already drained out to such an extent that the soil was no more than in good condition, even the foot of soil next to the gravel was not excessively wet, perhaps between twenty and twenty-five percent of its weight being water. This orchard consisted of a younger and an older part. The burning was in most cases very moderate, so moderate that one would be surprised if the result should be fatal unless the soil conditions should grow worse. A few trees had already died from this cause, though there were other dead trees with girdled crowns to which their death was probably attributable. There is no question of seepage involved in this case, but there is a good supply of irrigating water and a small ditch flowing just west of the orchard. The prevalence of this trouble throughout this orchard and the intensity of the burning on a few trees were matters of surprise to me. I had known of the occurrence of nitrates in very large quantities in this section for two years, but this and some others were new and wholly unexpected occurrences. I took two samples of soil, one to a depth of three inches, No. 977, the other from the fourth to the fifteenth inch inclusive, No. 978. The water-soluble in No. 977 equalled 2.92, in No. 978, 0.54 percent.

ANALYSES	LVII Water-Soluble Laboratory No. 977	LVIII Water-Soluble Laboratory No. 978
	Percent	Percent
Calcic sulfate	40.376	50.910
Magnesic sulfate	22.470	15.972
Potassic sulfate	3.686	8.639
Sodic sulfate	3.606	16.814
Sodic chlorid	23.930	6.039
Sodic nitrate	4.902	Trace
Iron and Aluminic oxid	0.196	0.288
Silicic acid	0.834	1.338
	100.000	100.000

Sample No. 977 gives us 65.5 pounds of nitrates available to each such tree as this, assuming that the roots occupy a circle of ground forty feet in diameter and that the whole of the nitrates in the top three inches, is by any means brought within the feeding area of the roots.

As I have elsewhere stated I do not know how small a quantity of nitrates will suffice to produce a burning of the leaves. The tree in question was burned, but scarcely enough to produce serious injury. Our observations would have to be continued into, if not through, the season of 1911 to form any reliable judgment in regard to this point.

This land is so located that it is difficult to believe that these nitrates could have been washed from any adjoining lands, and if they were brought to the surface by capillary attraction they must have existed in the soil itself, but our analysis of the soil taken from the fourth to the fifteenth inch inclusive shows only a trace of nitrates in the aqueous extract. It is also out of the question to think that the irrigating water, snow water, might contain enough nitrate to permit of such a concentration as we find even in this case. These points are mentioned in this connection because in many cases the conditions legitimately admit the question of transportation from higher lands either by seepage or washing. That is, they could fairly be raised whether they actually apply or not. A case in point, i. e., Case 8, has been presented in considerable detail to enable the reader to judge for himself whether washings from the higher lands or the seepage from them could possibly account for the nitrates occurring in the land described. The presentation of the analyses given is itself a proof that I have most seriously considered these possibilities, but I have failed to see how these theories of accounting for the presence of nitrates, never before met with in arable soils in such quantities and over such large areas, so far as I know, apply to these cases and especially to Case 8, which, as is stated in the presentation of it, is of all the cases discussed probably the one most favorable for the application of these usual explanations.

This is by no means the only instance of the occurrence of nitrates in this immediate neighborhood but it is the best example of the general effects of the nitrates in ground that we would usually consider almost entirely free from any objection that I can recall. There are very much more severe cases of this trouble in the neighborhood but the land is not so well located for orchard culture. One of the most striking cases in point was a five-or eight-acre orchard planted on ground that sloped toward a slight depression. A deep drain ran at the base of the slope and two lines of underdrain, six feet deep, extended up into the orchard. We dug a hole three and a half feet deep at a point which I thought a favorable one to find water but I found none. At three and a half feet we encountered a stratum of marl and below this there is, as shown by the ditch and drains referred to, a coarse gravel with some marl. The surface of this ground was very brown and mealy. The trees on July 18, 1910, were burning very badly and many of them were already dead. The owner stated that they began to die during the season of 1909, but I did not learn whether the trouble began in the spring or summer.

A number of other instances of trees similarly located could be mentioned. In some section of our orchard districts it is difficult to find an orchard which does not show more or less of the trouble at some time during the season. The trees that are at all seriously affected seem to have no recuperative power.

Case No. 18— This case, like several others, presents more than an orchard, but as an orchard is actually involved I have retained the designation. This is quite fully justified not only because a part of the land is set to apple trees but also because they present a marked case of this trouble. The case is an involved one; in part of the land there is an excess of water, in other portions the soil is shallow, a stratum of marl coming near to the surface, but in other portions the conditions are good, or fairly so. It is exclusively of the better part of the orchard that I shall write. The trees were twelve years old the first time that I saw them, now going on three years ago, and so far as I have been able to learn they had not at that time shown any of this trouble, though I took a sample of soil on my first visit to the orchard in order to test it for nitric acid. This sample contained 2.126 percent

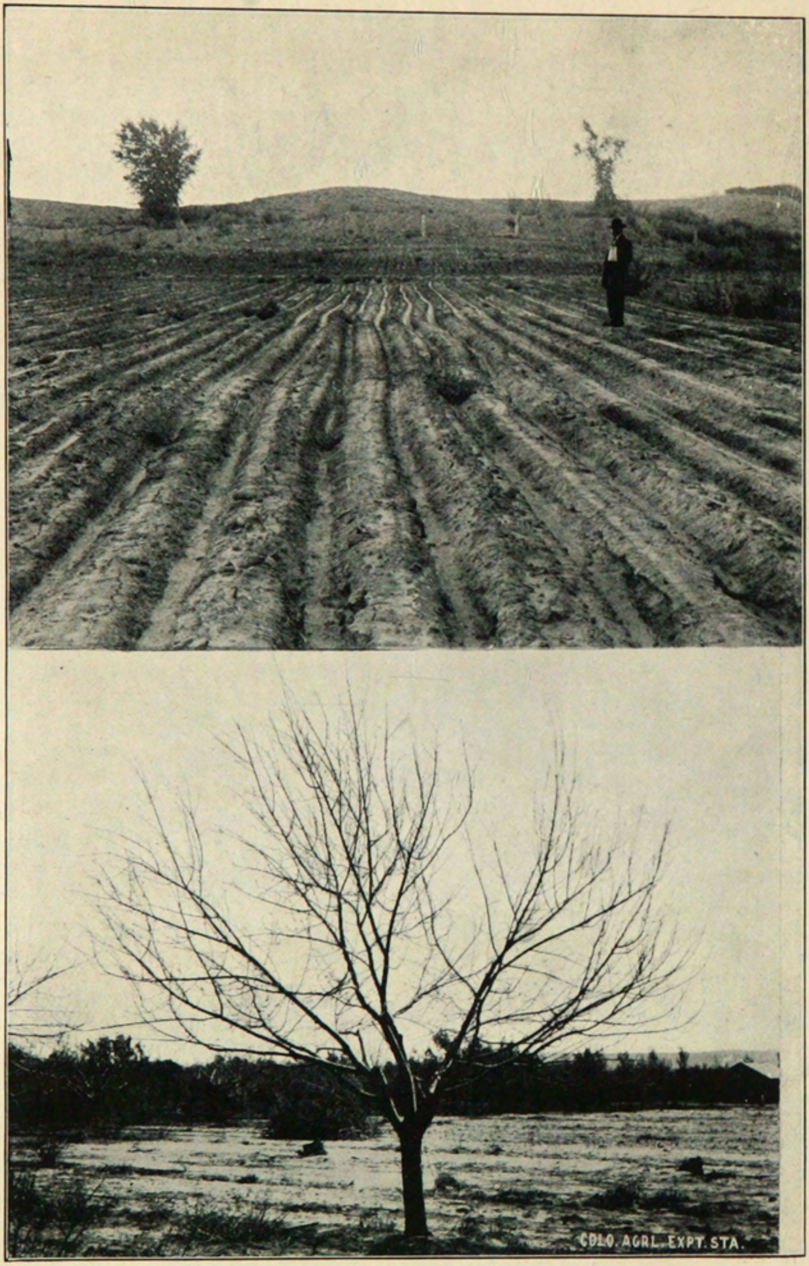

PLATE III.—See pages 45, 62 and 63.

No. 1 is the upper figure

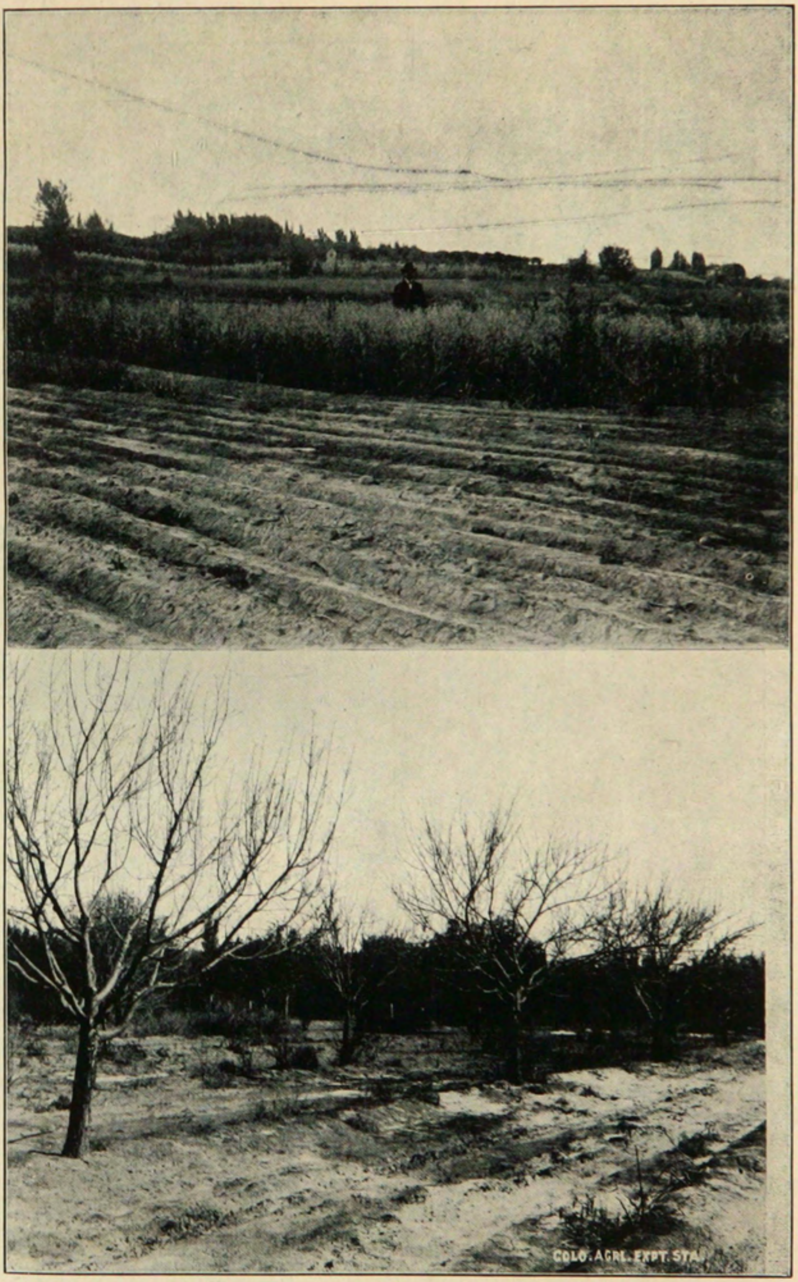

PLATE IV.—See pages 45, 63 and 67.

No. 1 is the upper figure

soluble in water and reacted strongly for nitric acid. The reaction depended on in all cases is that with ferrous sulfate and sulfuric acid. If a few grams of soil, from 10 to 25, will not give with 20 to 30 cc. of water, a solution which will give a decided reaction with these reagents it scarcely belongs to the class of soils, with which we are concerned. The owner put in a short drain to protect a portion of his orchard which he feared might be suffering on account of excessive water. This drain never collected much water, and was entirely dry on my next visit. The trees in this part of the orchard were at this time, July 23, 1910, burning badly.

We had in this orchard an excellent opportunity to compare the nitre burning with spray burning. The two differ in the point of attack, the nitre beginning at the apex and the margins of the leaf and very rarely, if ever, on the inner parts of the blade, and the color is lighter.

This is a piece of sloping ground and is at the base of a hill. There is no irrigation above it that I can recall. A little to the south and west of this orchard on the roadside is one of the most remarkable spots of this character that I have met with, not excepting the first one that I recognized and which is represented by Analysis No. 1, Bulletin 155, page 7.

These spots, for there are a number of them, are scarcely worse than some of the land in the orchard where the trees were burning very badly. This soil is actually kept moist by the deliquescent nature of the salts formed. A sample from such a spot in the orchard gave 12.10 percent soluble in water and the notes state that this residue had to be dried at 110° in the air-bath for 12 hours. Another sample gave 12.560 percent soluble in water, and this extract bears a special label "had to dry at 115° for 20 hours to get dry enough to put into the bottle." I am giving these details perhaps *ad nauseum*, but I find that they appear so strange to persons who have never met with such facts themselves as to seem wholly incredible. The analyses of these samples may be their own witnesses.

ANALYSES	LIX	LX	LXI	LXII
	Water-Soluble Laboratory No. 791 May 10, 1909	Water-Soluble Laboratory No. 823 July 23, 1909	Water-Soluble Laboratory No. 790 May 10, 1909	Water-Soluble Laboratory No. 828
	Percent	Percent	Percent	Percent
Calcic sulfate	55.242	21.249	14.495	4.401
Calcic chlorid	———	———	47.523	28.313
Magnesic sulfate	15.021	14.253	———	———
Magnesic chlorid	11.883	———	4.363	18.801
Magnesic nitrate	———	———	10.792	0.491
Potassic sulfate	———	1.606	———	———
Potassic chlorid	3.005	———	2.114	———
Potassic nitrate	10.001	———	———	2.711
Sodic sulfate	———	35.798	———	———
Sodic chlorid	———	10.607	———	———
Sodic nitrate	4.273	16.395	20.585	45.283
Iron and Aluminic oxid	0.139	———	———	———
Silicic acid	0.436	0.092	0.128	———
	100.000	100.000	100.000	100.000

ANALYSIS	LXIII
	Soil Laboratory No. 791* May 10, 1909
	Percent
Sand	67.910
Silica (sol.)	3.280
Sulfuric acid	0.760
Chlorin	0.200
Phosphoric acid	0.170
Carbonic acid	2.640
Lime	4.250
Magnesia	2.060
Sodic oxid	0.530
Potassic oxid	0.880
Ferric oxid	3.900
Aluminic oxid	4.400
Manganic oxid (br.)	0.280
Moisture, 110°	3.510
Ignition	5.640
Sum	100.410
Oxygen equiv. to chlorin	0.050
Total	100.360
Humus	0.380
Humus ash	0.382

This is an extremely interesting instance of the occurrence of nitrates. The ground slopes toward a meadow, a part of which has been converted into a reservoir but the land is decidedly higher than the meadow, as it is on the lower slope of a hill. The field along the roadside where one of these spots occurs was in alfalfa; the land was good, and the alfalfa healthy, so that one seems

*The depth to which this sample was taken is not stated. It was probably about three, certainly not more than four, inches.

justified in assuming that no considerable rise in the water table has taken place for a number of years, and further that it is reasonably low.

The ordinary soil analysis shows nothing which we might interpret as indicative of any deficiency or trouble.

Case No. 19—While this number is used to designate a specific locality, it will embrace a number of minor occurrences within a stretch of country about five miles long, lying approximately one hundred and fifty feet above the river bottom. Portions of this mesa are seeped and a drainage system has been put in, with what results I am not able to state, but it is claimed that it has been of benefit.

This section was scarcely more than referred to in Bulletin 155, as only two analyses, one of an alkali, Laboratory No. 595, and the other of the water-soluble portion of a soil, Laboratory No. 588, were given with a very meagre statement of the conditions. These samples were taken in 1907. It is true that attempts have been made to drain the land since that time, and the water conditions have doubtlessly been ameliorated, but this nitrate condition has, in my judgment, become more intense, for in 1909 and 1910 there were many patches of nitrates which could not escape the attention of anyone, and which were not present in 1907; besides, the analyses of samples taken in 1907 are by no means so rich in nitric acid as the samples gathered in 1909 and 1910.

There are many points in regard to which my information is not satisfactory, for instance, it is almost impossible, at this time, to obtain reliable data relative to conditions only a few years ago. The properties have changed hands and the present owners will very often make positive statements about conditions which cannot be substantiated. The fact is that they are so averse to acknowledging ignorance of these things that they prefer to give you such statements as it pleases them to make. The owner of the land which is, perhaps, becoming worse each succeeding year does not like to rehearse his misfortunes, especially if he suspects that you may be a prospective buyer of his or other property in the neighborhood. Many of them feel that it is disloyalty to their community to acknowledge patent facts. This trait, in their judgment, and in that of many others, may be wholly praiseworthy, but it hinders greatly in a study of this sort in which one has, in a measure, to depend upon the testimony of the residents for many facts in the recent history of a section. That there was a period of greater prosperity for this section is attested by the remnants of orchards, fields which a few years ago were productive, abandoned houses now falling into decay, etc. These witnesses to the very poor judgment of former occupants or to a period of better conditions, are usually dependable, but we must determine which of the two it is.

I believe that there is no doubt but that the settlers of this section suffered many disappointments and that while events showed that they misjudged the difficulties, they had at the time no way of recognizing these difficulties, or of knowing how serious they were. In portions of this section the water plane in 1889 was, according to the information that I have been able to obtain, twelve feet below the surface. In October, 1907, I found it four feet below the surface. How much it had been recently affected by the irrigation of neighboring lands I do not know. Here is a difference of eight feet in the height of the water plane, and why this water did not drain out was not apparent. In 1907 a very considerable area of this land was seeped and there was some nitrate present but not enough to become an easily recognized feature. Drainage has since that date been introduced on a considerable scale and in 1909 and 1910 nitre spots were recognizable in many places. I wish at the present time simply to record the sequence of facts. I will first consider a piece of land, a part of which had been planted to barley and a part to oats. The whole piece measured several acres. Both the barley and oats had been creased for irrigation after sowing. In very many places there were no oat or barley plants between the creases. The seed had never come up, or the young plants had been killed. There were abundant indications that the latter had been the case, whether the former had been or not, but from my observations on other areas I have no doubt but that it, too, was the case here. i. e., that much of the seed did not come up. The plants were confined to the sides of the creases just above the edge of the water. The bottom of the crease or furrow was, of course, free from plants, and the crown between the creases was brown and barren and extremely mealy.

The question of where the water which had raised the water table in the years between 1889 and 1907, eight feet, came from is appropos. So far as I know this rise was wholly due to the irrigation of these lands, in other words, this section does not receive the drainage from other lands higher than it.

I did not attempt to take a sample of this soil, only one of the mealy surface portion. The sample, 981, was taken with an irrigating shovel and I probably took some of the soil as deep as two inches. This sample as taken contained 28.44 percent of its weight, air-dried, which was soluble in water. It is no wonder that the oats and barley died. This is so great an excess of salts that one is tempted to ask whether sodic sulfate or any other relatively innocuous salt would not have sufficed to account for the conditions presented. I will record the facts as I find them, here as elsewhere, without regard to the question of whether they appear to be in harmony with my views or not. The quantity of soluble salts in this surface, mealy soil is exceptionally high and contains an unusually large amount of organic matter for our samples. In judging this amount and the effects of the salts in this sample it must be borne in mind that it was taken to represent the surface portion only and the fact that I possibly got some portion of the sample at a depth of two inches was an accident due to the fact that I took it with a round-pointed shovel. The great bulk of the sample was made up of the mealy, almost dry, surface portion. This did not form an incrustation of effloresced salts, as we often find where the common white alkali prevails. Professor Sackett tells me that the soil extract made from the surface sample which he took failed to develop azotobacter in his culture medium. They had probably been killed as well as the other plants due to the concentration of the salts. This is not the only sample in which this has been found to be the case. In the case of Orchard No. 2, Bulletin 155, pages 13 to 17, we found this to be true. Samples from the surface of excessively bad portions gave no development of azotobacter, whereas samples from below the surface or at or near the edge of the bad territory gave a very abundant development. It is therefore, quite what might be expected, i. e., to find this ground, so extremely rich in soluble salts, devoidof azotobacter.

The following samples are from the same section of country but not from the same place. No. 590 and 595 are from the same place but 981 is from another, a mile or possibly more north of it. I used the term spots in describing these occurrences in Bulletin 155 and again spoke of the nitrates occurring in almost continuous but irregular areas, but have not deemed it necessary to give analyses of alkalis and soils outside of these areas except in Case 8, as the amount of the nitrates are so unusual that I have deemed it unnecessary. Samples 590 and 595 are from the same piece of land and taken not far from each other on the same date. They were both originally taken as samples of alkalis, as we were studying, at that time, the effects of alkalis and the maximum amount of them compatible with good crops, etc.

The water-soluble equalled in 590, 7.57, in 595, 33.33 and in 981, 28.44 percent. Samples 590 and 595 were collected in 1907 and 981 in 1910.

ANALYSES	LXIV Water-Soluble Laboratory No. 590 Percent	LXV Water-Soluble Laboratory No. 595 Percent	LXVI Water-Soluble Laboratory No. 981 Percent
Calcic sulfate	19.561	9.102	3.651
Magnesic sulfate	11.236	8.076	3.558
Potassic sulfate	1.039	——	1.034
Sodic sulfate	52.457	56.254	70.746
Sodic chlorid	10.827	22.609	16.109
Sodic nitrate	Trace	2.771	4.854
Sodic silicate	0.247	0.308	——
Silicic acid	——	——	0.048
Loss	(4.633)	0.880	——
	100.000	100.000	100.000

Another sample of soil, 826, taken about one mile and a half south of No. 981, and a year previous, is interesting because the occurrence was a new one at the time. It was on the face of a low bank where they had plowed and scraped out dirt in working the road. I am quite familiar with this road as it is a section in which I have observed the alkali question for going on five years, and I feel quite safe in making the statement that the occurrence was one which had appeared there within a few months, certainly within a single season. I do not know how deep the water table was at this place but the land was so high that seepage would not ordinarily be thought of; in this case, however, the presence of so large an amount of soluble salts, 16.30 percent, will appear to some as indicative of a seeped conditon. In this connection I repeat again the observation that I have not yet found this condition in places where the water table is near the surface of the ground, especially if it is permanently near the surface, but in such places as have an abundant, but not an excessive, water supply. I do not pretend to know all the conditions which are necessary to determine the development of these nitrates, but that water is one of the conditions is very evident. For in ground that is in good condition, with which, ordinarily speaking, no fault can justly be found they, the azotobacter, will develop along the margins of irrigating furrows; again, they are apt to develop near a ditch, even on level ground, and are especially liable to appear on the outside of a ditch bank where the apparently flourish.

Under the caption of Case No. 8, I have given, it appears to me, conclusive proof that neither the alkali, nor the soil, nor yet the ground water contained any nitrates, still the outside of a ditch bank running beside this land, practically running through it, is almost or quite black in color, which color is continuous for considerable distances, and the surface soil is decidedly rich in nitrates. This color is not due to the wetness of the soil, nor to the alkalis, including calcic and sodic chlorid, in the usual use of this term but to the presence of azotobacter and nitrates which do not come from the adjacent land or the ground water, nor from the water that flows in the ditch, but are developed in the soil, and the controlling factor in this case is the constant and abundant supply of moisture. To some the facts given may not be fully convincing that the nitrates are formed *in situ*—to me they are, but we will give, in the proper place, further proof that this is so. This is true, too, of the sample which we are discussing; the ground is not seeped but there is a ditch perhaps ten feet away which probably furnishes the necessary moisture. I do not know why this had not developed in this place prior to 1909, but it was there in 1909 and I had not seen it there before. This and the next following samples were taken during a shower and I have made no notes of how the samples were taken. They may have been, and probably were, shoveled up hastily as it was not a good time for making notes. The samples were taken to learn the character of these surface salts. This accounts for the high content in water-soluble which amounts in No. 826 to 16.30 percent, and in No. 822 to 32.07 percent. The latter sample, No. 822, was taken a mile or more south of sample No. 826 and near to the edge of an alfalfa field which was in good condition at the time, and so far as I know is at this time. There was, however, a depression immediately south of this which is, at times, filled with water.

ANALYSES	LXVII Water-Soluble Laboratory No. 826 Percent	LXVIII Water-Soluble Laboratory No. 822 Percent
Calcic sulfate	16.044	7.973
Magnesic sulfate	8.411	7.911
Potassic sulfate	1.074	0.999
Sodic sulfate	49.623	73.105
Sodic chlorid	22.345	9.074
Sodic nitrate	2.394	0.839
Iron and Aluminic oxid	———	0.040
Silicate acid	0.109	0.059
	100.000	100.000

The territory from which the last five samples were gathered is above the shales which were described and analyses of which were given in Bulletin 155 pp. 28 and 29, Laboratory No. 645, and while this locality is not the one referred to in explaining the occurrence of nitrates in certain waters and in the shales themselves in which I state, "The occurrence of nitrates in the waters and apparently in the shales is susceptible of an easy explanation, i. e., the nitre spots which are only exaggerated instances of a general condition, occur in lands above the shales," it exemplifies the condition described in a most satisfactory manner.

The following analyses of a soil and its aqueous extract will help to give a fuller view of the general state of affairs in this section. The soil was, of course, strongly impregnated with alkali, and judging from the age of the orchard that occupied it, had been under cultivation for a number of years, not less than fifteen, and probably more than twenty. The water-soluble equalled 6.65 percent of the air-dried soil.

ANALYSIS	LXIX Soil Laboratory No. 588 Percent
Sand	42.745
Silicic acid (sol.)	26.526
Sulfuric acid	3.187
Chlorin	1.799
Phosphoric acid	0.111
Carbonic acid	1.345
Lime	3.634
Magnesia	2.032
Sodic oxid	4.020
Potassic oxid	1.191
Ferric oxid	3.792
Aluminic oxid	5.483
Manganic oxid (br.)	0.113
Ignition	(4.428)
Sum	100.406
Oxygen equiv. to chlorin	0.406
Total	100.000

ANALYSIS	LXX Water-Soluble Laboratory No. 588 Percent
Calcic sulfate	22.550
Magnesic sulfate	7.381
Potassic sulfate	2.468
Sodic sulfate	36.168
Sodic chlorid	24.884
Sodic nitrate	6.297
Silicic acid	0.252
	100.000

It is difficult to see how the drain waters from such a section, abounding as this has during the past year in such spots, can fail to be comparatively rich in nitrates. Analyses of two drain waters, and two seepage water were given in Bulletin 155. The two seepage waters were from the base of another mesa, but in this general section of country; the two drain waters were from an entirely different section of the country but one where similar conditions prevailed. We are justified by these facts in assuming

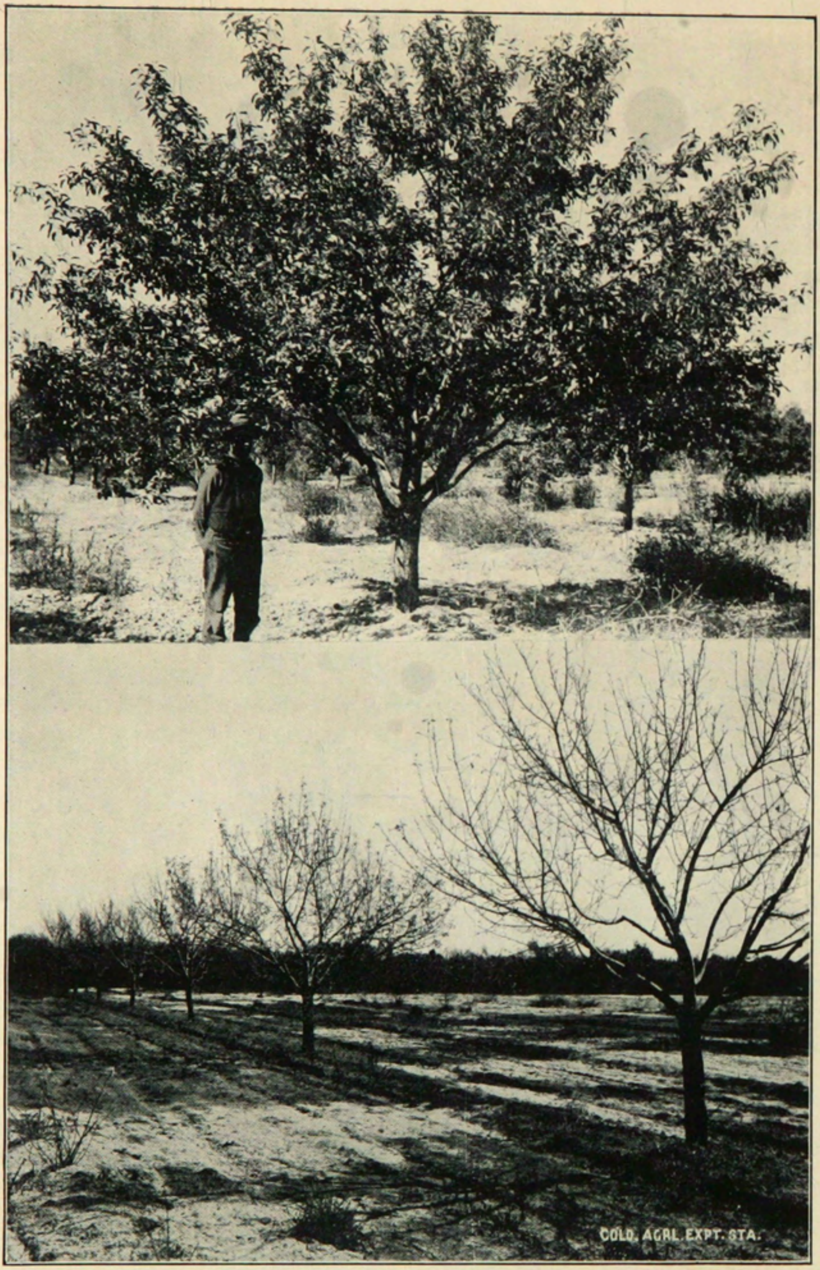

PLATE V.—See pages 62 and 63.
No. 1 is the upper figure

that the seepage and drain water from this area contain nitrates enough to account for all the nitrates which we found in the shales which actually underlie this mesa.

Case No. 20— On page 19, Bulletin 155, I gave a very brief description of the conditions obtaining in the field where our Laboratory No. 680 was collected. I mention it again merely to give the salient features of its condition in 1910, a little over two years after that sample was taken. The land was described as having been an oat field in 1907; the surface was stated to be puffed up and mealy. A sample taken to a depth of two inches yielded 5.42 percent of water-soluble salts salts which contained nitric acid equivalent to 21.719 percent of sodic nitrate. This land was in very bad condition in 1909 and barren in 1910. Of the original 25 acres more than 15 acres (estimated) has been rendered valueless by the combined effects of the seepage and nitrates. What the seepage has not ruined the nitre has, with the exception of possibly ten acres or less. The following four samples were gathered in September, 1909. No. 837 was gathered from a portion of the field where the water had probably done no damage, but where there was much white alkali. The water-soluble equalled 12.96 percent of the air-dried sample. My field notes mention the fact that the brown spots appear on the outer or upper edge of the white alkali. This is a sample of such material as occurs in these mixed spots. No. 839 is a soil sample taken from beneath a brown spot after the surface portion had been removed. The sample represents six inches of soil, five to ten inches inclusive. The water-soluble equalled 12.67 percent. Nos. 841 and 842 are samples of the "black alkali" from different places in the field. The water-soluble equalled 10.30 and 10.40 percent respectively. This land, where these samples were taken, was still in pretty good condition in February, 1908, but in September, 1909, the land was already in bad condition, and in July, 1910 I have entered the note that this land was ruined. There still remained from five to seven acres of winter wheat which was very fine indeed. No samples were taken in July, 1910, because a very heavy rain had fallen only a few hours before my visit.

ANALYSES	LXXI	LXXII	LXXIII	LXXIV
	Water-Soluble Laboratory No. 837 Sept. 22, 1909	Water-Soluble Laboratory No. 839 Sept. 22, 1909	Water-Soluble Laboratory No. 841 Sept. 22, 1909	Water-Soluble Laboratory No. 842 Sept. 22, 1909
	Percent	Percent	Percent	Percent
Calcic sulfate	1.086	41.538	12.503	8.719
Calcic chlorid	—	3.675	23.624	28.047
Magnesic sulfate	20.124	—	—	—
Magnesic chlorid	—	9.802	3.655	2.952
Magnesic nitrate	—	—	20.699	20.522
Potassic sulfate	1.404	—	—	—
Potassic chlorid	—	2.369	—	—
Potassic nitrate	—	—	4.899	4.021
Sodic sulfate	14.854	—	—	—
Sodic chlorid	26.067	1.589	—	—
Sodic nitrate	36.078	40.258	33.820	35.077
Iron and Aluminic oxid	0.285	0.452	0.323	0.247
Silicic acid	0.102	0.317	0.397	0.415
	100.000	100.000	100.000	100.000

The location of this land is such that we cannot account for the presence of the large amount of nitrates by supposing them to have been brought into the area by surface waters and scarcely by underground flows. The seepage in this case is probably largely due to leakage from an irrigating ditch and in some measure to the excessive use of water by a neighbor, but the acreage from which such water might come is too small to account for the conditions as we find them. This land, like the most of our lands, contains the so-called alkalis.

Case No. 21—This is the same as No. 4 given in Bulletin 155, page 18. The reason for mentioning it is that it presents conditions which contrast quite strongly with the last instances given under the captions of Nos. 19 and 20. This piece of ground has been so dry every time that I have visited it, that it has seemed impossible that the nitrates should develop if I am correct that there is a minimum quantity of water necessary for its most rapid development, and that this minimum is rather high. Without having made any experiments to determine this amount I would judge it, according to my observations, to be above 18 percent of the weight of the soil. The bacteria can, without doubt, survive long and pretty thorough drying, and if a favorable degree of moisture be supplied at any time they are ready to develop. Whether they be able to endure greater changes in conditions than other kinds of bacteria or not is a question that I know nothing about, but unless I am greatly in error in the whole matter, the conditions in the present case become of considerable interest in this discussion. In discussing Nos. 19 and 20, as well as in my statement of the general proposition, I have connected it so closely with that of seepage that some may infer, as I know that some have already done, that there is no nitre problem independent of seepage even though I have, perhaps, gone almost to a ludicrous extent in digging holes and giving the depth of the water table, the character of the soil and the drainage conditions to show that the death of the trees and other vegetation had not been brought about by an excess of water *per se,* and I have further given analytical data, as it seems to me in superabundance, to show that it is not due to an excessive amount of other salts which we think may be injurious.

I shall deal with this latter subject more fully in another bulletin, wherein I shall try to set forth more facts in detail which pertain to the effects of the presence of excessive water, large quantities of alkalis, and the presence of nitre—for the time being it will suffice for the fair-minded to consider that in the most disastrous cases—and I use this adjective advisedly, granting the reader the privilege of reading into it as much pessimism and prophecy as he may desire—that I have described; have been on land which has been set to orchards for from twelve to twenty-eight years, well drained and otherwise well cared for, in some cases it has been excessively irrigated to combat this very trouble, which shows that in some cases the natural conditions and the intelligent efforts of men have combined to prevent the accumulation of either water or salts leached from adjacent lands, which we have furthermore shown do not contain nitrates, and yet we have recorded the utter destruction of a twenty-seven or twenty-eight-year-old orchard in the short period of six weeks. If this were the only destruction wrought I would not at all be justified in using the language that I have used, or even in presenting the subject, except from its purely scientific side, but it is not a thing which has happened in one piece of land, nor in twenty pieces of land, but in very many pieces scattered over hundreds of square miles—not in patches of a few square feet but in large areas which, though irregular in contour are practically continuous for five, ten or even more miles. While the scientific features of the problem are of primary interest to me and the most of my readers, the magnitude of the land values involved and the questions of the future add reality and an importance to this question which the public has failed to recognize, or recognizing fear to acknowledge. There is a saying the "Fools rush in where angels fear to tread." Perhaps I have done this. Neither my folly nor courage alters the fact that the damage already wrought is immense, and I have elsewhere stated that unless something intervenes—what it may be we cannot forsee—the situation is serious. This is the practical side of the question.

The conditions obtaining in this case are the justification for presenting it as they emphasize the distinctness of this question from those of seepage and alkali. The land is on a hillside with a south and southwest aspect. Six years or more ago water was stored in a reservoir in the northeast corner of the field. My information is that this reservoir was used for about four years but has not been used within the past six years. The field was in alfalfa four years ago. It was broken up and in 1908, set to apple trees. The area is, I think, 20 acres, possibly more. About four acres of the trees died. This land was reset in the spring of 1909. So good as none of the new trees lived. By midsummer of 1909 the area of dead trees had extended to twice its original size. In 1910 there are from twelve to fifteen acres on which but few trees are living.

Plate VI, lower Fig., a photograph taken Oct. 29, 1910, shows how large a portion of this field is wholly barren, not even Russian thistles or other weeds being able to grow on it. The rows that show in the plate are furrows between the rows of corn planted this season but which did not grow. That the land has been irrigated this season and the last time, at least, with a good flow of water is evidenced by the washing of the soil in the bottom of the furrows. Aside from this one piece of evidence most observers of this crop and the trees would raise the question whether the land had not suffered from neglect at the hands of the manager and for the want of water. I did not attempt to determine the depth of the watre table in this case as there is a deep wash at the west side of this hill not more than a few feet from the corner of this field, and there is, at this place, no water coming in above the bed of the wash. This land is underlaid by a shale at varying depths in different parts of the field. The trouble in this case began prior to 1907, as I was informed, somewhere about the middle of the land shown in the foreground of the plate. I took a sample of the surface soil in March, 1909, and another October 29, 1910, from almost the same place in the field. The former was taken to a depth of two inches, and the latter to a depth of four inches.

The analyses of the water-soluble portion of the two samples follow:

ANALYSES	LXXV	LXXVI
	Water-Soluble Laboratory No. 759	Water-Soluble Laboratory No. 1026
	Percent	Percent
Calcic sulfate	18.986	26.940
Magnesic sulfate	29.771	19.972
Potassic sulfate	1.387	1.109
Sodic sulfate	39.914	43.117
Sodic chlorid	1.474	1.661
Sodic nitrate	8.173	6.631
Ferric and Aluminic oxid	——	0.348
Silicic acid	0.295	0.222
	100.000	100.000

The water-soluble in No. 759 amounted to 8.23 percent of the air-dried mass; that in No. 1026 to 5.277 percent. These samples were taken nineteen months apart. The difference in the depths to which the samples were taken is unfortunate as the reader will be apt to overlook this in comparing them. I found No. 1026 entirely free from chlorin after the third washing, but the sample was rich in calcic sulfate and some difficulty was experienced in washing out the last of it as it was almost impossible to filter the well washed soil. The difference in the amount of water-soluble is less than one might expect, considering the different depths to which they were taken.

Cases Nos. 22 and 23—These are adjoining orchards and ordinarily would be considered as cases of seeped land. I shall say but little about orchard No. 23 for all that may be said of No. 22 is applicable to No. 23, except that No. 22 is a more recent development. The soil of these orchards is mostly a sandy loam but in places this is either underlaid or wholly displaced by gumbo, a calcareous, clayey soil which when thoroughly wet retains water wonderfully well. We attempted to dig a hole in one of these orchards but the ground was so tough that we abandoned digging and tried to force a bar down to water. We were assured before we began that we would not succeed, not only because of the character of the ground, but also because the water was not so near the surface as we imagined. We succeeded in putting the hole down nearly four feet but without striking water; the gumbo was, however, extremely sticky. An idea of the manner in which this soil holds water may be conveyed by the fact, related to me, that shortly after we dug this hole a heavy shower filled it with water which did not seem to pass into the soil at all and was removed apparently by evaporation. That this ground was not always in this condition is proven by the fact that the apple and other fruit trees had lived for thirteen years and made a good growth in this soil. Further, the dying of the trees in parts of this orchard in which these conditions do not obtain shows that the wet, sticky conditions did not kill the trees but are themselves caused by the conditions which bring about the death of the trees. I have elsewhere suggested this because of the peculiar condition met with in the soil, but in this case because it seems to follow directly after the other trouble. The statement has been made in connection with several orchards that while the soil itself was practically a mud there was no proper water table found at depths of six to six and one-half feet. In the present case we did not succeed in digging to a greater depth than a little less than four feet, but the house stands at the edge of the orchard and a little lower if anything than the point where we tried to dig. The cellar under the house is stated to be about eight feet deep in which water rises and falls with the seasons. From this we found that at the lower edge of this very bad area the water plane was almost exactly six feet below the surface, at the end of the irrigating season. The cellar was dry when dug, now six years ago.

This orchard has taught us quite a number of things. We have been able to observe the death of the trees in a zone at the edge of this bad area just as the brown color extended. There was no trouble during the thirteen years of the life of the trees when no "black alkali" appeared, but as soon as this "black alkali" appeared the trees began to die; some of them began to burn and died within two weeks. From one-half to three-fourths of an acre died between August 18 and October 29, 1910, while other trees not more than twenty-five feet away remained in fine condition. In this case the trouble continued to spread till the end of the season. I did not learn whether there was any relation between the times of irrigation and the virulence of the attack on the trees and the rate of their dying. The manager has recently written to me that he irrigated this orchard about the first of December, 1910, and that the surface of the ground became intensely brown immediately after the application of the water even at the north end.

A hole dug just north of this orchard encountered a little water at four and a half feet, but the shale beneath this, to a depth of five feet more was entirely dry. A tile drain has been laid the entire length of the north side, varying from four to six feet in depth. My information is, that it is entirely dry.

The water is not in the irrigating ditch long enough, during the season, to affect the area in question. I asked the manager of this orchard repeatedly in regard to the possibility of the trouble being due to water and he as often repeated his answer that he could not believe it to be due to this cause. The depth of the water table, as shown by the water in the cellar, six feet, with very little variation throughout the year, supported his view. The water table, as indicated by the water in this cellar on December 28, 1910, was seven feet two inches, giving us a variation of fourteen inches for the year. The accompanying plates from photographs kindly furnished me by Professor Sackett, illustrate the condition of the land and orchard October 29, 1910. Fig. 1 indicates the upper and Fig. 2 the lower figure in the plate. Plate V shows the condition of a Paragon tree which had not been affected at the time the photograph was taken while Fig. 2, Plate III, shows a tree which died between August 18 and October 29. The tree at the extreme right of Fig. 2, Plate V is the next tree immediately east of Fig. 1, same Plate. Fig. 1, Plate V shows no brown areas while Fig 2 shows them very well. Fig. 2, Plate III shows a tree killed since August 18 and entirely denuded of leaves. The photograph looks southward and shows that portion of the land from which the trees had been removed. There was white alkali showing on a portion of this area at the time the picture was taken but it cannot be distinguished from the sunshine on unstained ground. The white patches in the other figures are due to sunshine. Fig. 1, Plate V looks westward into that portion of the orchard not yet affected. Fig. 2 of the same plate looks eastward across the affected area. Fig. 2, Plate III looks southward across the worst portion of the land while Fig. 2, Plate IV looks northward toward the still healthy portion of the orchard as the background shows. It will be noticed that the third row and even some trees in the second row were in good condition at the time the picture was taken, October 29, 1910, but they died so rapidly that in the spring of 1911 five rows of these trees including the row of dead trees in the foreground were dug up and by June four more rows of trees had been killed.

The following are analyses of white alkali, water-soluble portions of this soil, and the ground water.

Laboratory No. 996, white alkali within bad area, 18.67 percent soluble in water.

Laboratory No. 1027, white alkali within area where trees were killed, 22.71 percent soluble in water.

Laboratory No. 1029, soil from orchard designated, Case 23, surface of soil brown, trees dying, 11.44 percent soluble in water.

Laboratory No. 999, water taken from cellar August 18, 1910, total solids 14,230 p. p. m.

Laboratory No. 1040, water taken from cellar December 28, 1910, total solids 17,561 p. p. m.

Laboratory No. 1028, surface soil, composite sample, one to two inches deep. No white alkali, trees dead, 3.11 percent soluble in water.

Laboratory No. 1046, brown, mealy soil four inches deep, composite sample, 1.29 percent soluble in water.

Laboratory No. 1041, water collected from sixteen-foot hole January 6, 1911, total solids 22,100 p. p. m.

ANALYSES	LXXVII	LXXVIII	LXXIX	LXXX
	Water-Soluble Laboratory No. 996 Aug. 18, 1910	Water-Soluble Laboratory No. 1027 Oct. 29, 1910	Water-Soluble Laboratory No. 1029 Oct. 29, 1910	Water-Residue Laboratory No. 999 Aug. 18, 1910
	Percent	Percent	Percent	Percent
Calcic sulfate	7.607	8.979	18.873	4.942
Calcic carbonate	———	———	———	4.536
Magnesic sulfate	31.447	24.794	36.407	19.604
Potassic sulfate	3.986	0.859	1.330	0.719
Sodic sulfate	52.776	56.877	28.816	59.415
Sodic chlorid	4.137	4.332	8.235	7.214
Sodic nitrate	———	4.017	6.094	3.688
Iron and Aluminic oxid	———	Trace	0.076	0.085
Silicic acid	0.047	0.142	0.169	0.117
	100.000	100.000	100.000	100.000

ANALYSES	LXXXI	LXXXII	LXXXIII	LXXXIV
	Water-Residue Laboratory No. 1040 Dec. 28, 1910	Water-Soluble Laboratory No. 1028 Oct. 29, 1910	Water-Soluble Laboratory No. 1046 Feb. 1, 1911	Water-Residue Laboratory No. 1041 Jan. 11. 1911
	Percent	Percent	Percent	Percent
Calcic sulfate	10.946	41.451	44.886	6.208
Magnesic sulfate	41.809	6.020	0.081	37.659
Magnesic chlorid	———	9.296	8.768	———
Potassic sulfate	1.012	———	———	1.210
Potassic chlorid	———	1.021	2.727	———
Sodic sulfate	33.267	———	———	51.876
Sodic carbonate	———	———	———	2.422
Sodic chlorid	7.726	19.234	15.847	0.556
Sodic nitrate	5.083	21.377	26.640	none
Iron and Aluminic oxid	0.080	1.203	———	———
Silicic acid	0.077	0.398	1.051	0.069
	100.000	100.000	100.000	100.000

This orchard presents three distinct problems—seepage, alkali, and nitre, which questions present themselves in the following forms, First, has the water collected in this area to such an extent as to make the land unfit for ordinary agricultural purposes unless it be drained? Second, is the concentration of the so-called alkalis so great that they alone have caused the difficulties? Third, have the nitrates brought about this soil condition and also caused the death of the trees?

I simply state the facts as we have found them and as they are exhibited by the analyses given. I long ago made the assertion that Colorado has no alkali question which does not resolve itself into one of drainage, and again, that I have not seen any crop seriously injured by alkali alone though I have seen some crops drowned out. Even soils that are very rich in the sulfates of soda, magnesia and lime will, if they be not at the same time all too wet, grow crops, sometimes good ones. In these cases it is the water rather than the alkali that does the damage. This is not the case with nitre, it kills trees and other plants in a characteristic

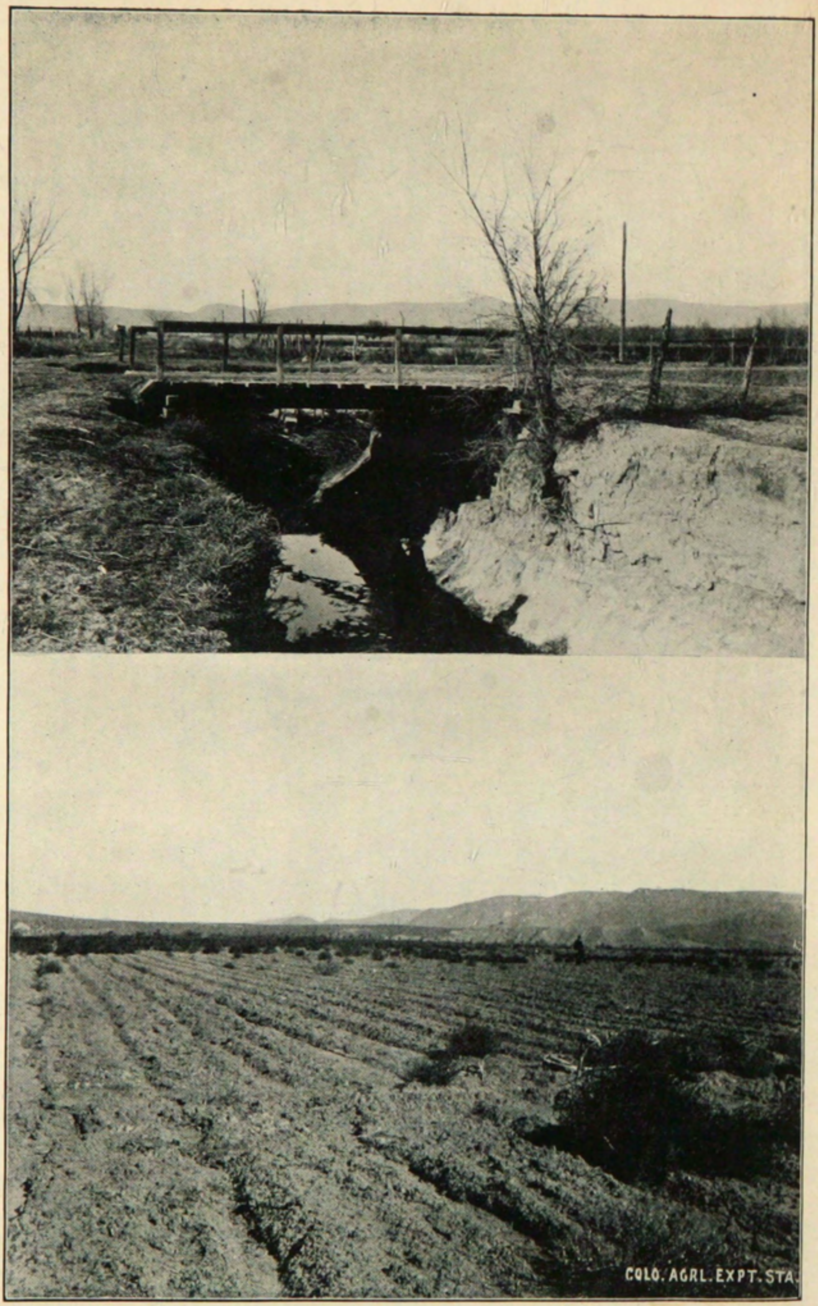

PLATE VI.—Upper Fig. represents wash mentioned in Case 13, p. 35. See also p. 60.

No. 1 is the upper figure

way when there is no excess of water, as we have demonstrated by experiments.

In regard to the water question in this case the facts are not clear. I have given the depth of the water plane as seven feet and stated that the annual variation above this is probably not more than ten or twelve inches. These statements are based upon the heighth of the water in the cellar of the house standing at the lower edge of the low portion of this land and also upon the results obtained by digging a hole nine feet deep and extending it by means of a post-hole auger to sixteen feet when the water rose to within seven feet of the surface. These figures were given to me by the manager of the property and are entirely reliable. The water at sixteen feet is evidently under some hydrostatic pressure but not enough to force it nearer to the surface than seven feet. The cellar referred to is a large one, 25x50 feet, and I think gives the true heighth of the water plane. These statements are not made to indicate that the surface of the land is not wet, for it is, but to indicate that the wet condition of the surface is not due to a high water plane but to surface waters. This water near the surface is probably none other than irrigation water, it is certainly not due to the run-off from heavy rainfalls, and is not due to leakage from an irrigating ditch to the north of the orchard. A salready stated holes or wells dug north of the orchard but south of the ditch did not show much water and a trench from fou rto six feet deep, dug the whole length of the orchard developed no water. The only water that could collect on this ground would be that used in irrigating about twenty acres of land. The orchard must no wbe fifteen years set and so the concentration of salts by washing and evaporation must have been going on this long at least. During this time, however, some may have been carried away by run-off waters.

Laboratory No. 996 is a sample of white, effloresced alkali and contained no nitrates. No. 1027 is a sample of surface soil and alkali taken two months later than No. 996 from another, but a very bad portion of the land, in my judgment, the worst. No. 1029 is a sample of alkali and soil taken from an adjoining orchard indicated as Case No. 23 which is wholly neglected by its owner and no further mention will be made of it. No. 1028 is the water-soluble portion of a soil sample taken October 28, 1910, one and one-half inches deep. There was no white alkali at this place and the soil was in fine condition, but the trees were dying, the water-soluble in this sample was 3.11 percent but the nitrates present were equal to 0.676 percent of the sample. No. 1046 is another sample of soil taken Feb. 1, 1911, about four inches deep. This sample was taken west of the bad ground by taking smaller samples, uniting them and cutting down the mass to a convenient size. The water-soluble equalled 1.25 percent of the soil and the nitrates amounted to 0.333 percent of the air-dried sample. No. 999 is the residue obtained by evaporating a sample of the water taken from the cellar, August 1910, to dryness. The residue equalled 996.1 grains per imperial gallon or 14,260 p. p. m., while No. 1040 is a similar sample taken December 28, 1910 carrying 1229.27 grains per imperial gallon or 17,561 p. p. m. These samples cannot be taken as actually representing the ground water owing to the fact that concentration due to evaporation must have taken place. The dimensions of this cellar as stated are 25x50 feet and while the house is built over it the cellar windows were open and we are uncertain in regard to the changes in it principally due to concentration. The first water observed in this cellar came in in the winter of 1908-1909 or about eighteen months before the sample 999 was taken and the analyses present the following results: the white alkali which had effloresced contained no nitrates; the white alkali mixed with some soil from slightly higher ground contained some nitrates, one twenty-fifth of the weight of the water-soluble; but the soils which would ordinarily be considered as free from alkali contain nitrates equal to one-quarter of the weight of the water-soluble.

The present owner of this land has put in upwards of 15,000 feet of tile drains. I saw about 7,000 feet of the trenches open in the very worst part of the land. The surface of the land was muddy as though they had recently had a heavy rain or the land had just been irrigated, the second spit was decidedly dryer than the first and while there was some water in the bottom of the trench, here and there filling the depressions made by uneven digging, by far the largest portion of it was entirely free from running water. I was very much surprised at the small amount of water appearing in so great an aggregate of trenches. It should, however, be stated that water flows out of such land with exceeding slowness. The fact was that the very surface of this bad land was the wettest portion of it and my impression is that this was always the rule with it. The land at the north end of the orchard is dry and, as previously stated, I was informed by two men, both interested in the success of the work, that the drain trench, from four to six feet deep, developed no water whatever. The effect of ground water upon the trees depends upon the depth at which the roots actually feed as well as upon the heighth of the water plane and the capillary power of the soil. I saw this trench when it was partially dug and I called the owner's attention to the fact that it was rarely the case that the roots were more than ten inches deep, though we occasionally found them, small fibrous roots, fourteen inches deep. The manager informs me that some of the trees in this section of the orchard burned in the autumn of 1910 which seems to be very probable as they are practically dead in the spring of 1911, in fact a number of trees have been dug up in this portion of the orchard, just how many I do not know, but all of the trees shown in our photographs taken in October, 1910, seventy-five of them, have been removed, but by June 3, 1911 many more trees, nine rows in all, back from the foremost row in Fig. 2, Plate IV have died since August 18, 1910. All of this land is in good physical condition, mellow, well cultivated and free from water.

The white alkali collected in August, 1910 shows no nitrates, that collected from a very bad spot, in October, shows a rather small percentage, 4.017, and as this was surface alkali and soil it does not necessarily indicate a large aggregate amount. The samples of soil taken where there was no white alkali, while giving a low percentage of water-soluble, showed the presence of very large amounts of nitrates, 21.377 and 26.640 percent. While the trees did not die last year, 1910, where these samples were taken, they did die in May of 1911 as soon as the trees put out their leaves.

All of these trees and all others referred to through this and previous bulletins as having been killed by nitre, die in the same manner, with the symptoms produced by the direct application of sodic nitrate.

The water samples in this case are particularly interesting. The samples taken from the cellar, one in August, the other in December, 1910, are both quite rich in nitrates. The richer one of the two carrying approximately one and a third tons per acre-foot of water. The important question is whence these nitrates? The water had begun to come into this cellar about twenty three months prior to the taking of the last sample and the significance of the results depends upon the answer given to this question. The natural, and in this case, correct answer is unquestionably from the surface. The sample of water, No. 1041, taken from a hole sixteen feet deep in all, is very much richer in total solids but contains no nitrates. I take it that this represents the ground water proper of the section and agrees with the ground water proper of other sections showing that the nitrates are not transported to the affected areas by this means.

The destruction of this orchard has proceeded very rapidly. It began in the early summer of 1910 and at this time, June, 1911, almost the whole of a fifteen-acre orchard has been destroyed.

Case No. 24.—This is a very interesting occurrence. The land was sown to sorghum in the summer of 1910, but the crop was a complete failure. There is a large irrigating ditch running possibly six hundred feet to the north of it. The land is somewhat low but there is an orchard close by, in fact is immediately south and east of it and without knowing the actual difference in level I would estimate it as not greater than two feet. The field immediately north of this property was in beets, which were very poor indeed. This fact is mentioned to indicate that the people still considered it as tillable ground. The question of seepage is of course suggested by its position, but I dug shallow holes three to three and a half feet deep on different occasions without striking water. I was surprised that the water plane was so deep as three feet, but it was evidently deeper. I expect to give in a subsequent bulletin the best possible proof that beets will grow well and yield beets of fine quality with the water plane much nearer the surface than this, and I have seen a fine growth of sorghum on land in which the drainage ditches were not as deep as this. While I willingly admit that in my judgment the people did unwisely to choose these pieces of land for cultivation, they probably did not believe that the land was seeped at the time of planting or was likely to become so during the season, and as I have already indicated, I found no reason for thinking that the water plane was at any time less than three feet below the surface. I dug one of the holes referred to in June, the other in September, 1910. The general conditions that prevail are as I have just described them, but these alone would scarcely have induced me to have made mention of this land, though it is one worthy of study in this connection.

Circumstances enable me to give a few facts pertaining to the effects of flooding. I stated in connection with Case No. 8 that the owner had irrigated excessively till, in his own language, he had "washed the ground white" in expectation that by so doing he would correct the evil. We had, however, no results except the continued bad condition of the land to indicate the effects. Further, I showed that the drainage of his land was ideal. Again in connection with Orchard No. 3, described in Bulletin 155, I stated that the owner of that orchard had treated some of his land in the most drastic manner in an endeavor to correct this difficulty by washing. This party had run a furrow with a turning plow, followed with a subsoil plow and turned into the furrow one hundred inches of water but without any satisfactory degree of success; this statement is very conservative. The last time that I saw this man's orchard it and some of his other land was in a very bad condition. This flooding had leveled the land but it had not removed, if it had indeed alleviated the trouble for any considerable time.

I can, fortunately, present the effects of flooding in removing the salts and benefiting the soil in this case. I chanced to be in this section of the state on the 12th of August, 1910, when, due to torrential rains, the piece of affected land was flooded for about five hours. The flood waters which swept acress it were several inches deep. I learned that about a week subsequent to this another flood, due to the same cause, covered this land to a depth of two feet and that it was twenty-four hours before these flood waters had entirely disappeared. The flow of these waters, as indicated by the straw, weeds and other debris lodged on the posts and fence wires, was evidently strong, and the depth assigned, i. e., two feet, was probably correct; furthermore it had left very little or no sediment. I had taken a sample of the mealy surface soil on June 6, 1910, so I was glad for the opportunity to obtain a sample of the surface soil from as nearly the same place as I could locate it from memory, on September 25, 1910, not more than thirty-five days after the last flood. On this date I dug a second hole to see how near to the surface the water plane might be, and as stated before it was not within three feet either in June before the floods or in September after them, so the drainage of this land must be reasonably efficient. I may add that the soil at this place was sandy to the depth that I dug, while that of the beet field north of it was heavier, inclining to clay.

ANALYSES	LXXXV Water-Soluble Laboratory No. 956 June 6, 1910 Percent	LXXXVI Water-Soluble Laboratory No. 1038 Sept. 25, 1910 Percent
Calcic sulfate	7.535	14.126
Magnesic sulfate	12.130	16.097
Potassic sulfate	3.154	2.777
Sodic sulfate	59.793	58.432
Sodic chlorid	13.361	6.934
Sodic nitrate	3.817	1.296
Silicic acid	0.210	0.338
	100.000	100.000

The water-soluble in No. 956, taken in June was equal to 15.35 percent of the air-dried sample, that in 1038, taken in September equalled 9.533 percent and the nitrates, as sodic nitrate, equalled 0.582 and 0.123 percent of the respective samples. It is really an accident that we are able to give these data relative to the effects of these floodings and while they are far from complete they may serve to give us some idea of what we may expect to accomplish by trying to wash the soil, i. e., it will be a much more difficult problem in practice than it is in theory. It would have been very interesting to have been able to determine the distribution of the nitrates in this land immediately after the second flood and to have determined the rate a which they made their reappearance at the surface, for a rapid evaporation must have taken place from the surface of this land at this season of the year. One, however, would think that the flowing of such a volume of water over this land, as occurred on these two occasions, would have extracted and removed the nitrates rather than to have carried them down into the soil, for it is to be remembered that this land was covered several inches deep by a mass of water moving at a rather rapid rate for five or more hours about August 12, and again about August 20, to a depth of two feet for twenty-four hours. How much nitrogen as nitrates this flood water may have contained I do not know but it could not have been any relatively large quantity. The waters of a reservoir used in irrigating this section of country contained only a trace when last analyzed, now several years ago, and the return waters as represented by a sample of river water analyzed at the same time contained 1.5 p. p. m. Further, this water flowed off of and did not evaporate on this land, so I do not think that the question of transported nitrates is to be considered. The sample taken in September indicates, so far as it is worthy of consideration, that these floods removed approximately four-fifths of the nitrates present as indicated by the sample taken in June.

Case No. 25—This case is given because it presents an example of drained land. The area is twelve acres; it is much longer than wide, the west and south sides being represented by an irregular curve, the field being bounded by a low hill, along the flank of which runs an irrigating ditch, but its supply of water is not good so it is often dry. The owner thought that the bad condition of the land was due to an excess of water. It is now something over five years ago that he put in three lines of tile drain, from four to six feet deep. I have no map of this drainage system but two of the lines, I was informed, run lengthwise of the field for its whole length, and the third one is a line run with the idea that it would intercept the water that leaks from the irrigating ditch and deliver it into the main drains. I do not know the depth of the water table, but I do not think that it is at any place materially above the depth of the drains, i. e., four feet. This land has now been planted to beets for five years in succession and the owner has never harvested a full crop off of all of the field, and for the past three years he has had so good as no crop at all. In October, 1909, I made a note to the effect that from one-fourth to one-third of the field was absolutely devoid of vegetation, even of weeds. I visited this field several times during the season of 1910, and if there was any difference the conditions were worse than in 1909, but they were very bad in both years and the crops were practically failures. Two roads intersect at the northeast corner of this field. The field east of this one and across the road was also planted to beets, the stand was in places poor, the ground brown and mealy; the beets were, as a whole, poor. The field northeast of it was not cultivated, its surface was brown and mealy, but the common sunflower was growing in spots and was very luxuriant. I took two samples of soil about three inches deep, one near the south end and the other from the north end, on October 11, 1909. The surface at this time showed nothing unusual as a rainfall of 0.83 of an inch had fallen three days before, on the eighth of the month. The surface at this time was not muddy or wet. The sample from the southern part of the field, Laboratory No. 867, contained 2. 564 percent; the one from the north end contained 3.315 percent of material soluble in water.

ANALYSES	LXXXVII	LXXXVIII
	Water-Soluble Laboratory No. 866 Oct. 11, 1909	Water-Soluble Laboratory No. 867 Oct. 11, 1909
	Percent	Percent
Calcic sulfate	28.672	32.729
Magnesic sulfate	14.156	11.468
Potassic sulfate	4.345	3.495
Sodic sulfate	28.779	18.150
Sodic chlorid	17.197	28.256
Sodic nitrate	6.435	5.410
Iron and Aluminic oxid	0.162	0.070
Silicic acid	0.254	0.422
	100.000	100.000

We have in each of these samples essentially 0.16 percent of the top three inches of the soil consisting of sodic nitrate or its equivalent in other nitrates. Even beets have not grown in this soil for four years.

Case No. 26—This is as typical a location for seepage as I think can be found anywhere, not excepting Cases Nos. 22 and 23. The difficulty here has been unhesitatingly designated by the double term seepage and alkali by all local parties concerned up to the present time. The configuration of the country at this place is that of a flat tract bordered on either side by rising ground, the flat section varying in width up to two hundred paces or more, through the central portion of which runs a drainage ditch three to four feet deep and about five feet wide. The portion of this higher strip of land in consideration is about twenty feet above the surface of the lower portion and from twenty-three to twenty-five feet above the bottom of the drainage ditch. Persons really familiar with drainage problems in Colorado will not be misled by the apparently simple condition stated above. In this case borings showed that the water table, in the lowest portion of the cultivated area, was, in November, five feet below the surface, and that the water table at a distance of six hundred and fifty feet south of the drainage ditch was only one foot above, while the surface of the ground at this point was six feet above the bottom of the ditch. As elsewhere stated we will subsequently show that the beet will thrive, producing a fair crop of excellent beets with the water table much nearer to the surface than this. Borings to a depth of six feet and more at points more remote, failed to reach the water plane. Though the water plane at the lower limit of cultivated ground was five feet below the surface the soil was wet at a depth of two to four inches. The highest portion of this tract is the southeastern corner. The slope is from this portion, north and west to the drainage ditch. The central portion of this strip of land was planted to beets in 1908, 1909 and 1910, but we do not at this time intend to say anything about the beets nor about the land planted to beets, but will consider only the cultivated land west of this. I regret that I have no photograph of this land, for it is exceedingly difficult for any reader who has not actually seen these things to understand even the most faithful description or to have any adequate appreciation of the facts. In 1910 this land was planted to sorghum. There was here and there a little of it that came up but for the most part it was a complete failure, the land being entirely bare except along the irrigating furrows or lateral where, at the margin, showing the limit of the running water, a few small, stunted plants survived. These plants were not more than a few, from three to eighteen, inches high. I took a sample of this soil on November 2, 1910, weighing about forty pounds, and to depths varying from four to six inches. This sample was taken for experiments in incubation, but a preliminary test showed that the soil extract gave very unsatisfactory results, in fact, it was a failure. The azotobacter seemed to have been killed. The water-soluble portion of this soil equalled 4.518 percent of the air-dried soil. A nitric acid determination made on this sample corresponded to sodic nitrate equal to 38.867 percent of this water-soluble or 1.756 percent of the air-dried soil, being at the rate of 70,240 pounds of sodic nitrate per acre-foot; or restricting the calculation to the top six inches actually taken, we have 35,120 pounds, or 17.56 tons per acre, a degree of concentration which is very difficult for those who know nothing about this matter to believe possible.

The water-soluble in the following sample, 1024, equalled 5.54 percent.

ANALYSIS LXXXIX

	Water-Soluble Laboratory No. 1024 Nov. 2, 1910 Percent
Calcic sulfate	18.377
Calcic chlorid	18.740
Magnesic chlorid	12.030
Potassic chlorid	1.882
Sodic chlorid	4.550
Sodic nitrate	32.997
Iron and Aluminic oxid	0.115
Silicic acid	0.219
	100.000

It is no wonder to me that the soil was mealy and barren and that our culture experiment showed no living azotobacter. The desirability of a series of nitric acid determinations as well as that of the total nitrogen in samples of such a soil taken at stated intervals is evident, but it has not been and scarcely will ever be feasible to prosecute this work in such detail in the field; there are other difficulties besides the remoteness of the locality from the laboratory. Had I forseen the developments that took place in this land in 1910 I could have arranged matters better. This is all that I wish to say about this case at the present time. I may say something more at a future time.

Case No. 27— This is a sample of earth taken from the roadside near a neighboring town. A vertical face of earth two and a half to three feet high left in working the road, as well as the flank of the road were decidedly brown and looked moist and oily. An irrigating ditch runs about sixty feet north of this point, the bottom of which is between four and six feet above it. There was no undue amount of moisture either at this point or on the other side of the road to indicate leakage from the ditch. The earth is a red, gypsiferous and somewhat sandy clay. The sample was taken from the surface, but a portion of it may have been more than an inch deep. The N_2O_5 present equalled 1.079 percent of the air-dried sample.

Cases Nos. 28 and 29—In this investigation only two occurrences of nitrates have been met with which must be considered as owing their origin to leaching from the soil. How far the nitrates in these two cases may have been transported is, as a fact, wholly unknown.

In the case which I have myself seen they probably came from the immediately surrounding country, as the line of hills about the place is not far away and the occurrence is clearly a surface one. These two occurrences are shallow wells, one of them twenty-seven feet deep, the other said to be forty feet deep. I have not seen the latter, the water of which was sent to me. We had a little over two litres of water to evaporate down. It was a mistake that we adopted this method of procedure but it was too late to change it when this occurred to me. The water was not a fresh sample when we analyzed it. The total solid equalled 560.8 grains per imperial gallon, 8,012 p. p. m. This water is yellow in color, has a bitter taste, foams strongly when poured or aigtated and had no odor though the sample was old when its container was opened.

The following analysis has been calculated to one hundred:

ANALYSIS

	XC Water-residue Laboratory No. 1202
	Percent
Calcic sulfate	35.926
Calcic chlorid	4.348
Calcic carbonate	5.105
Magnesic carbonate	4.095
Magnesic nitrate	44.939
Potassic nitrate	1.870
Sodic nitrate	3.717
	100.000

This analysis shows that the salts in solution are principally calcic and magnesic salts in which magnesic nitrate is particularly abundant. I know of this well only by correspondence . It was the only well in the neighborhood yielding such water, other wells near by yield sweet water.

The other well water to which I refer is also yellow. Its taste is at first cooling, afterwards bitter. It, too, foams on agitation or pouring. The well is twenty-seven feet deep, the water was encountered at the depth of twenty-three feet. The ground yielding it was described as one foot thick; no water came in below this. There was at the time I visited this place four feet of water in the well, i. e., the well was filled up to the top of the water-bearing zone. The well was not curbed except in the upper portion, but was provided with a ladder so that it was easy to go down into it. This well was sunk through a somewhat mottled clay. I took the mottling to be due to aggregations of calcic carbonate. This clay was tenacious enough to stand without peeling off or sloughing. There was no water entering above the twenty-three-foot point and no indications that any water had ever trickled down the sides. The owner has prospected his ranch for water by boring holes from eighteen to twenty-eight feet deep, without success. He has even dug a fifty-foot well which proved to be a dry one. This well is sunken for the most part in Niobrara shales. A little water, apparently a little pocket, was met with at a depth of forty feet. This was said to have been good water but there was no quantity of it. The well, with this exception, was dry when dug and is still dry. The striking of water in the first well seems to have been an accident. The flow is not strong and comes from the direction of the higher land. The owner stated that one man could not pump the well dry but that two men taking turns could pump it out. The water is unfit for any use, even for irrigation. There were a few hills of corn near the well which had been watered with this well water; the corn was burned and I doubt whether it will survive. There were also some onions which did not show any effects of it. This well is near the owner's house and on ground sloping to the south. The land which the owner prospected for water by borings is lower and at times is flooded by rain water. The surrounding country is not irrigated and the rain fall is not sufficient for the growing of crops. The owner, who is holding the land in the hope that sometime it will be brought under irrigation, stated that he had not gotten enough out of his crops to pay for the labor expended on them. The source of the nitrates contained in this water is unquestionably, I think, the higher lying surface soil to the north of this place. Why the water should be confined, as it apparently is, to this particular area is not evident. There is nothing in the contour of the country to suggest a reason. The first sample of this water that I had, one which was sent to the Station by the owner, contained 1819.5 grains per imperial gallon or 25,993.0 p. p. m., the sample which I collected myself and shipped in glass gave 1692.6 grains per imperial galon or 24,180.0 p. p. m.

ANALYSIS	XCI Water-residue Laboratory No. 1077 Percent
Calcic sulfate	9.553
Magnesic sulfate	56.650
Potassic sulfate	0.769
Sodic sulfate	6.142
Sodic chlorid	3.266
Sodic nitrate	22.480
Iron and Aluminic oxid	1.140
	100.000

The question of the existence of brown spots here would seem to be excluded. Brown spots of course are taken as a positive indication of the presence of nitrates and of azotobacter. Such a concentration of nitrates in surface waters like these calls for a most extraordinary supply of nitrates or a very long period of concentration and the separation of the accompanying "alkali" salts. The activity of the bacteria is conditioned by temperature, moisture and a neutral or an alkaline medium. The temperature and alkalinity prevail in this section and the only factor which is lacking is the moisture to bring about the formation of nitrates. The correctness of this view is indicated by the occurrence of the brown, greasy-looking spots along the irrigating ditch in a neighboring section of the country, where the land is similar though it is still native prairie. The conditions are not well enough known to justify definite assertions pro or con in these cases. I have not permitted myself to make any prophesises but simply to record the facts as I see them. It would, however, be very interesting to be able to watch the developments in this section for five years if it could now be supplied with an abundance of water for irrigation and we could grow a series of crops on these lands. This experiment, while altogether too big a one to be undertaken by an individual, will in all probability be made and while I cannot hope to be able to study it in detail, I do hope to be fortunate enough to be able to follow it in a general way. It will certainly be instructive to those who shall see it.

DISCUSSION

I have given a large number of cases but each case, with very few exceptions, represents different conditions—not only different from one another, but different from the conditions given in Bulletin 155. I have endeavored to give different conditions and at the same time widely separated localities and samples representative of large areas. The aggregate area described in Bulletin 155, was between eighty and one hundred acres. The area described in this bulletin aggregates more than three hundred acres, and does not include any of that described in Bulletin 155. This is only a very small part of the total area involved in the state. So far as its distribution throughout the state is concerned the areas given represent nine counties, extending from the Kansas boundary to that of Utah and from the Cache la Poudre to the Arkansas river, and even further south, to the New Mexican boundary.

The total percentage of the irrigated or cultivated lands affected by this trouble, to the extent of the instances given, is more considerable than we might wish, but it is not a large percentage of the whole, still if we consider it in square miles and bear in mind the value of the lands affected, as estimated by the owners, it becomes a very serious matter. The four hundred acres described in this and in Bulletin 155 are representative of large districts, I think that as a very conservative estimate we may state the districts affected as aggregating from three hundred to four hundred square miles. In a large portion of this territory the conditions are very bad. The most serious feature is that these very bad portions may only represent extreme developments of a general condition which exists in our soils which only awaits the occurrence of some optimum condition for its excessive development. One of the factors in this optimum condition is an ample and continuous supply of moisture.

The question of the influnece of the character of the soil has been frequently raised since the publication of Bulletin 155. The wet condition of two of the soils described in that bulletin tended to leave the impression that the whole trouble might be due to water, especially in the minds of readers who might consider the wet, muddy condition of the soil the only cause for the death of the trees, and not to consider this condition itself as the result of conditions other than the presence of water. It was distinctly and repeatedly stated in Bulletin 155 that the water in these cases was not free so as to form a water table at depths of six to six and a half feet. In the case of Orchard No. 3, I stated that the land where the sample of mealy, surface soil was taken was sandy and that the ground was only fairly moist at a depth of six feet. In Cases 5, 7, 8 and 9 we again have sandy and in part light clayey loam with sandy subsoils, and no excess of water at depths reached by the roots of the trees. In the Cases of Nos. 8 and 9 we have excellent drainage. In these cases, especially in the latter, the trouble can in no manner be attributed to an excess of water. Still Case No. 9 was one of the most severe ones that I have yet seen, though it is underlaid by a stratum of gravel at a depth of from five and one-half to eight feet. The same is true, in different measures, of Cases 10, 11 and 12. The soil in Case No. 10 is decidedly sandy with a stratum of coarse granitic gravel at a depth of only three feet and yet this land is in such bad condition that the owner has not yet, after repeated attempts, succeeded in getting his fruit trees, peaches and pears, to grow. In Case 12 a beautiful orchard has been destroyed outright in one season. This point is not a matter of opinion but one of fact, and for this reason so many cases, to which Cases Nos. 16 and 20 might be added, have been given. The conclusion is evident that the trouble is not due to the presence of an excess of water, nor to the character of the soil for these sandy soils have shown it to as great a degree as heavier clayey soils of which Cases Nos. 6 and 12 may be cited as examples. No. 6 is an especially bad case, but the results were no worse than in Case 9—they could not be, for two and one-half acres of large trees were killed within a few weeks. The attack in Case No. 6 was not so violent nor did it involve so much ground at one time.

The trouble is not to be attributed to ordinary alkali. In Case No. 8 a part of the orchard is free from the nitre but is rich in ordinary alkali; the trees have died only in the nitre area. There are many orchards scattered throughout the fruit growing sections which have been planted on ground rich in alkali, which are in good condition. Nearly every case cited in which an orchard is involved is one in illustration of this fact. Cases 5, 6, 7, 9, 11, 12 and 21 were old orchards, from fourteen to twenty-eight years old, in which the trees had thriven till within a few weeks before their death. The soils in these orchards are not richer in alkalis now than they have been in years past, nor richer than the soils of many other orchards which are still in a flourishing condition. Water does not kill so quickly nor in this manner.

The trouble in the cases of orchards is not at all related to the age of the trees, for trees of all ages have been killed. Older trees with large root systems seem to be more readily affected than younger trees but I have seen a nine and an eighteen-year-old tree standing within twenty-five feet of one anotner attacked and killed in practically the same time.

This trouble has spread very rapidly since the summer of 1909 when I first observed bad attacks in orchards. Orchards Nos. 1, 2, 3 and 4, mentioned in Bulletin 155, had been observed previous to that time, but during the past year, 1910, I have seen many orchards, distributed over a wide area, seriously injured. In former years I have seen no injury done in May or early June, but this year, 1911, the damage already wrought is large and the outlook is very ominous.

Orchard lands are by no means the only lands in which this trouble occurs, other lands are as badly affected as are the orchard lands, but orchard lands are conspicuous because of dead or dying trees, or of vacancies caused by the removal of dead trees. Cases 19, 20, 24, 25 and 26 are examples of ordinary cultivated lands.

Apple trees have been mentioned so nearly to the exclusion of others that one might think that the apple is the only tree or plant that is killed. This is not the case. The following trees and other plants have been noted: the apple, pear, peach, plum, apricot, cherry, quince, maple, cottonwood, ash, currant, grape, corn, tomato, bean, pumpkin, cantaloupe, pea, elm, willow, Lombardy poplar, Carolina poplar, sorghum, oats and barley.

I have made no experiments in addition to those recorded on pp. 43 and 44 of Bulletin 155, to demonstrate the effect of nitre on apple trees. The results of those experiments were stated as follows: "The effects were in all respects similar to those produced in the affected orchards, the beginning and progress of the effects, the killing of the leaves, the throwing out a few whitish-yellow leaves, their speedy death 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." The experiments, eight of them, were concordant and conclusive.

The only new thing that I have noticed during the past year in the deportment of these dying trees was their tendency to come into bloom in September and later. Sometimes a tree would put out quite a sprinkling of bloom.

The question of concentration of nitrates has also been suggested. I had this question in mind when, in Bulletin 155, I referred to the popular idea that the irrigating waters bring the "black alkali" to the surface, and discussed the fact that some seepage waters issuing from certain shale banks contain significant quantities of nitrates. It was then shown that the shales contained no more nitrates than could be readily accounted for by assuming their origin to be in the soils of the mesas above them, which assumption is suggested by the occurrence of areas which are very rich in nitrates on various parts of these mesas. Case 19 in which we find a very considerable number of such occurrences stretched along for a distance of probably five miles, is one in point. This area lies above and extends southward from the point where the shale sample showing 0.03 percent of nitrates was taken. The intensity of the fixition or fixation and nitrification which has taken place in this area is indicated by the analyses given in connection with this case. While many of these occurrences made their first appearance in 1909 and 1910, over 2.0 percent of nitrates was found in an alkali collected on this mesa in 1907 and the aqueous extract of a soil sample taken the same year, 1907, contained nitric acid equivalent to 6.00 percent of sodic nitrate calculated on water-soluble or nearly 0.40 percent calculated on the air-dried sample. It is evident that leaching from the shales cannot possibly account for the occurrence of nitrates in the soils many feet above them. A similar argument applies to all of the geological formations occurring within the affected territory, i. e., they are wholly inadequate to account for the observed occurrences which are found above as well as below the various strata which might be taken as illustrations; in other words, the occurrences are wholly independent of the geological formations.

It may be further mentioned that no other occurrences of nitrates have been found either in excavations, borings or elsewhere which might be considered the source of any of the nitrates. Again, as previously urged, the general distribution of these nitrate patches requires for its explanation the existence of some very widely distributed source or generally occurring cause.

The fact that these nitrate spots are generally associated with wet land has led to the idea that the ground and even ditch waters may be accountable for them and consequently that drainage will obviate the trouble. It would in some cases be of decided benefit to drain the lands, and might possibly change the location of the nitre area by changing the area in which the condition of optimum moisture prevails, but my observations lead me to have little hope for immediate and satisfactory results from drainage. In Case No. 8 I gave the conditions of the ground and those of adjacent lands in some detail for the purpose of showing that these adjacent lands do not furnish the nitrates and that the ground water would not, even if it flowed into this land, Case No. 8, account for the presence of any nitrates as they are not present in this ground water, nor yet are they, the nitrates, contained in the white, ordinary alkali of the surrounding lands which is essentially a mixture of sulfate and chlorid of sodium.

In regard to drainage, Cases Nos. 8 and 9, light clayey to sandy loam soils, with sandier subsoil underlaid by gravel, located on the river bank and from 12 to 15 feet higher than the river bed present ideal drainage conditions, and yet these cases presented, in 1909 and 1910, extreme instances of very high degrees of concentration of nitrates with most disastrous results, so far as the orchards and crops were concerned.

The ground water from the adjacent land but also the drain water from an adjoining similar soil showed actually less nitrates than is often present in good drinking waters, yet there is a very rich nitre patch near the river bank east of this drain. We have in this connection conclusively shown that such drain water cannot be the source of the nitrate. It is easy to suggest various explanations and remedial measures as applied to individual cases, especially if they are simply suggested explanations without regard to a wider range of facts, or suggested remedies never to be taken seriously as the basis of acts. The facts in such cases as have just been cited do not support these suggestions nor commend these remedies. Drainage, for instance, so far is I know, has given in these cases mostly disappointing results. Cases Nos. 8, 13, 15, 24 and 25 can all be interpreted in this sense. Apropos to this point I may mention the statement of a field agriculturist in answer to my question relative to the general results obtained by drainage; his answer was that they were generally more or less disappointing. We have cited two instances, Nos. 8 and 9, in which nature has made a perfect application of this remedy and it proved wholly inadequate to ward off or to mitigate the evil. I know of no more intense instance of this trouble than is presented in Case No. 9, while Case No. 8 is very bad. In the latter case the successive owners have combated the trouble persistently for about seven years. They have tried the application of extremely large quantities of manure, frequent and thorough cultivation, also frequent and excessive irrigation in the endeavor to wash out what they thought to be black alkali. Prior to 1904 there was no trouble with this portion of the field; it was as good and as productive as the rest of the land, but from that time on it has been bad and has slowly grown worse during the time that I have had it under observation.

It may be wise to state that it is not intended that any one should infer that I doubt the value of drainage in removing excessive water from land, but simply to state that at the present time I do not believe that we have much reason to hope for any material relief from this trouble by drainage, even in cases of comparatively low lands, while it is wholly out of the question in cases of high or naturally well drained lands. If these lands could be kept covered with water to a depth of several inches, twelve or more, for a number of days and then be thoroughly drained out the aerobic bacteria might in this way be killed off and the excess of nitrates removed; but this could be applied to small and favorably located areas only; the costs would be heavy and the permanency of any benefit doubtful. This, however, has not yet been tried.

Cases Nos. 8 and 24 of this bulletin and No. 3 of Bulletin 155 present the facts relative to what we may hope from flooding or persistent washing of the soil more fully than any others that have come under my observation. Case No. 8 is particularly instructive because the drainage is apparently perfect and it received twelve profuse irrigations in the season of 1909, and yet in 1910 the puffed and mealy condition of the soil was as bad as I had ever seen it and the surface soil was very rich in nitrates. The effort made in 1909 to wash out this soil was apparently futile, and we have shown by analyses of the soil, of alkali and of the ground water from adjacent lands that these nitrates do not come from these sources and the nitrates found in 1910 do not represent a resupply from this source. There is no question but that these nitrates can be temporarily washed out of the soil, but they were as abundant, if not more so, in 1910 than they were in 1909 when the land was irrigated twelve times in the endeavor to wash out the "black alkali." I have presented in Case No. 24 an analysis of a sample taken in June which, as I take it, represents the salts present in the surface soil under ordinary conditions; also of a second sample taken in September, because this ground was flooded twice in the month of August, once to a depth of two feet which required 24 hours to flow or drain off. The easy solubility of the nitrates makes it a matter of surprise that we should find about a month subsequent to the last flooding not only so large an amount of soluble salts but also so large a quantity of nitrates present. Case No. 3 was given in Bulletin 155; in this case the owner had tried for 16 years to bring these spots under subjection; he had plowed and flooded, but without success. I have not as yet seen or learned of any result obtained by flooding which gives any solid basis for expecting very permanent, beneficial results from this operation. Perhaps frequent and repeated flooding combined with drainage, where needed, might prove effective.

If the nitrates are not present in the various geological strata and there are no local deposits scattered all over large sections of the state in which we may find the source of these nitrates occurring in our soils, the question, Whence do they come? is germane.

The facts stated in connection with Case No. 8 are, I believe, perfectly applicable to all other cases and it can be stated, without any material modification, that these nitrates are not the product of concentration of ground waters flowing from other lands as they, these ground waters, contain no nitrates; neither did the soil, examined to a depth of three feet, nor the white or common alkali which was abundant on this adjacent land contain any nitrates in 1907. Further, they are not due to the concentration of surface washings.

There is one remote possibility, which so far as I know, has not been suggested, i. e., the water used for irrigation. While this is an extremely remote possibility, we can answer the suggested question. We have sanitary analyses of several of the river waters, also of reservoir waters, which are used for the purposes of irrigation, and the nitrogen present as nitrates varies from a trace to 0.400 part per million, a quantity not only too insignificant to be considered a factor in the problem, but so nearly zero that it shows that there are no nitrates in the rocks of the drainage areas of these rivers to which the nitrates may be traced.

The answer that I suggested in Bulletin 155 was that these nitrates are formed where we find them. That the nitrogen is taken from the atmosphere by azotobacter and is subsequently changed into nitric acid, respectively nitrates, either by the azotobacter themselves or by other bacteria. So far in this bulletin I have presented facts in abundance to establish the occurrence of very large quantities of nitrates in certain of our soils, and that the concentration in hundreds—I am fully justified in saying thousands—of instances, is most remarkable, but all proof adduced bearing upon their origin has been by a process of exclusion, i. e., the nitrates are present but they have come from nowhere, therefore they are formed in *situ*.

In Bulletin 155 I showed by nearly 300 nitrate determinations that many of our soils contained very notable quantities of this substance. At the time these determinations were made, October, 1909, we found this quantity varying from 12 to 1,920 pounds per acre in the top six inches of soil, calculated as sodic nitrate. These samples were from cultivated fields in good condition which had been planted to beets. The highest results were obtained in the turn rows.

I have been unable to find any more satisfactory data relative to the amount of nitric nitrogen in soils than was given in Bulletin 155, page 37, based upon Rothamsted results which showed that in lands cultivated as bare fallow about 80 pounds of nitrogen were converted into nitrates in 14 or 15 months. This includes the nitric nitrogen removed in the drain waters. If this amount were all present at one time and contained in the surface foot of soil it would amount to only 0.002 of one percent. In the top 18 inches of another field they found in September and October 49 pounds of nitric nitrogen. If this were all contained in the surface foot at a given time it would correspond to 0.001225 percent. The statement is made that this large amount is due to the richness of the soil in nitrifiable matter, showing that 49 pounds per acre to a depth of 18 inches was considered high, if not unusual. The ratio of the nitric nitrogen to the total nitrogen at any time is not given. It is well known that the nitric nitrogen present in soils varies from time to time owing to several causes, but the easy solubility of the nitrates makes it very probable that the amount of them in the surface soil will be dependent upon the amount of rainfall and the time which has elapsed between the last rainfall and the taking of the sample. The character of the soil, i. e., the readiness with which it allows water to pass through it, its power to retain the nitrates, and the evaporation which takes place from its surface will also influence the amount of nitric nitrogen present at a given time. Rainfall does not usually play the important part with us that it does in England or in the eastern states; if it ever does, it is only for short periods of time.

The samples of soils used for the determination of nitric nitrogen in Bulletin 155, pp. 38 and 39, were taken at the close of a wet season, that is, for Colorado. We had had 3.36 inches of rainfall between September 12 and December 1, and .47 inches during the month of December, and yet we found a maximum of 320 pounds of nitric nitrogen in a set of 46 samples taken between October 1 and 15. The samples were taken to a depth of six inches. In another set of 54 samples taken January 26-31, we found a maximum of 280 pounds of nitric nitrogen in the top six inches of soil. It is to be remembered that these samples were from fields which had been planted to beets. The last sample was taken from the turn row. These quantities are so materially higher than those given for Rothamsted soils, though these Rothamsted fields had been cultivated as bare fallow, that we can scarcely compare them at all. In the case of the 80 pounds of nitric nitrogen per acre in the Rothamsted soils the nitric nitrogen removed by drainage has been determined and included. In these Colorado samples only the nitric nitrogen which was present in the soil to the depth of six inches at the time the samples were taken is considered—drainage or greater depths are not considered.

I have the record of a considerable number of analyses of our Colorado soils and they scarcely average over one-tenth of one percent total nitrogen which, judged by ordinary standards, cannot be said to be more than a fair supply of nitrogen.

The prairie soils of Illinois, as given in their Bulletin 123, contain from two to four times as much, and even their subsoils contain more nitrogen than our surface soils. The soils of Kentucky, Bull. 126, are likewise much richer in total nitrogen than ours. Storer, Vol. II p. 76, says that Krocker, and Payen also states that cultivated land seldom contains less than 0.10 percent of nitrogen and that they usually contain a much larger quantity. He states further that A. Mueller found, on an average, 0.26 percent of nitrogen in the surface soils poor in lime and 0.15 percent in their subsoils. In the surface soils of limestone regions he found, on an average, 0.66 of nitrogen.

King states that the mean amount in eleven arable soils at Rothamsted is placed by Lawes and Gilbert at 0.149 and for eight others at 0.166 percent. Four Illinois prairie soils were shown by Voelcker to contain 0.308 percent; seven Russian soils according to C. Schmidt contained 0.341 percent. The average of these thirty is 0.219 percent. Lawes and Gilbert gave four Manitoba soils as containing 0.373 percent of nitrogen. Hilgard states that from 0.1 to 0.2 percent of total nitrogen in non-acid soils is considered adequate.

Our Colorado soils are non-acid soils. I have as yet, found but one case of an acid soil, not considering beds of peat. In seventy-three analyses of Colorado soils taken in various parts of the state twenty-two of them contain less than 0.1 percent total nitrogen and fourteen contain 0.2 percent or more, leaving thirty-seven or a little over a half of the samples considered which contained 0.1 percent and more, but less than 0.2 percent. It is only a few weeks since, that an analysis of a Colorado soil was submitted to me for my interpretation. The reason for this was that parties in Illinois having the purchase of a tract of Colorado land under consideration had a sample of the soil analyzed and as it contained only 0.08 percent of nitrogen or a trifle less, they, I understood, declined to buy it.

Other soils from sections of this state have, according to reports, been found to be deficient in nitrogen and yet these soils produce excellent crops of corn and wheat. According to our analytical data there can be no question but that many of our soils, according to the standards adopted, are low in nitrogen but they produce excellent crops, in favorable seasons, 60 and even 80 bushels of wheat to the acre, while from 35 to 50 bushels per acre are common yields. The standards adopted and our analytical data are not in perfect harmony with the common facts of actual practice. This has been observed by others and is not new. Trained and practical agricultural chemists who have had years of experience in this state, have stated to me that they had not observed any indication that our crops ever suffer from the lack of nitrogen, and they were perfectly well aware of the fact that according to analytical results many of our lands are deficient, or at best only moderately well supplied with this element.

In regard to the ratio of nitric nitrogen to the total nitrogen in soils the statement that it, the nitric nitrogen, seldom amounts to 5 percent of the total is attributed to Warington. This may be taken as a maximum. There is recorded in Bulletin 126 of the Kentucky Experiment Station, 24 analyses of soils in which both the total and the nitric nitrogen have been determined, which show that the nitric nitrogen varies from 0.0 to 1.263 percent of the total nitrogen present. The total nitrogen in the sample showing the largest amount of nitric nitrogen was 0.238 percent of the soil. The land from which this soil sample was taken had been set to tobacco which had failed. The authors, A. M. Peter and S. D. Averitt make the statement: "The effect of the large amount of nitrate was evident in the better growth of the wheat where the tobacco failed." In another case in which the nitric nitrogen amounted to 0.826 percent of the total nitrogen the authors make a similar statement. "The larger proportion of nitrate where the tobacco was poor is to be noted here, as before, and the effect of this upon the wheat was very apparent." The authors consider these quantities of nitric nitrogen as large and apparently as injurious enough to account for the bad condition of the tobacco. In our Laboratory No. 697 we find the total nitrogen equal to 0.080 percent of the soil, which is probably a little too low, while the nitric nitrogen in the same sample equalled 0.0377 percent of the soil or 47.07 percent of the total nitrogen. This was a sample taken to a depth of twelve inches. It is a very bad soil but not nearly so rich as some samples with which we have met, especially in the cases of surface samples. In Case No. 6 the surface foot of soil, which proved to be an exceptional one, as it was poorer in nitric nitrogen than the second foot, the nitric nitrogen constituted 1.86 percent, in the second foot 1.9 percent and in the third foot 55.3 percent. This is almost the only instance in which we find more nitric nitrogen in the deeper samples than in the shallower ones. The surface soil is not included in the sample designated as the first foot. The nitric nitrogen in the surface portions of this soil, taken perhaps thirty feet north of where these soil samples were taken, amounts to 0.053 percent of the air-dried soil or 530 parts per million. The total nitrogen in this surface sample was not determined. Judging from results in other samples, the nitrogen was probably almost wholly present as nitric nitrogen. In a series of 54 soil samples taken to a depth of six inches the minimum of nitric nitrogen equalled 1.5 percent while the maximum, debarring an execptionally high one, was 17.1 percent of the total nitrogen. I have already cited an instance in which the nitric nitrogen in the third foot of soil was equal to 55.3 percent of the total nitrogen, this, however, was an exceptional sample, not in the amount of nitric nitrogen present but in the location of the nitric acid in the soil.

The nitric nitrogen in other, mostly surface samples, ranges from 16 to 93 percent of the total nitrogen. The latter percentage, 93, seems extremely high but the total nitrogen was determined in duplicate and the determination of the nitric nitrogen was also made in duplicate by different parties, using slightly different methods of preparing the material for the determination of the nitric acid. The agreegent between these determinations was entirel ysatisfactory. The difference falling in the third decimal place. Two samples, our No. 1054 and 1055, illustrate the great variation in the amount of nitric nitrogen in affected and unaffected soils. No. 1054 is a sample of surface soil taken to a depth of four inches near to a recently killed tree, while No. 1055 is also a sample of surface soil taken from supposedly unaffected ground 600 to 800 feet north of the former and just outside of the orchard. No. 1054 contained 0.0932 percent total nitrogen and 0.0150 percent nitric nitrogen, or 16.09 percent of the total; No. 1055 contained 0.0844 percent total and 0.0003 percent nitric nitrogen or 0.355 percent of the total. The soil conditions were entirely different in these two cases though they were relatively close together.

Fixation—In Bulletin 155 I presented the fact, ascertained by Professor Sackett, that the aqueous infusion of some of our soils induced a very marked fixation of nitrogen, the maximum given at that time being 13.02930 milligrams in 20 days for each 100 c. c. of mannite solution. The questions pertaining to the relation of the azotobacter to fixation and nitrification may be worked out in detail by Professor Sackett, but I have endeavored to determine the practical facts on a large enough scale to be conclusive so far as these processes in our soil are concerned. For this purpose I took five portions of soil of 1,250 grams each. The moisture content was determined at 100° and boiled, distilled water added to make the total water equal to eighteen percent of the moist soil. The weight of the dish and soil was determined and noted in order to be able from time to time to add water enough to replace loss due to evaporation. At the same time samples of the soil were brought to a thoroughly air-dried condition and the total, and also the nitric nitrogen determined. Four of the large dishes with their charges of soil were placed in an incubator and were kept at a temperature of about 29° C. for 27 days, when a sample was removed from each dish for examination. The fifth dish was covered and placed in an unused room.

Two of the four dishes placed in the incubator were inoculated by the addition of 25 grams of another soil in which the total and nitric nitrogen was determined, because a culture test made from the sample of soil taken for this experiment gave unsatisfactory results, as no proper membrane was formed, only a few gelatinous masses at the edge of the culture medium. I feared that I would have to collect other samples of soil and repeat the experiment, as I had already had to do once, for the first sample of soil that I gathered for this purpose, though it was very rich in nitrates, seemed to contain no living bacteria which Professor Sackett, on whose judgment I relied, was willing to accept unqualifiedly as virile azotobacter. This precaution, however, proved to be unnecessary, for a sample of soil taken from the fifth dish, on the thirteenth day of the experiment, gave a very heavy membrane in four days. The soil in this dish had already begun to show a change of color on its surface at the time this sample was taken. The membrane in the culture flask began to show brown points by the eight or ninth day. This fifth dish had been kept in a south room where for part of the day it received the sunshine, modified by a screen of paraffined paper. We have five dishes, each containing originally 1,250 grams of soil with eighteen percent of moisture. On the twenty-seventh day I removed from each dish 170 grams of the moist earth, brought it to a thoroughly air-dried condition and made nitrogen determinations in triplicate on each sample. I have mentioned five samples, but I added another, i. e., a sample of the original soil which had been put into a show bottle while moist and allowed to stand in the room. If moisture, air and an equitable temperature be the requirements for the fixation of nitrogen I could see no reason why I should not expect an increase in this sample as well as in those placed in the incubator, perhaps not so great an increase, but still an increase. Samples A, B, C and D were put into the incubator, sample E was moistened and kept at the room temperature and F was the original sample in its moist condition.

The original soil, thoroughly air-dried, gave 0.105875, 0.11000 and 0.105875 percent of nitrogen, average for total nitrogen 0.10725 and 0. 0035 percent of nitrogen as nitrates, equal to 3.263 percent of the total.

	Percent total nitrogen at the end of 27 days.		Milligrams gained per 100 grams soil in 27 days.
Sample A gave	0.11688 0.11688 0.11963	Average 0.11779	10.54
Sample B gave	0.11550 0.11688 0.11825	Average 0.11688	9.63
Sample C gave	0.11413 0.11413 0.11413	Average 0.11413	6.88
Sample D gave	0.11550 0.11413 0.11550	Average 0.11504	7.79
Sample E gave	0.11275 0.11275 0.11413	Average 0.11321	5.99
Sample F gave	0.11275 0.11130 Lost	Average 0.11207	4.82

The fixation obtained and given in Bulletin 155, p. 46, is given for each 100 c. c. of the culture medium. In order to make the figures easily comparable we have given these results in milligrams per 100 grams of soil. The soil experimented with was simply a good, arable soil collected from the College farm at or near a point where I had observed the development of brown patches. It is not one of the soils in which we have observed excessive quantities of nitrates but even here the nitric nitrogen amounts to 3.27 percent of the total. The quantities fixed in 20 and 30 days in a mannite solution inoculated with an infusion of 10 grams of soil are exhibited in the following table along with the fixation accomplished in these samples of soil in 27 days. The inoculation of the two samples seems to have made no difference whatsoever.

NITROGEN FIXED

	Milligrams in 100 cc. in 20 days	Mannite-Solution in 30 days	Sample	In 100 grams of soil in 27 days
Sample 1.	0.00000	1.05075	A	10.54000
Sample 2.	1.19085	0.56040	B	9.63000
Sample 3.	3.08220	3.43245	C	6.88000
Sample 4.	6.16440	12.46890	D	7.79000
Sample 5.	0.84060	3.08220	E	5.99000
Sample 6.	0.77055	3.57265	F	4.82000
Sample 7.	3.50250	3.01215		
Sample 8.	2.38170	2.87205		
Sample 9.	13.02930	10.15725		

All of the ordinary analytical precautions were taken and the nitrogen obtained in the blank test, also run in triplicate, has been deducted. Each of the seventeen separate determinations made on these six samples show a decided increase in the amount of nitrogen. In this climate I find that the thoroughly air-dried material presents almost as good a basis for comparison as is possible for us to get, which would not be the case in a humid atmosphere.

When we consider the nitrification we find equally interesting results. As already stated, this sample of soil contained at the beginning of the experiment 0.0035 percent of nitrogen as nitrates, on the twenty-seventh day of the experiment the various samples gave the following:

NITRIC NITROGEN IN SOIL SAMPLES INCUBATED FOR TWENTY-SEVEN DAYS.

	Percent in Soil		Percent of Gain
Sample A.	3/3	0.0055	54.29
Sample B.	3/3	0.0057	62.85
Sample C.	3/3	0.0060	71.43
Sample D.	3/3	0.0065	85.71
Sample E.	3/3	0.0036	———
Sample F.	3/3	0.0043	22.85

These results show clearly that both fixation and nitrification took place in all of the samples except E, in which nitrification is insignificant or zero, while the fixation amounted to 5.99 milligrams per 100 grams of soil. At one time one of the dishes in the incubator smelled distinctly of butyric acid, but this odor disappeared within a few days and all of the dishes had the pleasant odor of fresh soil when the samples were taken out of the dishes.

The remaining portions of the samples, after having been thoroughly wetted with boiled, distilled water were returned to their original positions and only a little more water, not weighed, added till the forty-eighth day when this series of experiments was terminated. Four of the dishes were replaced in the incubator. One dish was covered and placed at the bottom, the other three dishes were not covered as in the first period except as each succeeding one served as a cover for the one next below it. The top one of course was without any cover. Two beakers, containing water, were also placed in the incubator to aid in saturating the atmosphere with moisture and to lessen the evaporation from the soil. The moisture in the samples on the forty-eighth day was determined and found to be for A, 13.5, for B, 14.5, for C, 17.0, and for D, 20.0 percent. These are the four dishes placed in the incubator. Sample E, which was kept in a covered dish at the temperature of the room, contained 17.5 percent of water. The moisture in sample F, which was the original soil kept in a show-bottle, was not determined.

		Percent of total nitrogen in soil at the end of 48 days.		Milligrams nitrogen gained by 100 grams soil in 48 days
A	1	0.12276		
	2	0.12144	Average 0.11968	12.43
	3	0.11484		
B	1	0.11484		
	2	0.11748	Average 0.11748	10.18
	3	0.12012		
C	1	0.11616		
	2	0.11880	Average 0.11792	10.60
	3	0.11880		
D	1	0.11484		
	2	0.11748	Averege 0.11660	9.30
	3	0.11748		
E	1	0.11616		
	2	0.11880	Average 0.11924	12.00
	3	0.12276		
F	1	0.11484		
	2	0.11356	Average 0.11529	7.99
	3	0.11748		

Sample E, which contained 17.5 percent of water at the end of the experiment and had received direct sunlight every day, developed quite a growth of algae, showing on the surface as green and brown spots. These proved to be, for the most part,oscillaria and diatoms, which became very evident in a culture of these made on sand. The incubator samples of course showed no growth of this sort, but sample A made even a larger gain in total nitrogen and the same gain in nitric nitrogen as sample E on which the algae grew. So it is not clear whether the algae exercised any influence upon the result or not. The gain in both total and nitric nitrogen was, however, much more marked in sample E during the second period of the experiment than in any other sample during this period. The order of the samples in regard to gain during the second period is E, C, F, A, D, B, but in no case had reverse changes set in to such an extent as to wholly conceal the increase. It is, perhaps, unfortunate that I did not extend the examination of the soil to include the ammoniacal and nitrous nitrogen at the beginning and end of the experiment as well as the total and nitric nitrogen.

Returning to the increase of total nitrogen in the soil it may be well to state it in terms of perecntage, calculated on the amount of nitrogen originally present. Such a statement gives us for A, 11.589; E, 11.188; C, 9.883; B, 9.492; D, 8.671 and for F, 7.449 percent. The maximum gain calculated on the amount of nitrogen present at the beginning of the experiment is 11,589; the minimum 7.49 and the average for the six samples is 9.712 percent.

The gain of the total nitrogen in the case of sample F, is worthy of special note. This sample was the original just as it was gathered and put into a round bottomed bottle loosely closed with pieces of paste board and allowed to stand in the room where the sun shone on it part of the day. In this case we find a gain of 7.99 milligrams for each 100 grams of soil in 48 days, equal to 7.449 percent of the nitrogen originally present. In this connection an observation made in 1900 is interesting. The observation is noted in Bulletin 65, p. 45, and raises this question of the increase of nitrogen in samples kept in the laboratory for some time, in the case mentioned, fifteen months, though air-dried, bottled and corked but not sealed. We found a gain of twenty-eight pounds of nitrogen per acre-foot, too small to be conclusive.

Nitrification—The original sample contained nitric nitrogen at the beginning of the experiment equal to 0.0035 percent, and at the end of forty-eight days, the samples contained the following amounts:

		Percent nitric nitrogen in soil at end of 48 days.		Gain in percentage of nitric nitrogen originally present in 48 days.
A	1	0.0060		
	2	0.0060	Average 0.00600	71.43
	3	0.0060		
B	1	0.0060		
	2	0.0060	Average 0.00587	67.71
	3	0.0056		
C	1	0.0080		
	2	0.0070	Average 0.00750	114.24
	3	Lost		
D	1	0.0080		
	2	0.0090	Average 0.00833	138.00
	3	0.0080		
E	1	0.0060		
	2	0.0060	Average 0.00600	71.43
	3	0.0060		
F	1	0.0040		
	2	0.0040	Average 0.00417	19.15
	3	0.0045		

These tables show beyond a question that both fixation and nitrification have taken place, the former in far greater degree in absolute, but the latter in an even more marked degree in relative measures. In two samples the nitric nitrogen has much more than doubled.

All of these samples except F had become decidedly darker on the surface than they were at the beginning.

We have in these samples the reproduction of the main features presented in our fields, the production of nitrates, the fixation of nitrogen and the browning of the surface soil. The water content of the samples was chosen at about 18.0 percent because my observations in the field have led me to the conclusion that the optimum amount is probably below rather than materially above this percentage. The determination of the optimum amount of moisture under specific and varied conditions would be interesting but is a detail not included in the general features which I am endeavoring to present. We have the maximum nitrification in the sample containing 20 percent of water at the end of the experiment. My judgment is that this amount had scarcely varied at all during the experiment. On the other hand we have the maximum fixation in the two samples containing 13.5 and 17.5 percent respectively. These results may be accidental but they agree well with my observations in the field. The amount of fixation, however, is quite uniform and the addition of water, at least up to 17.5 percent has clearly promoted it.

The chemical composition of this soil is fairly represented by our Laboratory Nos. 724 and 725, representing the soil and subsoil from a portion of this same tract. These analyses were given in Bulletin 155, p. 36.

ANALYSES	XCII Soil Laboratory No. 724 Percent	XCIII Subsoil Laboratory No. 725 Percent
Insoluble	54.653	57.068
Silicic acid	19.805	12.754
Sulfuric acid	0.047	0.049
Chlorin	0.032	0.059
Phosphoric acid	0.120	0.127
Carbonic acid	3.048	6.312
Lime	6.100	8.465
Magnesia	1.355	1.448
Sodic oxid	0.290	0.432
Potassic oxid	0.872	0.742
Ferric oxid	5.601	3.499
Aluminic oxid	3.738	5.397
Manganic oxid	0.118	0.026
Ignition	5.072	3.887
Sum	100.851	100.265
Oxygen equiv. to chlorin	0.007	0.013
Total	100.844	100.252
Total nitrogen	0.147	0.069
Humus	0.426	

While these analyses are not made on the soil actually used they serve to represent its composition as well as a sample taken in any fair-sized field may represent its soil.

The amount of nitrogen fixed is very large and seems incredible. Taking 10.54 milligrams as the quantity fixed in 100 grams of soil in twenty-seven days and calculating the amount that would be fixed in the top two inches of the soil per acre, we have 937 pounds, or for an acre-foot 5,622 pounds, equivalent to about 17.5 tons of proteids (N x 6.25) per acre-foot, a quantity which seems extremely large, but this is the result actually obtained.

The maximum gain in nitric nitrogen calculated per acre-foot per annum corresponds to five tons of sodic nitrate.

Perhaps emphasis should be laid on the fact that these soil samples experimented with were, as stated, samples of an ordinary soil collected from the College farm at or near a point where I had observed the brown color which serves me as a guide and which I suggested was probably due to the brown azotobacter pigments. Further, that nothing was added to the sample except distilled water which had been boiled to expel any trace of ammonia that it might contain.

However puzzling the facts may be they are simple; the nitrates are present in large quantities in areas scattered over 300 to 400 square miles as a conservative esitmate. These occurrences of nitrates are independent of geological horizons and do not owe their origin to the neighboring or surrounding country. Nitrates occur in some lands surrounded by others in which nitrates do not occur. They are not present in the alkalis or the ground waters occurring in these surrounding lands; again, they occur on elevated mesas at such heights and under such conditions of location, that they could not be accounted for in this way, i. e., as concentrations from other lands. On the other hand we have shown that both fixation and nitrification take place in our soils, in a notable degree, and we have every reason to believe, because of the observed intense local developments, that our results, obtained with the samples of soil from Fort Collins, are much less intense than those actually produced in many localities. I know that there are questions unanswered, but it seems to me that it makes little difference to the facts, whether we know whence comes the energy which is assumed to be the *sine qua non* for the development of azotobacter or not, the fact is, they do develop. In our case a culture test at the beginning of our experiment gave unsatisfactory, but not absolutely negative results; another sample taken from one of the dishes, not inoculated, after a period of 13 days gave in four days a very strong membrane. The two samples were in no way comparable in their development. There were positive indications on the surface of the soil in the dish that it was becoming brown before we took the second sample. The rapid and profuse growth of azotobacter in the culture medium indicated either a very greatly increased abundance of the bacteria themselves or an immensely increased virility. The question of whether the azotobacter both fix the atmospheric nitrogen and convert it into nitric acid, respectively nitrates, or whether this latter work is done wholly by another genus or other genera of bacteria is, perhaps, a question to be settled—but, be it settled as it may, our facts remain the same that we have instances of the accumulation of very large quantities of nitrates in our soils always associated with the brown color which we know to be caused by the azotobacter. I believe, and this belief is based upon tentative facts, that the azotobacter are at the same time nitrifiers, i. e., that the possess a double function which I believe has already been asserted but not generally accepted. I will state that Professor Sackett is not in any way responsible for this view and I do not know his attitude on this specific subject. These matters of theory and function are open ones but the fact of fixation of nitrogen and the formation of nitrates in our soils to such an extent as to kill fruit trees and ruin the land are established ones.

I expect to present another bulletin in the immediate future dealing with another phase of the subject, i. e., the general effects of the nitrates upon the sugar beet, which will also continue these soil questions.

SUMMARY

The problems presented involve the occurrence of nitrates in such unusual quantities, that I may say, I hope without offence, that even the oldest and most experienced men have not seen the equal of it and have no conception of the facts.

These nitrates occur so abundantly on very many square miles of otherwise good land as to be either prejudicial or fatal to vegetation.

The apple tree has practically been adopted in this and preceding bulletins as the criterion whereby to judge of the intensity and extent of the injurious effects of the nitrates, though other trees and crops, especially the sugar beet, have been mentioned.

The damage done to apple orchards in this state is very serious. If we should estimate the trees killed within the past two years as equivalent to six hundred acres of orchard I believe that it would be a conservative estimate.

These injurious effects of nitrates in cultivated soils are so new and so extensive that we cannot wonder that the layman or even the scientific man who has not seen them, fails to grasp them as facts or if they do and realize their importance, that they hesitate to acknowledge it.

The trees all die in the same manner. This applies to the apple, pear, peach, apricot, willow, elm, cottonwood and other poplars, and to vegetation in general.

Experiments were made with sodic nitrate by applying it to apple trees, when it produced the same effects on the leaves and killed the trees in the same manner as these orchard and shade trees are observed to die.

This series of experiments, eight of them, was not repeated because the results were concordant and conclusive. Experiments were also made using sodic chlorid, common salt, in sufficient quantities to injure the foliage. The effects were unlike and easily distinguished from those produced by sodic nitrate.

The manner of attack, the effect produced and the very rapid termination of the trouble in the death of the trees indicate the action of the same cause.

The identity of these effects with those produced by sodic nitrate, and the presence of very unusual quantities of nitrates in all of the soils where this trouble is met with are accepted as conclusive proof that the nitrates are the cause of it.

No attempt has been made to determine the limit of tolerance of the apple tree or other plants for nitrates. It has, however, been observed that an established beet plant can endure immense quantities of them, but not without deterioration in quality.

The problems presented are not those of ordinary alkali, nor of seepage, nor yet of the occurrence of nitrates produced in the soil by

nitrification as generally understood, but their occurrence in unusual, detrimental and fatal quantities, over areas measured by the square mile of territory.

The nitre question presents a distinct problem whose relation to the problems of alkali, seepage and drainage is not so intimate as is indicated by the statements made in Bulletin 155.

The statements of Bulletins 155 and 160 in regard to the cause of the "brown spots," the character of the salts present, their fatal effects upon vegetation and their extremely deleterious action upon the soil are corroborated.

The spread of the trouble during the year 1910 was very marked.

The intensity of the attacks has increased rather than abated.

Some instances of a very rapid development combined with extremely intense action have been observed. In one fourteen-year-old orchard not less than twelve acres of trees, apple, plum, pear and cherry, together with currant bushes and other small fruit have been killed in less than a year. The water table in this land was not, at any time, near enough to the surface to do any damage.

No single instance of the death or eradication of a brown area, a nitre spot, has been observed; but the interior of such areas has been found so excessively rich in salts that the ground has become barren, even of the azotobacter flora.

This deportment of the bacteria suggests the probability that the land may again become fertile after a few years, in fact, varieties of Atriplex, saltbushes, are already taking possession of land which has been devoid of vegetation for several years.

The drainage in several of the cases given is excellent, in other cases drains have been laid for periods of from one to five years without preventing the formation of nitre areas.

Trees badly affected by this trouble show almost no recuperative power, probably due to the continued excessive supply of nitrates in the soil, possibly to the severe toxic action of the nitrates. So afr as our observation goes both factors seem to be involved. Slightly affected trees may recover but no badly affected tree has been observed to do so.

The generally observed change in the soil, indicating danger to the trees, is a turning brown of the surface which is expressed by the statement that "The soil turned brown or black and the trees died."

The samples of brown soil have, without exception, contained excessive quantities of nitrates.

The color is not due to the nitrates nor to sodic carbonate or black alkali proper but to the development of pigments by the azotobacter. This applies to the soils here described. Some soils may have a brown color due to other causes.

This condition is usually preceded and accompanied by a mealiness of the soil, often described as ashy. There is usually but little or no efflorescence on such soils, though it sometimes occurs.

The time required for the killing of a tree varies with the virulence of the attack, in bad cases from four days to two weeks. Slightly affected trees may linger a long time.

These areas may occur in perfectly drained land, situated in the midst of land which shows no abnormal quantities of nitrates.

In one case, and possibly in others also, injury to many trees followed the application of water, probably due to the washing of the nitrates down into the soil.

The river waters used for irrigation, whether stored or not, contain no unusual quantities of nitrates.

The ordinary white alkali that commonly occurs in these sections is, for the most part, free from nitrates, but the brown and white areas frequently overlap.

The ground waters, unless derived from nitre areas, are free from nitrates and these nitrates cannot be accounted for by the evaporation of such water from the surface of these areas.

In some sections practically the whole of the irrigated land has been affected, thus eliminating the question of transportation except as to the river water used for irrigation. Our river waters carry from 0.00 to 0.4 part per million of nitrogen as nitrates.

The localization of these areas and the rate of increase also preclude the theory of transportation and concentration.

Excessive irrigation for the purpose of washing out the "black alkali," nitrates, has not been successful, but this failure has probably been due to the method used.

The liberal application of manure has not given permanent, if indeed, any relief.

Thorough and frequent cultivation has not been followed by the beneficial results expected.

The soils of Colorado are, generally speaking, poor in nitrogen, but the ratio of nitric nitrogen to the total nitrogen is frequently very high, 17 to 50 percent being not uncommon.

The nitrogen in these soils is fixed by azotobacter which use the nitrogen in the air to build up their tissues.

The fixation of nitrogen, in a sample of ordinary soil from the College farm, collected December 12, 1910, on incubation for twenty-seven days, was found to have taken place at the rate of 5,222 pounds of nitrogen, equal to 17.5 tons of proteids per acre-foot of soil per annum.

The nitric nitrogen present in this soil at the beginning of the experiment corresponded to 840 pounds of sodic nitrate per acre-foot of soil; this had increased in 48 days to 1,999 pounds as a maximum, a gain of 1,159 pounds which would give, if this rate were continued for a year of three hundred and sixty days, a gain of 8,676 pounds, or four and a third tons of nitrates per acre-foot of soil.

The incubated samples, with but one exception, showed a darkening of their surfaces.

No addition of anything except boiled, distilled water was made to these samples before or during incubation. A large bottle was partially filled with some, approximately eight pounds, of the original sample just as it was collected. This bottle was loosely stoppered, inverted and kept in a room where the temperature was fairly high and even. This soil was analyzed just as the incubated samples were and showed a decided increase in both the total and nitric nitrogen, 7.45 and 19.15 percent respectively.

Fixation takes place rapidly in this soil in the presence of from 13.5 to 20 percent of water. The rate of fixation of nitrogen obtained is sufficient to account for the nitrates found in the soil provided that it is nitrified.

The rate of nitrification obtained is sufficient to account for the formation of the nitrates found, in most cases if not all of them.

The brown color of these soils is due to pigments produced by the azotobacter.