NITRATES IN THE SOIL

An Explanation of so-called "Black Alkali" or "Brown Spots"

BY

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NITRATES IN THE SOIL

By WM. P. HEADDEN

Bulletin No. 155 of this Station, entitled "The Fixation of Nitrogen in Some Colorado Soils," gives the results of our field observations on this subject up to the latter part of the year 1909, together with those obtained in the laboratories in more detail than is absolutely necessary for a general understanding of the subject.

The people in many sections of this State understand perfectly well what is meant by the expression "brown spots." This expression was more appropriate a few years ago than at the present time, for then the term spot described quite accurately the area involved, as it does in some instances today. There are, at this time, however, areas measured by acres, which the term does not describe. What was five or six years ago a spot has now grown to involve as much, perhaps, as six, eight or more acres, and the use of the term spot is justified only on the ground that it was at first used to describe a condition as well as an area.

The condition which it describes is well known to the people of some sections of the State where it appeared a long while ago as barren places, or spots, the surface of which had a brown color. Sometimes they were shining and looked as though they were wet or perhaps oily. Some of the worst spots to which my attention has been directed appeared as though they had been wetted with a thick, black oil. The fact that nothing grew on these spots has been used by many correspondents as descriptive of them. These spots occur in a great variety of soils, from heavy adobe to light, sandy loams and silts. The spots are only local and exaggerated expressions of a condition which is becoming quite general. I have met persons who really knew but little about the matter, though they assumed to know a great deal, and who have insisted that these were seepage spots. It is true that a regular and fairly abundant supply of moisture seems to be a very favorable factor in the development of this condition, but I have not observed it anywhere, where there is an excess of moisture, especially at the surface. In some extremely bad places, I have found a very peculiar condition of the ground, beginning at depths varying from a few inches to two and a half feet below the surface which I cannot describe in any other way than as muddy. This ground is very soft and wet but retains the water so persistently that the water runs out of it very slowly, or so good as not at all. On the surface of such lands we often find a thin crust and just beneath this a mealy mass, sometimes as much as three inches thick. This brown color is by no means always associated with this wetness of the soil but is gener-
ally, though not always, associated with this mealy, or, as the people often describe it, ashy condition. We sometimes find it, the brown color, on sandy soils in which we can find no unusual amount of moisture until we get down to a depth of six or seven feet or strike gravel.

It might be inferred from what has been stated, that these brown spots, or the condition expressed by this term, occur only or mostly in low ground. While they do occur very frequently in such ground they are not at all uncommon on high ground. I have recently found excellent examples of this brown color on the College farm at Fort Collins in land which it would scarcely be possible to seep, and I know of a number of such occurrences on high mesas from 80 to 150 feet above the river bottoms, which lie immediately below them.

Persons acquainted with our soils know that we have some conditions which make drainage very difficult if not impossible. In some places, it is necessary to run a drain to almost every wet spot in a field or meadow in order to drain it. It is not an uncommon experience to find a drain within a few feet of a mud hole which has no effect on the latter. I recall opening a partially filled underdrain, laid at a depth of about four feet. I found it open and some water flowing in it, and yet water was standing on the surface of the ground ten feet away. This water was not due to recent rains or irrigation but came from the ground below. A gentleman once asked me why his alfalfa was dying, and what he should do. I answered: "Drain your land," to which he responded that it was so good as impossible, because one spot in this field might be too wet, and the alfalfa perish for the want of water within fifteen or twenty feet of it. This man told the truth, improbable as it may seem. Some may think that these brown spots are associated with bad drainage. This is not true, for while the ground is in some cases muddy, as previously stated, the soil in which this trouble is met with is more often well drained. I recall three instances in which the soil is sandy or silty and underlaid by gravel at from five to eight feet. The brown surface soil in each of these cases occurs within three hundred feet of the river which is from eight to twelve feet below the level of the land; one could scarcely find better drainage than this. In two other cases we dug holes, in one of which we struck gravel with water at five and a half feet; in the other we struck neither gravel nor water at a depth of seven feet; both soils were sandy. This condition then is not restricted to low land; 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.

The brown spots have often been considered as indicating the
presence of black alkali. This is not to be wondered at; in the
first place the color of the surface soil is suggestive of the name
and in the second place the bad effects upon vegetation which are
associated with this color, lead the average man to attribute the
cause of this to the only agent with which he is familiar, and which
is believed to be adequate to produce this effect, namely, black
alkali or sodic carbonate. Another reason which has apparently
justified this inference in regard to the presence of sodic carbonate
is the fact that the soil when moistened with an acid effervesces;
this is due to the presence of calcic carbonate or marl, a form of
limestone, and is not a proof of the presence of sodic carbonate.

The appearance of a white coating or efflorescence on the sur-
face of the soil indicates, with us, the presence of the sulfates of
lime, magnesia, and soda in the soil and usually an excess of water.
The excess of water may be very injurious but these alkalis do not
do any serious damage. These brown spots may or may not occur
in association with the white alkalis. The intimate association of
the two is so rare that we may state that they present distinct oc-
currences. When they occur in the same piece of land, they usually
occupy distinct areas, the brown being on higher ground than the
white where there is a less abundant supply of water.

Concerning the effects of the brown spots there is but one
testimony, i.e., that nothing will grow. It is common to hear the
expression that the white alkali is not bad but that the black is
ruinous. We have had occasion to see the effects of it in many
places, especially about Grand Junction, during the past season,
the summer of 1909, when many apple trees and some shade trees
succumbed to its influence. The effect that it produced was a
burning of the leaves beginning at the tips, then extending along
the edges till the whole leaf was brown. Sometimes only a few
limbs on the tree were attacked in this way but very often all of
the leaves were attacked and the tree was killed. I saw a great
many apple trees killed during the summer of 1909 in this manner.
I know of one orchard from which 110 trees have been removed
this—the spring of 1910—from another 200; and in another more
than 200 have been removed or are dead. There are many orchards
in which a few trees, from one to twenty or more, have died. Fur-
ther, there are young orchards in which the trees have refused to
live. I recall several pieces of land which have been reset to or-
chard, peach, apple and pear several times, as many as eight accord-
ing to my information, and many of the trees are dead at this time.
The condition indicated by the brown color affects both young and
old trees. None of the trees alluded to above, as having been
pulled up, were less than 14 and some of them were 27 years old.
Some of these trees were nearly two feet in diameter and had
yielded as many as fifty boxes of apples at a picking. The young orchards alluded to are not confined to one section of the State, and I recall at this time nine such orchards.

The only reason for writing of orchards rather than of other crops is that the injury is more obvious in the case of trees than of some other crops, alfalfa for instance. Complaint has been received very often that alfalfa is dying in spots. It does not follow that every spot of dead alfalfa has been killed by this so-called black alkali, but many of those that the writer has seen, have been. The same may be said of sugar beets. Sometimes large spots of bare ground occur surrounded by a very large growth of tops, with a few plants scattered throughout the area, showing a similar luxuriance in the growth of the leaves. This condition is, as a rule, associated with the brown color of the surface with a slightly incrusted, and under this a mealy condition of the surface soil. These are not the only questions which have to be considered in regard to the effects of this condition on the crops, but they are visible effects which can be easily recognized; the effects upon the quality of the crops grown cannot be seen by the eye but must be studied and determined in other ways.

Inasmuch as the injury to the trees observed during the season of 1909 did not seem to affect the roots of the trees, I hoped that there would be, at least, some recovery in the case of those trees which did not die outright at the time of the attack, but observations of such trees this spring, 1910, give but little reason to expect any recovery. Whether this is due to the fatal effects of the poison present last year, or to an injurious supply of it in the soil at the present time, I do not know. I cannot candidly state that I have seen a single case of recovery but I have, on the other hand, seen a number of cases in which there is no reason to expect the trees to live.

We have now stated something about the occurrence and distribution of these brown spots, their appearance and visible effects upon vegetation. We do not know when they began to appear but some of them have been observed for several years past. This condition is rapidly becoming more prevalent. The land occupied by the orchards referred to as having been seriously injured in 1909, had evidently not been in such bad condition before during the time that they had occupied the land, from 14 to 27 years in the different cases.

The people very generally refer to the spots as "black alkali spots," but there is no sodic carbonate or only a very little of it in such spots and the color is not due to dissolved humus as would be the case if black alkali were present. These black spots, moreover, are only very extreme cases of a condition which is very widely
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distributed throughout the cultivated sections of the State. The brown streaks often seen around the edge of a wet place in some lawns, or along the margins of an irrigation furrow, are in very many instances due to the same cause. The writer has found very marked examples of this on the College farm this season, and has seen it occurring abundantly in other parts of the State.

Many people imagine that this black alkali is brought to the surface by water rising from below, such is not the fact as follows from the consideration of the general distribution of this same color in places where there is no rising water plane, others think that it is alkali dissolved out of other lands and brought into these places by seepage water, but this notion is refuted by the occurrence of just such brown spots on mesas which are themselves the highest cultivated lands in the section.

The most of us think of the soil as a mass of very small particles of rocks and some moisture which furnishes physical support and sustenance to the plants that grow in it, and nothing more. We do not think of it as teeming with life, but it is. Some of this life is beneficial to the growth of the cultural plants which furnish us our food and pleasure, but some of it is indifferent or perhaps prejudicial. Most of us have, during the past few years, heard of the part played by certain germs, which acting in succession effect the conversion of organic nitrogen, vegetable or animal, into nitric acid forming nitrates in the soil, in which form the nitrogen is taken up by the plants. This change of organic nitrogen, either of vegetable or animal origin, into nitric acid or nitrates, is called nitrification, and consists, as intimated, of several separate processes. This is not the only process going on in the soil which is dependent upon the presence of germ life, or micro-organisms. Among others is one which has to do with the building up of nitric acid or the formation of nitrates. The preceding process, nitrification, depends upon the vegetable or animal matter in the soil for its supply of nitrogen and there are three steps in the process of converting it into nitric acid, but in this one the source of the nitrogen is the atmosphere and the agent which takes the nitrogen from the atmosphere and converts it into nitric acid, respectively nitrates, is also a germ that lives in the soil. There is a number of species of this germ, one of which produces a brown pigment. This germ is abundant in our soils and apparently grows with great luxuriance. The brown color, whether in spots in a field or on the side of an irrigation furrow, or as a broad zone about the edge of a moist spot, is of itself not injurious but it is usually conclusive testimony of the presence of this germ, and a sample of soil taken from such a place will readily react for nitric acid. These germs are not necessarily detrimental to our trees and crops. If they would produce only just enough
nitric acid or nitrates, they would do us a great service, but they have built up too much of these compounds in many places. The brown color is not due to the presence of the nitrates, for they are colorless, but to a coloring matter formed by these germs. This coloring matter is soluble in water and may be partially, or at times possibly wholly, washed into the soil with the nitrates. The brown spots and soils scattered throughout our valleys and irrigated sections have been the cause of many inquiries during recent years. There are some instances in which the color may not be due to these germs but they are the cause of almost all of it. This is not the only germ which converts the atmospheric nitrogen into nitric acid or effects the fixation of nitrogen, as it is designated, but it is a common one in our soils.

It is not the brown color that does the damage, but it is the nitrates which are formed by the same agent in quantities large enough to kill the trees and other vegetation. It is the nitrates that produce the mealiness of the soil, at least nitrate or soda applied to the soil produces the same condition. Nitrate of soda applied to apple trees in excessive quantities, produces a burning of the leaves and the death of the tree in a manner similar to that shown by the trees in the orchards.

The amounts of nitrates found in the various samples of soils taken from affected areas strike one as almost incredible. We found in a sample of surface soil 6.54 per cent of sodic nitrate. This is the largest amount found in any sample and indicates the presence of nearly eleven tons in an acre of ground taken to a depth of one inch. Many samples indicate the presence of extremely large amounts of nitrates in these soils.

While these nitrates in small quantities are beneficial to vegetation they are poisonous when applied in larger quantities. The death of trees, for instance, was due to excessive quantities of nitrates formed in the soil.