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ARSENICAL POISONING OF FRUIT TREES

BY

Wm. P. HEADDEN

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The Agricultural Experiment Station

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ARSENICAL POISONING OF FRUIT TREES

In Bulletin 131 of this Station, issued in July 1908, were recorded the results of our studies to determine the cause of the death of many of our apple and pear trees. Professors Paddock and Whipple had addressed themselves to this subject for some years, and were unable to satisfy themselves that any of the well known causes usually producing the death of trees could be appealed to as the actual agents in these cases. Mr. Whipple, now professor of horticulture in the Montana Agricultural College, had sought for fungus and bacterial troubles in vain. The results of our observations forced us to the conclusion that the cause was not to be sought in the soil per se for to quote Prof. Whipple's words, "Soil conditions seem to have no relation to the disease, as it is found on all kinds of soils."

While I recognize the fact that it is necessary to control the insects injurious to our crops, I have entertained grave misgivings in regard to the ultimate effects of spraying arsenic on our trees and soils and when the other members of this Station, men thoroughly competent to determine the facts, found none of the causes usually producing disease in trees present in these cases, I became more deeply impressed with the probability that the trouble was primarily due to the action of the arsenic applied to the trees as a spray. I gave in Bulletin 131 a definite experience with a case in which it was charged that arsenic, lead and copper had been the cause of the death of trees, grass and even of animals eating the grass, and I am fully convinced that

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AN EXPLANATION.

In Bulletin 131, Arsenical Poisoning of Fruit Trees, I did not give the location of any orchard or the name of a single owner, nor have I given either in the following pages. My reasons for this are the following: I think that it would be a gross injustice to the owner of an orchard to publish a statement of his misfortunes or unwise practices throughout the state and nation by means of an Experiment Station bulletin. If the statements made are all true, it only makes matters worse rather than ameliorates them. Unscrupulous neighbors might take advantage of such statements to do the party named injury. I have been treated kindly by the orchardists in connection with this work, however, I understand that I have been the innocent cause of injury. The fact that I was interested in the study of an orchard problem, not arsenical poisoning, was made the basis of dishonorable representations which did the owner a serious financial wrong. It would, in my estimation, be wholly unpardonable to name the properties of men who have given me aid in this investigation when I know that it would be doing them an injury and requiting kindness by inconsiderateness and ingratitude. I have not, in any way, concealed or distorted a feature of the problem, but I have purposely used examples from different sections and different orchards in order that I might present the whole case—but by no means all of the different facts—without doing anyone an injury. If I have succeeded I shall be pleased, if I have failed I can only regret it.

W. P. H.

there is great danger of our adding arsenic enough in the form of materials used for spraying to jeopardize not only the life of the trees but bring about other conditions of a most serious character.

I have heretofore been very careful not to condemn the practice of spraying, but simply to call attention to the dangers accompanying the practice and particularly the excessive, even irrational, application of these poisonous preparations to the trees and eventually to the soil. If the soils themselves already contain arsenic enough to pass into the plant system it makes the application of more arsenic only the more ill-advised.

Up to the present time we do not know of any other practical and effective means of protecting our fruit against the codling moth than some form of arsenic, and so far as we now see we must continue to use this means. This, however, does not mean that we cannot improve the practice in several ways. It has been demonstrated that a much smaller amount of arsenic may be used than has heretofore been customary, with most excellent results. Prof. Gillette showed several years ago, that 95 per cent. of the protection given to a crop when three or four sprayings were made was effected by the first spraying. His investigations have shown that a single spraying, thoroughly well done, will produce clean apples unless there is some local source, an adjoining unsprayed orchard, from which moths may migrate and infest the orchard anew. There is another way of improving our practice, namely, by using a form of arsenic more insoluble in water than the forms now used and which will change but slowly into a soluble form in the soil. We have considerable reason for hoping that the sulfid of arsenic may be used with benefit in this direction. A still greater improvement would be to obtain some substance which would furnish our fruit the desired protection, but which would be entirely free from the serious objections which apply to the use of any arsenical preparation. This is not an impossibility, as indicated by the report of experiments with nicotine made by Prof. Gillette to the American Association of Economic Entomologists, at its recent meeting in Boston.

The assumption that the arsenical preparations used for spraying are insoluble in water is not justified, and yet this is a condition which they must fulfill in order that thay may be safely used. Further conditions may, and in some cases certainly do, exist in the soil which makes them more soluble than they are in pure water. I have met with many men to whom it was a matter of some surprise that the arsenic might accumulate in the soil, though they knew that they were spraying a number of times annually and that the amount of soluble arsenic in the soil might increase with the years.

Bulletin 131 states that this line of work was a direct outgrowth of my attempt to study the alkalis of the state. It was then thought that it was rather more than probable that the abundance of these salts in some of our soils had produced an exaggerated effect of the arsenic on our trees. There may be some truth in this view but I am now of the opinion that the effect of the alkali has been nothing more than to increase the action of the arsenic and has not been the cause of it. I am led to modify my views in regard to the importance of the part played by the alkalis because I have found cases of corrosion by arsenic under conditions which preclude their action. This in no way contradicts any facts established in regard to the adequacy of sodic chlorid or carbonate to bring arsenic in solution when present in the form of lead arsenate, calcic arsenite or as Paris green, but simply adds the fact that trees may be attacked in soils practically free from these salts, indicated collectively by the term alkalis.

The result of my study of this subject during the past year has strengthened my conviction that the conclusions presented in Bulletin 131 were not only fully justified by the facts presented, but were very conservative and I do not see any reason to modify any statement by making it less general or in any way milder. I have, furthermore, learned of no fact indicating any reason for altering the previous findings of Professors Paddock and Whipple. These gentlemen did their work thoroughly and with that conservatism demanded of the really scientific worker. In the following pages we shall present some new facts but they will in the main be a re-presentation of the main points set forth in Bulletin 131

In the bulletin just referred to three phases of the question were set forth: First, the corrosive action of arsenic which had already collected about the crown of the tree, and designated as local irritant poisoning; Second, the action of the arsenic which had been taken into the system of the tree and designated as systemic poisoning; Third, the action of lime, showing that it probably exercised a toxic action either alone or in conjunction with the arsenic. The possible action of both copper and lead is freely admitted, but that of the arsenic is candidly considered as clearly the most important one and these two are scarcely more than mentioned for the purpose of admitting the possibility of their exercising some influence.

The most striking effects upon the trees are produced by the corrosive action of the arsenic on the crown and roots, and this form of the trouble is the one which forces itself mostly upon the average man.

Description of the Trees.

The effect of the arsenic does not express itself in the appearance of the tree till its action has gone so far that the death of the tree is very near. The first general signs of trouble are an early ripening of the foliage the first year followed by heavy blooming and usually an abundant setting of fruit the second. This fruit is seldom matured as the tree usually dies in late summer or early fall, the fruit and leaves remaining on the tree. In the case of pear trees, the foliage is mostly of a deep purple on the badly affected trees while that of healthier trees is still green. An examination of such trees reveals the following conditions, the bark of the crown has been completely disintegrated and almost always that of the roots next to the crown. Its structure has been wholly destroyed and the woody tissue beneath has been stained brown. In bad cases its structure too has been destroyed so that under the rasp it often acts as though thoroughly charred, outwardly it is often blackened. The bark of such trees is usually a reddish yellow frequently showing longitudinal cracks. The woody tissue of the lower portion of the trunk is stained brown though the tree may still be alive. This is shown in Plate 3, Fig. 3, p. 14, Bulletin 131, which is a portion of the lower part of the trunk of a Ben Davis tree dug up when in full bloom. The bark on this portion of the tree was intact and the staining was not due to dead wood exposed to the air.

The Yellowish-Red Bark Not Diagnostic.

The yellowish-red color of the bark of the limbs and twigs of such trees is probably the result of malnutrition rather than of the direct action of the arsenic and while this color is very commonly present in cases of this trouble, I cannot consider it as a diagnostic feature.

The Point of Attack in Cases of Irritant Poisoning.

The attack on the bark is evidently made from the outside because we find patches on some of these trees where the girdling is not yet complete and while the outer portions of the bark may be disintegrated the inner portion may be apparently entirely healthy. There are no signs in such cases that the bark has ever been raised or loosened from the underlying tissues. These facts necessitated the examination of trees in which the trouble had not advanced to this stage. Samples were easily found showing all stages of the progress from the incipient attack in which the disintegrated bark formed only a very thin layer on the outside to those in which it had finally perforated the bark and attacked the underlying wood. In some orchards we find some degree of this girdling on almost every tree. I have in mind at this writing a pear orchard, containing possibly 300 trees, in which I failed to find a single tree which did not show this corrosive action of arsenic in a marked degree and in many cases the bark had already been perforated.

The Roots.

The above remarks apply to the roots especially at their juncture with the trunk; sometimes we find the whole of this portion of the root involved, again only the upper portion, if the attack has not approached very near to the final stages. On the roots we often find a very sharply defined limit to the trouble just as we usually do as we approach the surface of the ground. The distal portion of the roots are as a rule in better or even good condition. This point was well illustrated by the case of a pear tree root which I dug out. The root was entirely dead near the trunk, but was apparently healthy a few feet away and had thrown up sprouts.

The Trunk of the Tree.

The trunk frequently shows no effect of the trouble above the ground, especially is this true of the pear trees. Apple trees sometimes show, in such cases, chocolate brown spots on the trunk of the tree. On removing the bark, its inner side beneath these spots, as well as the underlying tissues, present a mottled appearance. The cambium layer is, in these cases, not darkened or discolored except in these spots; the bark is not loosened or at this time dead but it soon dries down to the wood. These areas often have an offensive odor.

The Varieties Affected.

The varieties of apples and pears in which we have found this trouble are so numerous that it is scarcely feasible to name them. Some varieties appear to be more sensitive in some localities while some other varieties are more generally affected in other localities. Mr. Whipple noted the fact that the Ben Davis and Gano are very sensitive to arsenical sprays. It is apparently a fact that in some localities these two varieties are more generally affected by this trouble than any others, in other localities this is not at all true. This statement can of course be made of the other varieties.

The Influence of the Age of the Tree.

Orchards which had attained a considerable age before any arsenical sprays were applied to them do not seem to show the effects of the arsenic to the same extent as those orchards in which the trees were younger when the first applications were made. I recall an orchard visited in company with Prof. Gillette, in which there were trees of very different ages, the most of the trees being of the first setting, now between 25 and 30 years old, but a few of them were much younger. We found none of the old trees which seemed to be in danger from this trouble, while several of the young trees were about to succumb to it. This by no means proves that old trees are wholly exempt, for I know of trees 30 years old or older that have been killed by this trouble. In one orchard a part of which is 25 to 27 years old, the rest about 14 years old, the older portion contains only a few affected trees, while there is quite a number of such in the younger orchard.

The Influence of the Soil.

We will make some general statements at this time, which while entirely adequate for our present purpose are not intended to cover specific features of the problem. Mr. Whipple's statement "Soil conditions seem to have no relation to the disease, as it is found on all kinds of soil," seems to be wholly justified. I have found it literally "on all kinds of soil." While the character of soil may modify the trouble, it does not determine it. I have found orchards set in most excellent loamy soil, well drained, irrigated with pure water, intelligently cultivated, and well located in respect to protection against severe weather and yet this trouble was exceedingly prevalent, while in other orchards on less desirable, even on bad soil, this trouble, though present, was by no means so prevalent. In other cases the problems presented were so involved that no student of this subject would undertake to unravel them. I am fully convinced that the soil itself does not produce the trouble under discussion.

Do Salts Other Than Arsenic Produce It?

The answer is a negative one. We have very marked cases of trees having been killed by the presence of excessive amounts of nitrates formed in the soils. I described some of these at the meeting of the Society for the Promotion of Agricultural Science in Portland, Oregon in August, 1909.. The action of the nitrates is wholly different from that of the arsenic, neither the crown nor the roots are corroded but the foliage and the tree are killed outright, sometimes within a few days. The attack expresses itself wholly differently, it is not gradual, but as above stated sudden, there is no ripening of the foilage but a strong burning and killing. The bark of the crown and the large roots at the time of the attack is perfecly normal in appearance in cases not complicated by pre-existing troubles.

I have found no conditions under which any trouble can properly be attributed to the presence of any excess of sodic chlorid. I have endeavored to determine the effect of sodic chlorid by direct experiment. It is beyond question that salt, in excessive quantities, is injurious to apple trees, but excessive quantities, according to our results, would mean very many times as much salt as we find in any of our soils. Its action was very moderate and expressed its only visible effect upon the leaves much in the same manner as the nitrate.

There is no carbonate of soda, worthy of mention, in our soils, so the action of this salt is eliminated from the question.

There is in some cases a rather large amount of sulfates (sodic, calcic, and magnesic) present but the action of these is not corrosive. Their action is so mild that seedling plants grew in soils to which I had added as much as two per cent. of the weight of dry soil of sodic sulfate and even the little seedlings were not corroded or injuriously affected. I have made a similar experiment with magnesic sulfate. These experiments were made years ago when the opinion prevailed that the alkalis were prejudicial to our lands. These experiments are in keeping with the fact of common observation in many parts of the state, i. e., the production of good crops on lands so rich in alkalis that a heavy incrustation covers them under conditions favorable to its formation. I know of very healthy orchards on land rich in these salts.

Is the Trouble Produced by Excess of Water?

This question is likewise to be answered in the negative. We know that we can destroy even pear trees by keeping their roots submerged in water but this is a condition nowhere obtaining among all the cases studied. The prevalence of this trouble in orchards on high, well drained lands is a sufficient answer to this.

The Area Involved.

In Bulletin 131 I stated that the principal orchard growing sections of this state were probably involved. It is now certain that the extent is wider than the boundaries of this state. There is no disposition on my part to seek consolation in the fact that I believe many sections of the country to be suffering, in a less degree I hope, from the same ills.

The Number of Trees Affected.

Under this caption in Bulletin 131 I stated that it would be difficult to obtain data on which to base even a rough estimate of the number of trees suffering from this trouble. I have visited many orchards since I wrote the above statement and am now convinced that it is difficult to find a fifteen-year old orchard in the state wholly free from this difficulty. There are probably a few but not many. I know of an orchard, the owner of which said to me: "I must have a thousand sick trees." I think that this was an overestimate, but it serves to convey a definite idea of how very prevalent the trouble is in some orchards. I have seen a pear orchard in worse condition even than this apple orchard. Both of these orchards, though many miles apart and on very different land, are within this state. I have not visited the apple growing sections of the southwestern portion of the state and so do not know the condition of affairs there but in the rest of the state no section is entirely free from this trouble. It is found in Larimer County as well as in Otero, Fremont, Delta and Mesa counties, and this represents a distance of nearly 350 miles from east to west and 200 miles from north to south. I am convinced that the number of trees already seriously affected by this trouble are not numbered by hundreds, but rather by tens of thousands.

This may not be an inappropriate place to state again, as I stated in Bulletin 131, that publication on this matter was not the result of any sudden impulse, nor of any desire to obtain a certain notoriety by creating suspicion and alarm in the minds of any class of orchardists, much less to protest against the general practice of spraying, but the publication was made simply because I was fully convinced of the sufficiency of the proofs that great injury had already resulted from the practice, particularly from the irrationally ultra manner in which the practice has been carried on, and that it was perfectly proper and right that the truth should be made known. The facts were presented conservatively. My colleagues agreed that it was wise to publish the results as simple facts. This is what I did and this is the only purpose that I have in view in the present bulletin.

Present Conditions in Regard to the Presence of Arsenic in the Soil.

Several questions relative to this subject may be raised such as the presence of arsenic in soils in general. Toxicologists have answered this in the affirmative, but the evidence of all is that it is present in minute traces. This is not true of our Colorado virgin soils, for they contain more than mere traces, which question will be discussed in a subsequent paragraph. The bearing of this fact on the question in hand is slight. The arsenic contained in the virgin soils examined, taken approximately to the depth of one foot, is just about one-tenth of the average found in the orchard soils, excluding extremely high ones. The maximum amount found in a virgin soil taken to a depth of one foot is almost exactly one-twenty-eighth of the maximum found in an orchard soil taken to the same depth. The orchardist is not concerned with the source of the arsenic but with its effect upon the trees. If there is already a little arsenic in some of our soils, enough to be taken up by the trees to such an extent that its presence may be shown, it does not argue that we do no damage by increasing this amount from 10 to 28 times.

Another suggestion is that the water used for irrigating purposes may contain arsenic. It is a fact that some spring waters contain minute traces of arsenic, so small, however, that its presence may best be established by examining the deposits from such springs. It is, however, not true of our river waters, so far as my knowledge goes, and if it were true, the quantity usually carried by spring waters, not river water, is so small as to be utterly insignificant in comparison with the quantities which we have been pouring upon our lands.

We have been using arsenical sprays in the various parts of our country for various purposes about 40 years. We, have been spraying our apple orchards about 28 years and in Colorado we have been spraying 18 or 20 years. The question is what has been the effect of this in regard to the amount of arsenic in the soil? The answer is given above, i. e., that, even in Colorado, we have increased the arsenic content of our orchard soils at least ten fold and in the older states it must be even worse if they have been nearly as zealous in spraying as we have been. But few people consider the real character of the sprays used and we cannot expect the ordinary orchardist to consider the possible results and there has been an abuse of the practice. The practice in this sense has been a dangerous one. I do not know that any station has ever advised six, eight or even nine sprayings in a season. Three is the maximum recommended by this station, and yet I know of men who have sprayed nine times in one season according to their own statements; four, five and six sprayings are still applied by some. The amount of arsenic used has also been unreasonable in many instances. I have in mind a man who, having been directed to use one pound of arsenious acid to the tank added one and a quarter pounds, and applied 90 gallons or a little over 0.56 pound of white arsenic to each tree during the season. I know another man who used almost exactly the same quantity of spray, 90 gallons to the tree, using

16 pounds of lead arsenate to the tank. This man claimed that this was his custom. Assuming this statement to be literally true, let us see how much arsenic acid he had applied to this orchard per acre in the six years preceding. As stated, he used 16 pounds of arsenate of lead to the tank and applied 90 gallons to each tree during the season. Assuming that the pasty arsenate of lead was one-half water it would give us eight pounds of dry arsenate of lead to the tank,0.04 pound in each gallon of spray and as he used 90 gallons to each tree he applied 3.60 pounds of dry lead arsenate, or if the dry lead arsenate contained 25% of arsenic acid, he added 0.9 of a pound of this acid to each tree or 72.0 pounds per acre each year counting 80 trees per acre. In six years he would add 432 pounds arsenic acid to each acre of his orchard, which if evenly distributed through the first foot of soil would give 108 parts per million. This calculation is much nearer to the facts in the case than such calculations are apt to be, for I found 61.33 and 128.83 parts arsenic acid per million in the upper portions of this soil. The other man who used 1.25 pounds white arsenic to the tank, said to me "you don't realize how heavily I have sprayed. This ground was all white with it." I do realize that he sprayed heavily, but he does not. He was adding arsenic acid to his soil at the rate of 51.84 pounds per acre per annum or taking it for a period of six years, as in the preceding case, he added 310 pounds per acre, or 77.5 parts per million of soil. The latter of these men used 26 times and the former 36 times as much arsenic as we now know would have sufficed to have assured them a crop with not more than 5 per cent. wormy apples. These men have lost a number of trees from this cause.

The Amount of Arsenic Now Present in Our Soils.

Determinations of arsenic in our orchard soils have indicated the following range; 25.5, 26.0, 30.6, 36.8, 38.2, 39.9, 61.3, 128.83, and 137.99 parts arsenic acid per million. The samples were taken, some from about the base of the tree and others out under the heads of the trees and to depths varying from four inches to one foot. The soils here represented are without exception desirable ones, they are free from seepage and alkali, and are well supplied with water. These orchards receive good care, still there is more or less of the trouble described as arsenical poisoning in each of them and some of them are very badly affected.

That the arsenic should accumulate in the soils is what we would expect. The materials used as sprays are not very soluble in water. The amount of water applied to our soils is not excessive, irrigation waters and rainfall together amounting to not more than 24 inches. The materials are not volatile and the evolution of arseniureted hydrogen from the soil has not yet been proven, though a slight elimination of the arsenic in this form, especially under favorable conditions, might take place. The fact, however, is exactly what we would anticipate, i. e., that the soils of orchards which have been sprayed for some years are already rich in arsenic.

Some of This Arsenic is Soluble in Water.

In the application of the sprays it was soon found that the arsenic must be insoluble or it would burn the foliage of the trees and in order to avoid this an endeavor was made to obtain a compound so insoluble that this effect would be avoided. To this end lime was added to the Paris green, and the lime, sal soda and arsenic preparation recommended. I do not know whether any consideration of the final effect of the arsenic on the tree was considered or not. The insolubility of the spray material is the only protection that our trees have had. The term insolubility as here used means nothing more than difficultly soluble and that in a somewhat popular conception of the term. The spray materials used are somewhat soluble in pure water and much more readily so in solutions of sulfate and chlorid of soda. The Kedzie formula was supposed to remove the whole of the arsenic from the solution because of great excess of caustic lime, but this is readily changed into a neutral salt, the carbonate, when its protective action is practically destroyed, besides there remains a considerable amount of arsenic in solution owing to the solubility of the lime salt. Paris green to which the proper amount of lime has been added yields arsenic rapidly to water, and arsenate of lead, $Pb_3(AsO_4)_2$, will yield 0.3% of its dry weight of arsenic acid. Soil, therefore, which contains these spray materials ought to yield arsenic to pure water and it does. I at first assumed that the presence of so much carbonate of lime, as is present in our soils, would wholly prevent any arsenic from going into solution, but this is not the case. Another agent which I thought would also tend to prevent the solution of arsenic is the iron which is fairly abundant in our soils, especially our red soils. A very large number of our soils are marly, namely, contain more than 5% of calcic carbonate, but neither the lime nor the iron nor both together prevent the solution of arsenic in our soils. This is an easily established fact. Sixteen samples of orchard soils from various parts of the state have been tested and found to carry very decided quantities of arsenic which is soluble in water. I have weighed the arsenic in a few instances and obtained the following figures: 0.68, 0.68, 0.84, 1.04, 1.166, 1.265, and 1.345 parts of arsenic acid per million of soil. These quantities corroborated by those obtained with nine other samples are conclusive in regard to the presence of water soluble arsenic in the soil in very decided quantities and that, too, in quantities which competent experimenters have found to be injurious to vegetation when present in nutrient solutions.

When I wrote Bulletin 131 I feared that the presence of water soluble arsenic in our soils might be largely due to the presence of sodic sulfate and sodic chlorid. That these salts are present in our soils in larger quantities than in eastern soils is a well known fact. It has been shown by experiment that lead arsenate, even the tri-plumbic salt, yields arsenic quite freely to dilute solutions of these salts and that calcic arsenite (lime, sal soda and arsenic) acts in a similar manner. It has also been previously stated that the arsenical compounds usually used for spraying are perceptibly soluble in distilled water. The statements made regarding this matter in Bulletin 131 are perfectly correct and I do not wish to change them except to lay less stress on the action of the alkalis, for soils entirely free from alkali contain water-soluble arsenic in weighable quantities. The solubility of the arsenic in the soil is undoubtedly favored by the presence of alkalis, but is not primarily caused by them.

For some years past, since about 1904, we have been losing a number of pear and apple trees by an affection which men, competent to determine the facts, have been unable to establish as due to any other cause than the corroding effects of arsenic. Among the causes considered were bacteria, fungi, King disease, winter killing, alkali, etc. The trouble is independent of the varieties of soil, it expresses itself uniformly in the same manner, attacks the trees at the same point, runs a very uniform course in regard to both manner and duration and is almost uniformly fatal. Here attention should be called to the fact that it has been only the badly affected trees that have been observed until very recently.

In regard to the soil we have shown the extent to which arsenic has accumulated in the soil due to the practice of spraying. Further we have shown that this arsenic in the soil is soluble in water to an extent that exceeds the limit of safety, and that the large quantities of lime and iron salts in our soils do not effectively prevent the solution of the arsenic by pure water. We have shown that the alkalis in our soils may favor, but are not needed, to cause the solution of this arsenic. We have also shown that our virgin soils, a goodly number of them too contain arsenic and will show in the proper place that this arsenic is slightly soluble in water in six out of seven cases.

The amount of arsenic present in our virgin soils, however, is less than one-tenth of that found in our orchard soils, and while it may play a part in some phases of this subject, it does not in any manner enter into the question of corrosive arsenical poisoning because it is associated with the marl and for the most part lies beneath the feeding area of the tree and is not collected about the crown of the tree.

The phase of arsenical poisoning under immediate consideration begins by attacking the outside of the bark at the crown of the tree converting it into a black, friable mass, finally eating its way through the bark, attacking the woody tissues and producing the death of the tree, either by starvation or otherwise, a question which the future may solve. The important fact is that the trees of which we are writing, and there are many thousands of them, are either doomed to die within the next two years or are already dead. That portion of the roots joining onto the base of the trunk is almost invariably involved. The attack may, in a few instances, begin on the roots but the number of these instances is small.

The Effect of Arsenic on Trees.

I have a record of about twenty trees, the greater portion of which I have seen myself, that have been injured or killed by arsenic, either in the form of arsenious acid, sodic arsenite, calcic arsenite or lead arsenate.

In Bulletin 131, page 19, I referred to experiments of others made to establish the effect of arsenic upon vegetation and gave the results of a few experiments made with greenhouse plants and cited the cases of two trees which I had met with, one of them presenting with great clearness the action of arsenic, particularly in the form of arsenious acid, upon the bark and woody tissues of the tree. I then stated that I gave the case in considerable detail because I believed it to present as conclusive an illustration of the action of arsenic upon trees as could possibly be adduced. I have since then seen several trees injured by the same cause, sodic arsenite, and while they each present an essential reproduction of that case, none of them have been any more marked or presented any feature more forcibly than it. I shall therefore use it again to show that soluble arsenical compounds when present in sufficient quantities will kill trees, secondly to show in some detail what the action of arsenic is on the tissues of the tree, particularly upon the bark and the woody tissues. The condition of this tree in the following April is shown in Plate I, taken from Bulletin 131.

The arsenic used in this accidental experiment was sodic arsenite emptied into an irrigation ditch, twelve feet distant from the tree. This was done in the month of June when the tree was in active growth. Two days later a portion of the tree was sick or dead, the person describing it said dead. I was not present that day. The limb never showed any signs of life afterward, the killing was thorough. Mr. Whipple and I subsequently dug out the poisoned root of this tree tracing it from the trunk to the point in the irrigating ditch where the arsenic had been emptied into it. The other roots of this tree which we encountered were apparently normal. Even those branches of this root which ran parallel to the ditch and whose feeding area had not received any of the arsenic also appeared normal. The rootlets within whose feeding area the arsenic had come were dead, being black and brittle. We could see the course of the arsenical solution from the rootlets to the tip of the twigs as the root lay in the trench which we had dug to expose it. The lateral branches of the root and the two side sections were normal in appearance, the top section and also the bottom section had been very strongly attacked. The bark of the root on the two sections attacked was thoroughly disintegrated and two irregular sections of the woody tissue of the root were killed and stained brown, shown in Plate II, Fig. I. The total

Colo. Ag. Expt. Sta.

PLATE I.

Fig. 3

Fig. 1-A

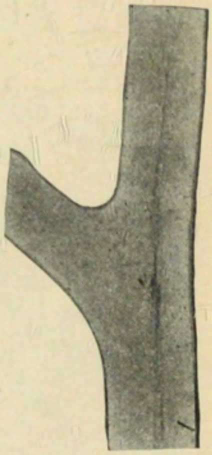


Fig. 1-B

Fig. 2

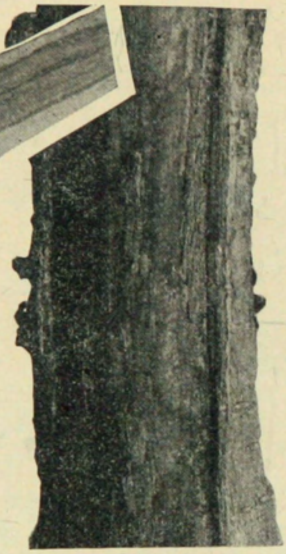


Fig. 4

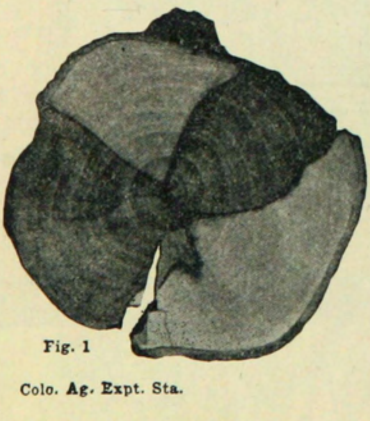


Fig. 1

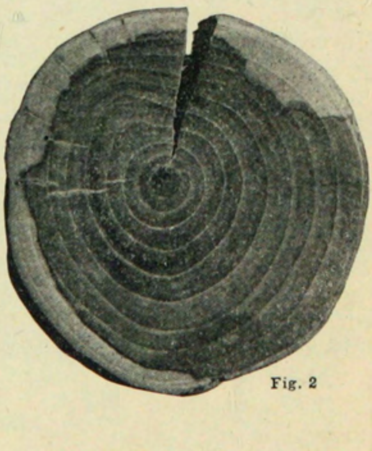


Fig. 2

Colo. Ag. Expt. Sta.

PLATE II.

disintegration of the bark on the root shown very distinctly in Plate II, Fig. 4, was continuous to the base of the tree. Here the bark became brown and sunken. This particular form of the injury extended some distance up onto the limb. Beneath this bark the wood was stained brown. The sunken part and stained wood is shown in Plate II, Fig. 2. The interior portion of the remoter branches of this limb was stained brown. This is shown on Plate II, Fig. 1-A, in longitudinal section, in Fig. 2 in transverse section. The other portions of this tree were perfectly normal, the bark was healthy, the woody tissues of both roots and branches showed no staining or "black hearted" condition. The healthy condition of the other roots and branches of this tree is also shown on Plate II by Figs. 1-B and 3. The so called black heart is in some cases caused by freezing but this case cannot be explained in this way, for we know its cause and can trace its course and action and the injury was done in the month of June. No one will, I think, suggest that these changes were subsequent to and a result of death and not of the action of the arsenic for all parts of the tree nourished by roots feeding outside of the poisoned area, even sections of this one root, remained apparently healthy and those portions of this tree which I have not cut off are still healthy.

I indicated clearly in Bulletin 131 that I was aware of the fact that this case, and all the cases do the same, raises questions regarding the course of nutrient solutions in the tree. I dismissed this whole subject with the following statements: "The course was direct and the flow of the poisonous solutions was confined to a comparatively narrow channel. * * * I am not concerned about any theory of sap circulation, but am simply tracing the discoloring effect of the arsenic through the roots into this portion of the branches."

I have personal knowledge of four other trees injured by the same agent, sodic arsenite, in a similar manner. The facts in these cases are even more interesting than in the preceding.

There had been fillers planted betwen the rows of apple trees. These fillers, plum trees, had been cut down, the owner poured one half teacupful of the sodic arsenite solution on each of the four stumps to kill them and at the same time get rid of the arsenical solution. No effect was produced for the next two or three days, at the expiration of which time the orchard was irrigated. The statement of the owner and his wife is, that within fifteen minutes after the irrigation water reached these stumps the leaves on one side of the largest of the four trees involved drooped and never recovered. The owner surmising the cause of the trouble dug a trench and cut off the roots of the tree on that side. The odor of the sap exuding from the wounds made on the limbs by the arsenic was very offensive.

The fourth tree in this group presented an interesting case. Two limbs on one side of the tree were injured, portions of them were killed. There was a narrow strip running from the ground up into a big limb of this tree and then divided, following two smaller limbs, breaking out to the surface in an apparently erratic way. The limbs were killed. Not being fully satisfied about the facts connected with this tree, I determined to examine its roots. I found two roots affected, one was still partly alive, the other was entirely dead. Neither of these roots was very large, a scant inch in diameter, but we traced the wholly dead one for twelve feet then we trenched across its course at several points and thus traced its dead rootlets to the stump on which the arsenic had been poured, 22 feet from the trunk of the tree. These roots presented externally the same appearances as the root previously described and is well represented by Plate III, reproduced from Bulletin 131. The other roots of this tree which we encountered were apparently normal. I examined several samples of wood from the first tree and found arsenic abundantly present and determined the quantity of arsenic present in the woody tissue of the root. The amount of arsenic present in the woody portion of the root of the first tree after the bark had been pared off corresponded to 34.5 parts of arsenic acid per million parts of tissue. The arsenic in the root of the second tree described corresponded to 24.02 parts of arsenic acid per million parts of tissue. The disintegration of the root was certainly remarkable.

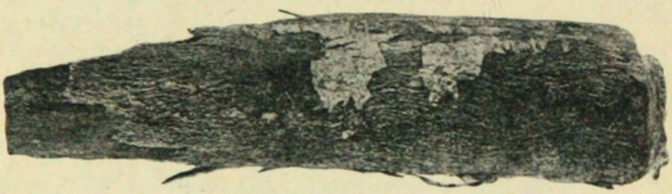


PLATE III.

I have information of several other instances in which similar results have been produced. According to the statements of the owners it seems probable that the arsenite of lime might have done the damage to their trees.

Mr. A. B. Hoyt, Horticultural Inspector of Mesa County, informs me that he has seen a cottonwood and a willow tree killed by the bursting of a jug of sodic arsenite which had been left beneath them.

I have the record of some other trees killed in a similar manner.

These cases are cited that we may present the effects of arsenic upon the tree and its tissues when it is present in the soil in a soluble form and in sufficient quantities to kill quickly.

We find in these cases the following features: the disintegration of the bark and woody tissues of the roots, the killing of the bark and tissues of the trunk, the production of a black heart, the exudation of ill smelling juices and a stunting in cases where a portion of the limb has survived.

The arsenite of soda mentioned above is the solution of white arsenic in sal soda, and is mixed with lime and water before it is used as a spray. It is mixed with lime to make the arsenic insoluble, though a very marked quantity of arsenic remains in solution in the alkaline liquid. This is contrary to general belief. I have had two lots of this preparation made with very excessive quantities of lime. Two hundred cubic centimeters of the supernatant solution gave a good test for arsenic by Reinsch's test. The sodic arsenite is not itself used for the purpose of spraying the trees but is added to the milk of lime to make the lime, sal soda and white arsenic preparation.

Dr. S. M. Bradbury, Horticultural Inspector of Mesa County for eight years, makes the following statement which is used with his permission. "Bands had been used in a certain orchard and on adopting the lime, sal soda and arsenic spray these bands were left on the trees, some of them for two or three years. Some of these trees died and on examining the bands we found that the bark beneath the bands had been entirely eaten up. The lime and arsenic had collected under the bands and destroyed the bark."

I know of another tree within a few feet of which the owner had mixed his spray material for several years in succession. This tree died and its wood was rich in arsenic. In this case arsenate of lead was used as far back as I have any information—about four years before the death of the tree.

I will cite but one more, though there are a few other instances which might be given. A man emptied his spray tank, containing arsenate of lead, about six feet from an apple tree; that side of the tree died. I did not take and analyze any portion of this tree because the owner did not wish me to deform the tree as he was sure he could cure it. The effects in these cases were in the main the same as in the cases killed by sodic arsenite, disintegration of the bark, the staining of the woody tissue, the production of a "black heart," and the production of a yellowish red bark frequently with longitudinal cracks. It will be remembered that I did not see the trees described by Dr. Bradbury, though I know the orchard very well and can testify that it has been in very bad condition for several years past. His description which I believe to be entirely reliable tallies exactly with what we find in the other instances. It is only through accidents that we have opportunity to observe the effects of sodic arsenite on 16 or 18 year old trees in commercial orchards, but the lime arsenite and the lead arsenate have been applied plentifully to our commercial orchards for years past and the action of these two may be found in almost any commercial orchard from 12 to 18 years old. No distinction can be made so far as I have observed between the action of these two sprays, except that the lime salt being more readily soluble than the lead salt probably has done the greater amount of injury to our orchards.

We have then a fair amount of evidence obtained by direct observation of the effect of arsenic in the three compounds, sodic arsenite, lime, sal soda and white arsenic, and lead arsenate, upon the bark, the woody tissues and the life of the tree. The sodic arsenite acts quickly, causing the death of all parts of the tree to which it may be carried; it causes the disintegration of the bark, especially of the roots, and may also destroy that of the trunk. It stains the woody fibre and causes its disintegration, sometimes producing a punky condition, and produces in the branches not so seriously affected a "black heart" condition. The lime arsenite and the lead arsenate produce essentially the same condition in the tree but their action is very much less intense.

Is Arsenic a Normal Constituent of Any Wood?

I have not examined many woods for arsenic with the object of determining this point, one sample of oak and a few apple trees. The oak contained no arsenic and I have found three apple trees in Colorado which were free from it, two of them were young trees and the third tree was one which had been killed by blight. The presence of arsenic in fodders, vegetables, meats and even in the human body are matters which belong in the province of the toxicologist and have but little bearing on a question dealing with such large quantities of arsenic as we do in studying its effect upon trees. I think that we are justified in assuming that normally arsenic is no more a part of an oak, an elm, or an apple tree than it is of the human body. In these days, however, when arsenic is spread broadcast upon our soils as superphosphates and arsenical sprays it would be rather surprising if it has not become so generally distributed that it might be found in the organs and bones of almost any person. I am certain that should the writer of these lines die suddenly and his body be subjected to a careful analysis, but little trouble would be met with in demonstrating the presence of arsenic in his liver, spleen, and possibly other organs, of which facts I hope to give good proofs in a later paragraph. I think that we may waive the question of traces and assume without any fear of being in error that arsenic is not a normal constituent of apple and pear trees in the quantities with which we are dealing, from one half to upwards of 20 even to 34 parts of arsenic, calculated as arsenic acid per million of the woody tissue.

Arsenic is Taken Up by the Trees.

I have endeavored to convey to the reader a clear notion of the amounts of arsenic which have accumulated in our orchard soils. As much as 138 parts of arsenic, calculated as arsenic acid, having been found per million parts of soil. This does not mean that every man's orchard soil is as rich as this nor does it necessarially follow that I could not have gotten samples from this orchard which would have run less, or perhaps more. This sample was a large one taken to the depth of one foot. I have shown that the water soluble arsenic in these soils in some cases exceeds 1.25 parts per million. The effects of soluble arsenical compounds on apple trees has also been shown. These cases were extreme ones, it is true, but they prove that apple trees may be killed by arsenic and they show the action of arsenic on the bark and wood of the tree. We will now give in some detail what we find in the case of our sick trees. No one can tell how many sick trees we have. I have examined several thousand, however, and in stating this it is to be understood that no trees suffering from neglect or blight or sunscald or nitre or trees in which there was any evident complication of troubles or even mechanical injuries are included.

Plate IV. is a photograph of an Anjou pear tree, taken in September 1909. The trees in the background are already attacked but will live two or possibly three years yet. The soil is a sandy loam free from alkali and seepage. A hole was dug at the base of the tree and there was no water at a depth of four and a half feet. The photograph shows where a large limb was cut off for examination.

The number of individual trees which have been analyzed is eighty-one, sixty-seven in connection with this bulletin and fourteen in connection with Bulletin 131, and of the eighty-one samples examined I have personally taken fifty-five, possibly more. I have not known the history of the trees in more than a few instances. Orchardists do not, except in rare cases, keep a written record of their doings and I find that any other record is of little value; more satisfying than none, it is true, but not to be depended on. This is in no wise a reflection upon the veracity of orchardists or others, but simply the statement of a very well known fact, i. e., that no one remembers their ordinary, every-day doings for more than a very short time, especially when these doings may be repeated quite frequently but at irregular intervals.

I have arrived at the point where I do not consider statements made pertaining to acts done much prior to the current year, and even then I consider a number of things before I place much value on the statements. This is very unfortunate for it necessitates the rejection of much information that might be very valuable and it increases our difficulties when the help that the information would afford is badly needed. I have been told very many times of trees that had never been sprayed; those trees, however, almost uniformly proved to contain arsenic, copper and lead. I admit that this is not absolutely rigid proof that the trees had been sprayed, but in as much as we have been using preparations of copper and arsenic, lime and arsenic and lead and arsenic with which to spray trees and as these substances eventually find their way to the ground from which the tree draws its nourishment, I submit that one is justified in interpreting the presence of these three substances, or even arsenic and either one of the others, in the woody tissue of the tree, as conclusive that the most probable source of the arsenic and lead or arsenic and copper was spray material which had been applied, rather than any original occurrence of these substances in the soil. This would seem the more probable as spraying of fruit trees has been practiced for not less than twenty-eight years and has been general in our section for about fifteen years. As the trees in question are usually from fourteen to thirty or more years of age, I prefer to accept the testimony of the chemical examination as to whether the tree has been sprayed or not rather than the state-

PLATE IV.

PLATE V.

ment of the present owner, who in many cases knows nothing about the earlier history of the orchard.

In writing of these trees Mr. Whipple made the following statement:

"Two seasons are required for the disease to kill the tree. The first season the trunk is girdled and the foliage drops early. This early ripening of the foliage is often the most prominent symptom and diseased trees can be easily picked out in the early fall. * * * The second season the tree starts in to leaf as the normal tree, generally setting fruit, and dies in midsummer, the fruit and leaves clinging."

This description is entirely correct, but it applies to trees in which the damage has already proceeded so far that we can, with a great degree of certainty predict how soon the tree will die. This too was the phase of the trouble at which we began to study it. We found a zone beginning just below the ground and extending down on to the roots where the bark had been destroyed and the underlying tissues stained brown. The similarity between these conditions and those produced by the arsenite of soda is perfect. The destruction of the tissue is almost as though it had been charred by dilute sulphuric acid but is more complete than would be accompanied by a like coloration if it had been produced by this acid. I have examined a large number of samples of the woody tissues of such trees, and have uniformly found that arsenic is present. The bark has not been used because the arsenical spray material might be mechanically included in it. For this reason the bark has in all cases been carefully removed. Further no dead wood which has been exposed to contact with spray material has been used, so that the results represent what has taken place in the tree itself.

The first samples examined were roots of a pear tree in which the trouble had not proceeded as far as the phase described by Mr. Whipple, but which were not healthy; these roots contained arsenic in large quantitites. Subsequently other pear trees and apple trees were examined with like results till we have examined in all eighty-one trees, apple, pear and peach. The results may be summed up as follows: in every case in which the death of the tree has been caused by corrosive arsenical poisoning we find the crown of the tree girdled, the bark below the surface of the ground is usually attached to the tree but is brown or black in color and its texture is wholly destroyed, the woody tissue of the root is colored mostly a deep brown and sometimes its texture too is destroyed. The wood of the lower part of the trunk is usually stained, though it may have no other sign of unhealthiness. This is in no manner similar to a spot of dead wood on the trunk of the tree above the crown caused by freezing or by a mechanical injury. The bark above the line of the ground is intact in most of these cases though there are some instances of trees resembling the one shown in Plate 2, Fig. 1, Bulletin 131, which, however, is not similar to cases of winter killing with which any of us are familiar. The heart wood even in the limbs and branches is generally, but not always, of a deep brown color with a decidedly darker brown margin. This coloring is irregular and does not conform to annual rings. The trees that die of this disease, and I believe that they all die, linger two seasons. Further it is safe to predict that every tree that we now find with a corroded crown and some dead roots will perish within the next few years if left to itself. We have many trees which show no sign of the trouble above ground this year, but which we can safely predict will die within the next two years. The signs above ground are those described by Mr. Whipple. The trees first submitted to analysis were naturally trees that were very sick. But few actually dead trees have been examined. No such sick tree has failed to yield a strong reaction for arsenic. This is most abundant at the crown of the tree, less abundant in the upper portion of the stem and still less so in samples of the branches, but is prsent in all parts of the tree.

I wish to emphasize the fact that we have two phases of the action of arsenic, first the local action of that which collects about the crown of the tree and that which has been taken up from the soil by the feeding roots and in this way passed into the tree with the nutrient solutions. It is evident that if the tree has been sprayed often enough to permit so much arsenic to collect at the base of the tree that it corrodes the crown and roots, the tree will also have gathered arsenic from the soil by means of its feeding roots and no one can say how much of that present in the woody tissue has been taken from the soil and how much has been absorbed through the wounds made by the arsenic on the crown and roots of the tree.

I maintain that we have strong reasons for believing that considerable injury has been done by arsenic absorbed with the nutrient solutions when it produces what I have designated as systemic poisoning. This feature was merely touched upon in Bulletin 131 because as there stated the cases of irritant poisoning are more numerous and, I may add, more evident.

It is evidently out of the question to give the details of sixty or more trees suffering from irritant arsenical poisoning. The observed facts are so uniform that it would only be to restate the same thing as many times as we should describe different trees. In every case we find a zone just below the surface of the ground and involving the large roots in which the bark of the tree is converted into a brown or black mass and the texture destroyed, the woody tissue beneath this is in many cases also destroyed, especially of the roots; in the trunk it is usually partially destroyed and always more or less stained of a brown color. As these trees approach death, usually indicated in the early fall of the year preceding this event, the foliage ripens early. The tree usually blooms profusely the next spring, sets fruit and dies early the next fall, the leaves and fruit often remaining on the tree in some instances until far into the winter or even the ensuing spring. In some cases we have a killing of the bark above ground. This occurs in continuous areas extending up so far as to sometimes involve a portion of a limb. This is shown in Plate 2, Fig. 1, Bulletin 131. The bark is not loosened but is killed, the juice that exudes is ill smelling and the area is continuous with the corroded crown. The whole section of a root may be involved or only the upper portion of it. There is frequently as sharp a line showing the limits of the attack on the roots as is shown by these patches on the trunk. This illustrated by Plate VI, rep-

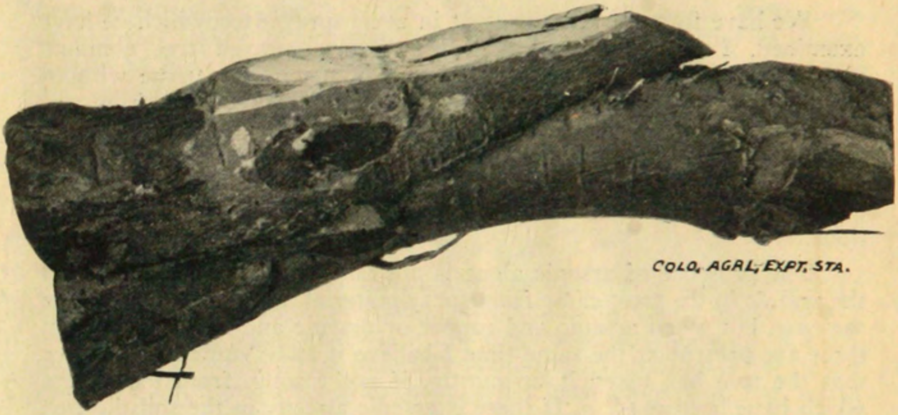


PLATE VI.

resenting the root of an apple tree, the further portion of which was perfectly healthy in appearance, which is also shown in the photograph. It may be of sufficient interest to justify a statement that this root was cut from the tree last May and the tree was practically dead this fall when I last saw it. I have found in such trees from 12.5 parts in the woody tissue to 24.65 parts of arsenic, calculated as arsenic acid, in the disintegrated bark.

Prof. C. S. Crandall, of the University of Illinois, formerly horticulturist of the Colorado Experiment Station, writes me that their chemist, Mr. O. S. Watson, obtained in samples of disintegrated bark which he collected while on a visit to this state 1.8 and 15.8 parts of arsenic per million.

In a sample of disintegrated bark collected from the crown of some pear trees 24.71 parts of arsenic per million, calculated as arsenic acid, were recovered. In the woody tissue of an apple tree root which we know was killed by sodic arsenite, 24.02 parts of arsenic acid were recovered. The inner portion of the bark on the pear tree is for the most part still intact and healthy but the bark is in many places very thin and occasionally we find it eaten entirely through and the underlying sap wood already attacked. The explanation that I offer for this condition is that the spray has been applied heavily enough to run down the trunk and collect around the crown of the tree just as the arsenic collected under the bands described by Dr. Bradbury. It has been soluble enough to saturate the bark to the extent stated, 24.71 parts per million, and to cause its destruction. This sample of disintegrated bark may have contained some arsenic in the form of the spray originally used. We tried to remove all the soil and adhering spray by sifting, this being the only feasible means of removing them.

The Source of the Arsenic.

We have found arsenic present in every sprayed tree which we have examined. I am fully convinced that every sprayed tree contains arsenic enough to permit of its detection in the woody tissue without the use of any very large amount of the wood. I believe that from two to 4 or at most 6 ounces of wood will suffice for the detection of arsenic. The perplexing feature in this work has not been to detect the presence of arsenic but to arrive at a definite conclusion in regard to its source and action. I have already answered both of these questions.

The presence of arsenic alone is not taken as sufficient proof that the arsenic in the trees came from spray material, though such might be the case, but when arsenic and copper or arsenic and lead or when all three are present at the same time I believe it to be sufficient evidence that the tree has taken it up mostly, if not wholly, from the sprays which have been used. If there is arsenic already in the soil the tree might without doubt obtain a trace from this source. This question, however, will be more fully considered under the subject of systemic poisoning, where it properly belongs.

The Cause of Death.

The crowns of trees growing in our neglected orchards are not corroded although the trees may be in bad condition. The trees that have been killed by nitre have perfect crowns. We have described the condition of the bark on trees showing cases of corrosion. We have shown that arsenic destroys the bark in this manner and have cited at least eight instances in which I have seen the trees. We have shown that this bark contains in the case of the pear trees arsenic equivalent to 24.71 parts of arsenic acid per million of the bark. This observation is supported by the findings of Mr. Watson, who obtained 15.8 parts of arsenic per million, which, assuming that Mr. Watson's figures mean metallic arsenic as I suppose they do, would correspond to 24.22 parts arsenic acid per million. These figures are so high that any other source than the spray material is out of the question; besides we know that the spray material does run down the trunk and into the ground at the crown of the tree. That this is a sufficient amount of arsenic to destroy both bark and woody tissue is plainly shown by the amount of arsenic found in the disintegrated tissues of roots which we know were killed by arsenic, in which was found arsenic corresponding to 24.02 parts arsenic acid per million. The maximum amount of arsenic found in any part of a tree, even when the arsenic was known to have been applied in such quantities as to have killed the tree quickly, corresponded to 34.5 parts of arsenic per million. We have stated that we find this corrosion of the bark in all stages of advancement from a mere film on the bark to a point where it has eaten through the bark and attacked the woody tissue and have found this woody tissue to contain arsenic equivalent to 13.20 parts arsenic acid per million. We have then this series of facts showing the progress of the disease till the girdling is complete, or so large a portion of the crown and roots have been destroyed that the tree dies. The amount of arsenic in the bark and in the tissues in extreme cases is as great as is found in tissues known to have been killed by arsenic but we do not know that the amount found in the destroyed root is not very many times the minimum amount necessary to produce this result. I have no hesitancy in concluding that arsenic applied to trees as arsenical sprays, i. e., as Paris green, as arsenite of lime (lime, sal soda and white arsenic), and as arsenate of lead has produced this trouble.

Arsenic in the Trunk and Limbs.

That I am unable to distinguish, in cases of trees which have died of irritant arsenical poisoning, how the arsenic found in the woody tissue was taken up is evident. The trees described were all in a dying condition but not dead, therefore imbibition after death is out of the question, but whether the arsenic found had been taken up by the wood from the injured crown or had been gathered by the feeding roots from the soil I cannot tell. Since this is simply a matter of fact which cannot be directly observed, I will assume that both methods have played a part. That the roots gather arsenic from the soil will be abundantly proven and further that they may gather enough to injure or even kill the tree. On the other hand it is very probable that arsenic is absorbed directly from the corroded crowns and roots, in which case we would expect the tissues in the neighborhood of the wounds to be richer in arsenic than those parts farther removed. This is, I think as much as can be said in regard to this point.

This is the case in these trees. We have in the woody tissue at the crown of a dying tree as much as 13.20 parts of arsenic, as arsenic acid, whereas in the limbs I have not found more than 3.28 parts per million and this was in a Bartlett pear tree which had been heavily sprayed, having received seven or eight sprayings annually for six years. The crown and roots of this tree were badly corroded and the roots contained 4.821 parts of arsenic acid per million. In a tree near which spray material had been mixed and which had killed the tree I found 8.32 parts per million in the roots and 6.35 parts per million in the limb. The roots and crown of this tree were badly corroded. This sample was taken in the month of March. I do not think that the tree would have put out any leaves if it had been allowed to stand. There is not always so marked a difference between the arsenic content of the crown and the limbs though a difference always exists; in the case of a pear tree, the one shown as a badly affected tree in Plate IV, the root showed 3.505 parts per million while the limbs gave 2.19 and 2.64 parts per million.

It is perhaps proper that I should say a word in regard to these determinations. It is a difficult task to manipulate the destruction of 60 or 70 grams of wood without losing some arsenic, again there is some loss in the Marsh-Berzelius method, again it is impossible to weigh such small quantities except on a button balance, which is not always at hand. In this connection I wish to acknowledge my indebtedness to Wm. Ainsworth & Sons who kindly placed one of their balances at my disposal. This balance was claimed by these makers to be accurate to 0.005 milligrams, and the balances are as represented. The weighings are accurate but the difficulties in the recovery of the arsenic will not justify us in claiming the highest degree of accuracy for them. One thing however can be said, i. e., they are all too low, and this without an exception. This I think will be readily acceded by persons competent to judge. The pages of a bulletin are not, in my opinion, the place to discuss analytical methods, therefore this subject will not be mentioned further than to reiterate the statement made in Bulletin 131: "That the reader is assured that the arsenic reported was not contained in any or all of the reagents used. The care taken was in all ways as circumspect, so far as the analytical work was concerned, as though human viscera were in my hands." Trouble was had in obtaining zinc so nearly free from arsenic that one could use it without misgivings.

The Part Played By Alkalis.

I was very explicit in my statements regarding this subject in Bulletin 131. I see no reason to change any statement made therein, namely that lead arsenate yields arsenic quite readily to dilute solutions of sodic sulphate or sodic chlorid and these are our common alkali salts. The other salts always understood, when we use this term, are the sulphates of lime and magnesia. Distilled water dissolved arsenic acid from the arsenate of lead which we used though it, the lead salt, had been previously washed, but water to which sodic sulfate or sodic chlorid, ordinary salt, has been applied will dissolve it more readily. This is true of the neutral lead arsenate and probably in a higher degree of the acid arsenate. Arsenite of lime (lime, sal soda and arsenic) is quite soluble in water but more readily so in water to which sodic chlorid or Glauber's salt has been added. I have, however, met with soils in which there is so good as no alkali and yet a very considerable amount of arsenic can be dissolved out of this soil by distilled water. I have even obtained soils from states in which alkali is not supposed to exist and these soils, too, contain arsenic which is soluble in distilled water and the quantity is so significant that it raises a doubt in my mind as to how big a part our alkalis actually play in the matter. It is evident that they may take some part in bringing the arsenic into solution in water but they are certainly not the primary cause of its solubility. As elsewhere stated, all of the arsenical compounds used as spray materials, Paris green, arsenite of lime and lead arsenate, are perceptibly soluble in water and consequently any soil containing these salts in sufficient quantities ought to yield arsenic to pure water, as they actually do. The alkalis in our soils certainly tend to increase this solubility, but as stated, we find so much water soluble arsenic in soils free from alkali that I am now very much inclined to attribute a rather small part to them, and to take the statement first made by Prof. Whipple, that "soil conditions seem to have no relation to the disease" in the broadest possible sense. I, however, am not willing to say that the alkalis have no influence but simply that I am convinced that they have much less influence on the question than I formerly thought. This view is not only forced upon me by the fact that soils free from alkali contain water soluble arsenic, but also by the fact that I have found so many trees injured by arsenic and yet the soil in which they had grown could not be called an alkali soil without actual disregard of facts.

In order to test this point further and at the same time to determine the difference in the deportment of the orthoarsenate of lead, $Pb_3(AsO_4)_2$ and the acid arsenate, $PbHAsO_4$ with dilute solutions of the ordinary "alkali" salts, i. e., sodic sulfate and chlorid, six series of experiments were made which extend those described in Bulletin 131 in that sodic carbonate is included in the solutions and further we have endeavored to determine the arsenic acid that went into solution.

The first solvent considered is sodic sulfate, because this is our common alkali. Three strengthes were used: one, two and three grams per litre. The strongest of these is weaker than many of our soil waters, but is probably as strong as the soil waters in the majority of our orchards. It is very certain that quite a number of orchards can be found in which the soil itself will contain a larger amount of sodic sulfate than 0.1 per cent, or one part per thousand; on the other hand there are a great many that do not contain this much. This statement is made because there are many places where we sometimes meet with saturated solutions of this salt and this condition is supposed to apply to all, or to a very large portion, of the orchard land which is too broad an inference. One and one-quarter gram of the lead arsenate was added for each litre of the solution and the whole shaken frequently.

The solubility of the acid lead arsenate in water was not determined but it has been previously stated that distilled water dissolves about 0.3 per cent. arsenic acid out of the triplumbic or neutral arsenate. According to this each litre of water would dissolve 3.7 milligrams of arsenic out of the 1.25 grams of ordinary arsenate of lead. Portions of the solution were taken at the end of 24 and 72 hours. We had some trouble to obtain perfectly clear solutions. The difference in the amounts of arsenic dissolved being quite small the range being from 3.9 to 7.2 milligrams per litre. I give the average of eight determinations made with the sodic sulfate which is 5.6 milligrams of arsenic acid per litre for the triplumbic arsenate. This includes the thre strengths used, 1, 2, and 3 grams per litre, or parts per thousand. The acid arsenate, $PbHAsO_4$, gave higher results from 3.8 milligrams per litre in 24 hours for the solution containing one gram sodic sulfate to 10.5 milligrams in 72 hours for the solution containing three grams sodic sulfate per litre. The average for the eight determinations made is 6.4 milligrams arsenic acid per litre.

The acid arsenate is more readily attacked even by these weak solutions than the ordinary arsenate of lead; but both yield significant quantities.

Previous experiments had inidcated that sodic chlorid (common salt) is much more vigorous in its action on lead arsenate than the sodic sulfate or Glauber's salt. Sodic chlorid is not present in large quantities in our soils and for this reason I used only one-half as much sodic chlorid as sodic sulfate, i. e., one-half, one, and one and a half grams to the litre. As the amounts dissolved and the differences are greater I will state them in tabular form. Ordinary lead arsenate is $Pb_3(AsO_4)_2$, the acid arsenate is $PbHAsO_4$. The results are stated in milligrams of arsenic acid.

		Ordinary	*Acid*
½ gram NaCl per litre	24 hrs.	31.2	68.6
	72 hrs.	——	72.4
1 gram NaCl per litre	24 hrs.	32.3	74.6
	72 hrs.	48.8	95.1
1½ gram NaCl per litre	24 hrs.	36.9	108.4
	72 hrs	47.6	113.4

Sodic carbonate (sal soda) was used in solutions one half as strong as the sodic chlorid, because it is present in our soils in quite small quantities.

		Ordinary	*Acid*
¼ gram Na_2CO_3 per litre	24 hrs.	48.1	114.5
	72 hrs.	56.7	131.1
½ gram Na_2CO_3 per litre	24 hrs.	44.2	157.6
	72 hrs.	56.7	160.9
1 gram Na_2CO_3 per litre	24 hrs.	54.4	157.1
	72 hrs.	55.0	158.7

The ordinary lead arsenate, $Pb_3(AsO_4)_2$, is attacked a little more freely by water containing only a comparitively small quantity of sodic sulfate than by pure water and the amount dissolved increased slightly when we increased the amount of sulfate from one and two to three parts per thousand. Even small amounts of soda chlorid and carbonate decompose the arsenate to a marked extent. The acid arsenate, with thirty per cent or more of arsenic acid, is attacked more vigorously by each of these substances, sodic sulfate, sodic chlorid and sodic carbonate, than the ordinary arsenate with about 26 per cent of arsenic acid. This difference is quite important as the acid arsenate is coming into more general use.

The Part Played By Water.

I know that Prof. Whipple had this condition in mind as much as any other when he made the statement that soil conditions seem to have no relation to the disease and I also had it in mind when I corroborated his statement. This trouble appears on high as well as low ground, on sandy soil as well as in heavy soil. The pear tree shown in Plate IV stands in a light sandy loam with a decidedly sandy subsoil changing to gravel at the depth of four feet. I sunk a hole a little deeper than this at a season when the whole country was being irrigated, namely, at the time of the autumn irrigation and at a depth of a little over four feet this soil was almost dry. I have seen trees drowned but the water in these cases had risen quite to the surface and had remained there for a long time, how long I do not know. These trees do not belong to this class.

In this connection I will again state that trees killed by nitre poisoning present nothing in common with those killed by irritant arsenical poisoning. Trees killed by nitre generally have perfectly healthy crowns and roots. Most of the cases that I have examined have had perfect crowns, in fact I think that they always have unless there is some complication of trouble, as irritant arsenical and nitre poisoning, in which case the tree might die of nitre poisoning though it had a corroded crown.

There is an orchard which I am convinced has suffered several years from a rising water plane and an excessive quantity of nitre. This orchard is drained by a 7x6 inch box drain which discharges a large amount of water but it is not sufficient. The water discharged from this drain carries 637.2 grains of mineral matter in each imperial gallon of which 14.5 grains was sodic nitrate or its equivalent. The crowns of these trees and the roots at the crown are apparently perfect but the trees are in bad condition and many of them have been removed. The distal ends of the roots are killed, rotted off. This I believe, has been done by the high water plane. These trees present an entirely different case from trees killed by irritant arsenical poisoning.

Trees That Have Not Been Sprayed.

I introduce this subject for the simple reason that through this claim for certain trees I found some very instructive and interesting cases. It is a very common thing for persons to state that "those trees have never been sprayed." I have been deceived by this statement so often that I now pay no attention to it at all. I have examined too many trees that "have never been sprayed" and found arsenic, copper and lead present which I consider as establishing a strong presumption that the tree has been sprayed. In this instance, however, I know the owner personally and he was so positive and his statement was corroborated by at least one other member of the family, that when I saw the trees which I thought were surely not sprayed I did not know what to think. I at once saw that I had to examine at least two of the trees, for if these trees had not been injured by arsenic then I had at last found an instance of apple trees with corroded crowns and all the other conditions which I had been attributing to the irritant action of arsenic which were not due to this cause. I took samples of the corroded roots of two trees and found arsenic without any trouble. I knew that my friends had not tried to deceive me and was certain that an explanation was to be had. I suggested to them that potatoes might have been grown between these trees and had been sprayed with Paris green or possibly lead arsenate. This proved to be the case, and while the trees had not been sprayed as apple trees, they had been sprayed with the potatoes. At this time it is impossible to learn whether these trees had ever had the poison applied directly to the body of the tree or not. A few points, however, are established: that the crowns of these trees were girdled, the roots were corroded, arsenic was present in the woody tissues of the trees, the trees have since died. They were never directly sprayed as apple trees but potatoes were grown between these trees and were sprayed with Paris green in the earlier years of the orchard and later with disparine, a trade name for arsenate of lead. I will here mention another case, a little different it is true, but somewhat to the point suggested by the preceding instance. Two young trees were set in the places of two dead trees and stood three years and died. Prof. Whipple was asked to examine the trees, and suspected that they had been killed by arsenic, but these trees had never been sprayed. I visited Grand Junction soon after that and he asked that I go and see these trees, for if the facts were wholly as stated to him I might have to make some exceptions to my general statements. I went and found that the owner had pulled them up and buried them. We dug them up, washed them off and examined them. I, too, felt certain that they had been killed by arsenic. The owner at first insisted that they had never been sprayed, which in one sense was true, but he admitted that the boys had turned the spray on them as they drove past them while spraying the orchard. I asked him for the history of the trees and found that he had a young orchard three years old and these two trees were from the same nursery lot which he had planted in the young orchard. I asked him how many trees had died and he said none but the two trees that he had set in the places of two old sprayed trees and which they had just sprinkled as they drove by with the spray tank. The crowns and roots were corroded and arsenic was present in the woody tissues of the one that I examined. I give the cases of these four trees as suggesting, but nothing more than suggesting, the answer to a question which has frequently been asked: Is it safe to plant young trees in an old, long sprayed orchard? I have uniformly confessed my inability to give an answer to this question. These cases certainly suggest the possibility of danger, especially if the soil filled in around the crown should chance to be rich in arsenic.

This and other serious questions are by no means new to many of our orchardists. One of them rather anxiously asked me in the early spring of 1909. "What are our old orchard lands worth?" This, too, is a suggestive question which I have not ventured to answer.

An elm tree first called to my attention by Mr. H. A. Richardson, Horticultural Inspector for Delta County, presents a most interesting case. Some may feel that the trees previously mentioned had in effect been sprayed; at least the cases need explanation in order that the claim that they had never been sprayed may be understood. There is no doubt but that the first two trees mentioned had not been sprayed, but no one can at this time so much as surmise what may have happened whereby the arsenic may have been applied around the base of the tree. With this elm tree, whose condition in October, 1909, is shown in Plate V the case is different. The bushes in the left hand side of the picture are lilacs; in the background are apple trees of different ages. That portion of the background occupied by young apple trees was formerly a pear orchard. In the spring of 1909 this tree was in such a condition that its owner became anxious about it, especially so as it is a tree the care of which has been a pleasure and whose growth has delighted the owner because it has attached to it memories and a sentiment which none but the owner may share. The conditions found are fairly indicated by the limb on the right; the leaves were dying and this side of the tree was in evident distress; the condition was so bad that the people were glad to have the limb taken for examination. The wound made in removing the limb bled freely and smelled very offensive. The interior portion of the limb was very dark and examination showed the presence of a considerable quantity of arsenic. I have endeavored to find something in the history of this tree which would explain this but I have found nothing.

A roadway passes in front of the tree and on this side of the road is the kitchen garden. The tree has never been sprayed. They did mix a little spray material, lime, sal soda and arsenic, just beyond the lilac bushes once, now seven or more years ago. I have been unable to find any other specific cause for the trouble. This case has been so interesting to me that I have made four visits to the place. The condition of the tree grew steadily worse throughout the past season. Beginning at the point where the limb was cut off one can follow an injured strip running somewhat spirally down the trunk. It is lost at the crown of the tree. I give this fact because I followed this injured strip expecting to find it leading to an injured root which I might follow to the place where they had mixed the arsenite of lime but I was disappointed. So with the aid of Mr. Herrick, our present Field Horticulturist in this section, I traced out the roots of this tree to see if we could find any of them either dead or showing injury. We traced five different roots for a distance varying from twenty to twenty-five feet and found no external injury to the roots except at one place and this I am sure had been done by the ploughshare. We, however, found some roots which were not healthy as they had spots on them and on stripping off the bark we found the inner side of the bark and the tissues of the root colored brown or brownish and livid. The soil at a distance of twenty-five feet from the base of the tree was well filled with fibrous roots of the elm tree. The soil showed by qualitative test that it contained an abundance of arsenic. There remained but one thing for me to do and that was to take more samples. I accordingly cut off one of the roots at a point six feet from the base of the tree and took a section of the root three feet long for a sample. I also took a small limb from the healthy appearing side of the tree. These samples showed the presence of arsenic in considerable quantities. We have in this case a tree which has never had any arsenic applied to it directly. It is not in any way indicated that the tree was injured by the lime arsenite which was mixed at some distance from the tree, but I do not say that it was not. I say only that I failed to find any proof that it was injured, and my judgment is that it is very doubtful whether that operation performed seven or nine years ago had anything to do with the present troubles, except as it has contributed to the general conditions. The root taken started out between the two little bushes near the tree, then turned to the right and ran straight back into the orchard. We find, that some of the roots show a diseased condition quite similar to conditions found occasionally on the trunks of the trees. We find that the woody tissue of the root contains arsenic and also that of the limb taken from the apparently healthy side of the tree. The limb which has been removed was dying; one of the limbs remaining on the right side of the tree is dead. It presented all the signs which accompany the death of trees killed by arsenic and arsenic is present. I have no hesitancy in saying that arsenic is the cause of the trouble and the death of the limb. This tree which has really never been sprayed, and which appears to have escaped accidental poisoning but whose roots were feeding in a soil rich in arsenic, is dying of arsenical poisoning.

The soil in this case is a red mesa soil somewhat clayey and at the same time calcareous, I would say marly, it effervesces freely with acids. I do not know how far it is to water, but judging from the line at which the seepage water breaks out below the edge of the mesa, twenty-five feet is a conservative depth to assume for the water plane.

The ash of the smaller limb which the plate shows as having been cut off shows the presence of copper, but the presence of lead is doubtful. A porcelean lamp was used in incinerating the wood; so that there is no question but that the copper was contained in the wood; besides the quantity present is too big to have come from the flame of a Bunsen burner in the ordinary course of work.

The virgin soil from this mesa was tested for copper, lead and arsenic. One hundred grams of soil failed to give a trace of lead. By careful manipulation we were able to establish the presence of a minute trace of copper, but there is a more decided quantity of arsenic present. The orchard soil is decidedly rich in copper and arsenic. It was not tested for lead and needed not to have been for arsenic, for we know that the arsenate of lead has been put on the soil in spraying the trees. The quantity of arsenic and copper present is much greater than that in the virgin soil and the presence of the two, arsenic and copper, is conclusive proof that this tree has obtained the arsenic which we find in its roots and branches from the spray material applied to the adjacent pear and apple trees, for the tree itself has never been sprayed. In this tree we have no corroded crown, but there is an injured strip running obliquely up the trunk. I could not trace it below the surface of the ground. While some of the roots show signs of disease none of them are corroded. One side of the tree is already dead and the trouble is involving more and more of the tree; arsenic and copper are present in the woody tissues of the limbs. The root was tested for arsenic only. There seems to me no other conclusion to draw from these facts but that the tree has gathered these poisons from the orchard soil.

Lead and Copper in the Trees.

The question whether these metals are playing any part in the troubles which we are discussing or not is certainly germane, but while I am ready to believe that they may have some influence the action of the arsenic seems so clearly to be able to account for all that we have found, that it seems needless to attempt to discuss either lead or copper though we know that the latter can and has injured trees when used in too large quantities.

I have examined a large number of trees for the presence of lead and have always found it. Lead has been determined in but one sample in which 0.003% metallic lead was found. This is practically all that we have done with the lead and copper, i. e., we have examined the woody tissues for them, because I consider their presence as establishing the source of the arsenic with a fair degree of certainty and not because I wished to consider the question of their poisonous character.

The Effect of Lime.

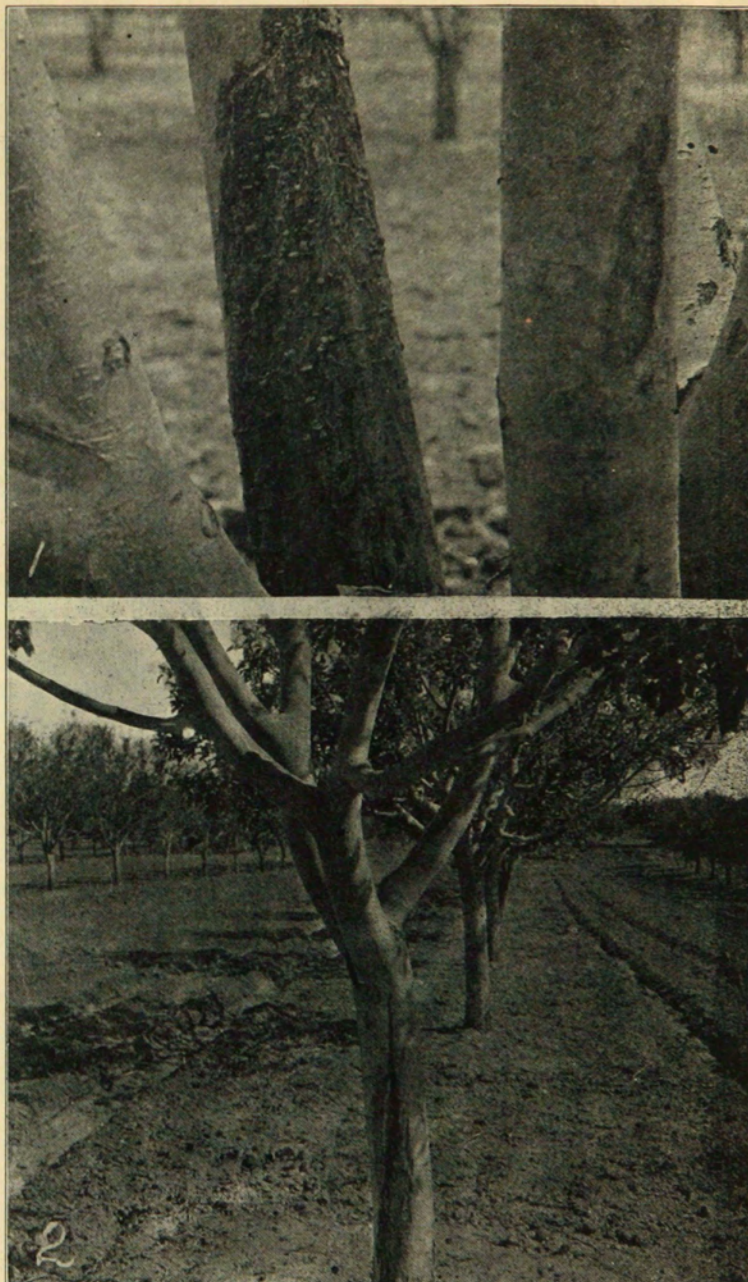
This question is involved in more obscurity than any other that has been met with up to this time. I know of several orchards in which the trees are small for their age and do not show the thriftiness that the care they have received would justify one in expecting. Four of the orchards that I have in mind receive excellent care, but many of the trees are not healthy. There is some irritant arsenical poisoning present but these cases are not numerous and it has nothing to do with the condition here discussed. The one feature that I wish to present in this paragraph is that of bleeding. Namely, the wounds made in trimming last season will bleed badly this season. They sometimes do not bleed the first season but bleed badly the second. In some of these orchards the bark splits and bleeding ensues. The splitting of the bark may take place on the limbs or on the trunk. The bleeding is almost always profuse. This bleeding is so far as I can recall at this time confined to land that is very marly or underlaid by a stratum of marl. Sometimes this stratum is quite thick, two feet or more, at others it may not be more than a few inches in thickness.

The bleeding is sometimes quite profuse, so much so that the outflowing sap may encrust the trunk with a yellowish white deposit for several inches below the split, or if on a limb for a foot or more. I have seen it drip and build little stalactites three inches or more in length and cover the limb with a deposit an eighth of an inch thick. This material seems to be gathered from the soil and is the sap or solution sent up into the tree by the roots and is probably not produced within the limbs or tissues of the tree. This of course cannot be observed, but the following example will make my meaning plain. A limb of a Jonathan apple tree was cut off on the eighth of April. It was cut off close to the trunk of the tree, not more than two feet from the ground. The tree was not healthy, but no more unhealthy than the average tree in the orchard. On the twelfth of May I found that this wound was bleeding and was already covered with the deposit described above. This sap was then exuding through the medulla, as was easily observable. No bleeding could be observed from the sap wood. This bleeding is very marked in some orchards and practically absent in many. The deposit is the same in appearance wherever I have seen it. The soil of these orchards is underlaid by marl and the soil itself is marly. I think that the great majority of our soils carry more than five per cent. of carbonate of lime. This deposit contains 25.00 per cent. of calcic oxid and 49.0 parts per million of arsenic, calculated as arsenic acid. The cracking open of the bark and the bleeding is shown in Plate 5, p. 16 of Bulletin 131, and as it is still representative we will use it again as Plates VII and VIII.

I know nothing about the contents of total solids in normal apple tree sap, but this sap is evidently very rich in total solids which as represented by these deposits are soluble in cold and hot water, but difficultly soluble in alcohol. If to the aqueous solution some alcohol, not enough to precipitate it, be added, fine acicular crystals deposit on standing. Calcium is essentially the only inorganic base present but is accompanied by a small amount of magnesia and the alkalis potassium and sodium.

Lime was not mentioned in the preceding section because it is always present to some extent in the ash of plants and in all soils, and the amount of lime added with the arsenite of lime is extremely small when compared with the lime in our soils for which an estimate of 65 tons per acre foot is very moderate. The soil of one of the orchards referred to carries in the surface foot calcic carbonate equivalent to 224 tons of burnt lime, while the subsoil is still more limey. The supply of lime is excessive, the ability of plant roots to dissolve calcic carbonate is well known, so the appearance of lime in these deposits is no matter for surprise, but the appearance of so large an amount of arsenic, 49 parts per million, is sufficient to raise a question in regard to its source and its relation to the lime.

Some plants are calcifugous but the apple does not seem to belong to this class, for it does well and lives long in limestone soils, not only in other states but also in Colorado. I know of a small or-



Colo. Ag. Expt. Sta.

PLATE VII. (upper), PLATE VIII. (lower)

chard set in a soil so thin that it scarcely covers the underlying calcareous shale and I could find none of this bleeding in these trees. The orchard is young and fairly thrifty. It is further true that this bleeding is not universal throughout the fruit growing sections of the state while the presence of lime in relatively large quantities is certainly the rule with only a few exceptions.

In Bulletin 131 I stated that the question is: Are these trees suffering from systemic arsenical poisoning, lime poisoning, or both? Again I have repeatedly expressed my opinion that it is doubtful whether we can distinguish the part which each plays in the case. There can be no doubt, and there is no doubt in the minds of thoughtful men conversant with the facts, but that something is the matter with these orchards. This does not mean that the trees are dead or that the orchards may not continue to give very handsome returns for years to come, but simply that the trees are not healthy and that the bad condition of some trees is possibly due to this cause. Arsenite of lime was at one time our generally used spray material and it is possible that soil conditions may have been such that this in some cases caused the injury.

The lime and arsenic may have been taken up together, that is, in combination, or taken up at the same time but not in combination and we are not able to distinguish their separate action. I would make no mention of this matter if I did not believe it to be of such importance as to demand mention.

I have studied these marly soils to see if I could find anything indicative of an explanation for this condition. Orchards do quite well on some of these lands, especially if the surface soil is twenty inches or more deep and not too rich in lime. The following analysis will give an idea of their composition:

ANALYSIS OF MARLY SOIL.

Insoluble	48.589
Soluble Silica	17.071
Chlorin	0.008
Phosphoric Acid	0.036
Carbonic Acid	8.532
Lime	11.695
Magnesia	1.674
Sodic oxid	0.374
Potassic oxid	0.589
Ferric oxid	4.890
Aluminic oxid	4.554
Manganic oxide (br)	0.179
Ignition (loss)	(1.776)
Sum	100.002
O Equiv to Cl	.002
Total	100.000
Total Nitrogen	0.386

According to this analysis, the amount of phosphoric acid present is scarcely good but the supply of other plant food is very fair That this soil contains arsenic is assumed as the orchard has been sprayed for years. The carbonic acid, CO_2, present corresponds to about 19.38 per cent. of carbonate of lime. The preceding is a surface soil.

One of these marly subsoils had the following composition:

ANALYSIS OF MARLY SUBSOIL.

Insoluble	55.683
Soluble Silica	2.866
Chlorin	trace
Sulfuric acid	trace
Carbonic acid	12.444
Sodic oxid	0.390
Potassic oxid	0.360
Calcic oxid	16.538
Magnesic oxid	2.438
Ferric oxid	3.428
Aluminic oxid	1.326
Manganic oxid (br)	0.260
	100.033

We have here about 28.28 per cent. of carbonate of lime or marl. This subsoil was taken at a depth of twenty-three inches, and though representing the subsoil of a sprayed orchard I deemed it of sufficient interest to determine the arsenic that it might contain and found 15.33 parts arsenic, calculated as arsenic acid, per million. I scarcely think that the spray applied to the trees would find its way down into this marl. This orchard had been given surface cultivation only, still I acknowledge the question as an open one whether this arsenic is an original constitutent of the marl or an adventitious one arising from the practice of spraying. Personally I believe that the marl itself has always contained the arsenic.

I will give an analysis of a marl from still another place. This sample was not taken in the orchard itself but from an adjoining piece of land belonging to the same owner as the orchard. I will state that this orchard showed a pronounced case of rosette.

ANALYSIS OF A MARL.

Insoluble	24.098
Soluble Silica	8.269
Sulfuric acid	0.350
Carbonic acid	27.115
Calcic oxid	34.525
Magnesic oxid	2.942
Iron and Aluminic oxid	1.960
Manganic oxid (br)	0.180
	99.439

This analysis indicates the presence of about 61.5 per cent. of carbonates, almost wholly lime carbonate and a quantity of decomposable silicates. The most interesting point, however, is that this marl contained 5.21 parts of arsenic, calculated as arsenic acid, per million. These marls open the question of the presence of arsenic in our marly virgin soils. I have stated repeatedly that the greater part of the soils to be considered in this connection are to be considered as marly. I have therefore tested some of our virgin soils from land not yet brought under irrigation. The two already given cannot be considered as virgin soils, i. e., the subsoil twenty-three inches below the surface with 15.33 and a marl with 5.212 parts of arsenic acid per million. I have determined the arsenic in five virgin soils concerning which there can be no mistake about their having never received an application of arsenic, at least not the whole five, which were taken from localities about sixty miles apart. I found in these soils the following quantities of arsenic per million parts of the soil: 2.8, 3.8, 4.2, 4.5, and 4.7 parts. I have further examined six other samples of soils concerning which some doubt might be entertained but I am fully satisfied that two of them have never been sprayed or received the application of any arsenic whatsoever and still it was present.

In connection with this bleeding I have been confronted with the assertion that some of it has been observed in the case of some trees which had never been sprayed. I have not seen such myself but if the observation be correct, it would point rather directly to the arsenical lime, whether native or artificially added, as the cause of this particular trouble, and I believe this to be the case. Those orchards in which I have found this trouble the worst are on such marly soil as I have described, and so far as I know their history, were treated very liberally with arsenite of lime when this preparation of arsenic was exclusively used as a spray material. The samples of virgin soil in which the arsenic is present and cannot be attributed to any known source contain a comparatively small amount of arsenic compared with the orchard soils, in round numbers one tenth as much. This statement does not consider the marly subsoil containing 15 parts arsenic acid per million because some of this arsenic may have been derived from the arsenical spray put on the orchard. No one has, so far as I know, attempted to determine to what depth these sprays may affect the arsenical content of the soil, but as they are decidedly soluble in water it is easy to conceive that the depth to which the arsenic may penetrate is greater than we might think. The sample of soil taken to the depth of one foot and showing 138 parts arsenic acid per million is also excluded from the above statement that the orchard soils contain ten times as much arsenic as the virgin marly soils. As our transplanted apple trees are shallow rooted, seldom feeding to a greater depth than two and one-half feet, it seems probable that they gather their food from the soil proper. I do not think that the marls underlying these lands enter into the question to a great extent, besides only one of them has been found to contain more than five parts arsenic acid per million.

In regard to the solubility of the arsenic in the orchard soils, I have shown that as much as 1.26 and 1.34 parts of arsenic acid per million of soil is soluble in water. The virgin soils on the other hand yield only traces or none. In this connection it is to be remembered that the roots of the trees may be much more effective in bringing the arsenic into solution than distilled water.

This bleeding takes place from cracks in the bark and also from old wounds made in trimming and is especially noticeable in wounds already one year old. I have watched this taking place, when the juices were issuing through the medulla while no other portion of the section seemed to be taking any part in the process. It is common to find this section of a wound surrounded by this deposit which is rich in lime and arsenic. The medullary tract seems to be the easiest channel for these juices to traverse, which may itself be an indication of a diseased condition. Prof. Longyear has suggested that the ducts whose function it is to conduct the sap of the tree upward, may be so clogged and the resistance offered to the upward diffusion of the sap so great, that it follows this unusual course. The Professor kindly consented to examine sections of affected trees and gives me the following statement of his findings:

"Three lengths of affected branches, two inches in diameter, in which an outer layer about one-fourth of an inch thick of healthy sapwood remained, were brought to me in a fresh condition in February, 1910.

"Transverse sections from different portions of these branches under the microscope showed the ducts in the uncolored sapwood free from obstruction and the cells of the medullary rays stored with starch. In the most highly colored zone, just between the healthy and the affected wood, the ducts were found to be filled with a yellowish or brownish gummy substance, insoluble in cold water and dilute solution of caustic potash. Toward the center of the branch this gummy material diminished in quantity quite rapidly but was not entirely lacking. In the colored area the medullary ray cells still contained in some instances a little starch but in most cases they were partly filled with brownish granules and globules of substances remaining or arising from the disorganization of the cell contents. It is evidently from these sells that the gummy matter has found its way into the ducts. This is shown by the fact that this material appears in a duct first on the side next to the nearest medullary ray cells."

In regard to the varieties affected I have seen this bleeding in the Jonathan more often than in any other, but it is not confined to this variety. I have also seen it in the Missouri Pippin, in the Spitzenberg and other varieties.

The facts seem to me to point to the action of arsenic in conjunction with lime rather than to the action of either alone as the cause of this trouble.

Systemic Arsenical Poisoning.

What I have said concerning the action of arsenic and lime might properly, perhaps, have been put under this head, but I have chosen to treat it by itself because it is so pronounced a feature that it is not possible to overlook it and it will be more easily recognized by those familiar with it than if it were included under this caption.

While there is no single feature in the cases of the trees remaining to be described which may be taken, as the destroyed bark of the crowns and roots in the first, or the deposition of an incrustation on the surface of the wounds or on the bark in the second case, as guiding features, we have some which force themselves on our attention, one is a reddish yellow color of the bark, especially of the limbs, another is the lack of thriftiness. The former is not, in my opinion, specifically diagnostic of arsenical poisoning but rather of malnutrition, itself a result possibly of the arsenic.

I have seen this color in an orchard which I am convinced is suffering more from other causes than from arsenic, though it may have contributed some in bringing about the bad condition of the orchard. As I shall not refer to this orchard again, I may describe briefly some of its more marked features. This orchard, in the spring of the year, is a very marked feature of that section of the country because of its abnormal color. There are but few or no signs of corrosion. A large number of these trees were pulled up in the late winter and spring of 1909. The ends of one half of the roots, this is the estimate of the man who pulled them up and not mine, were found to be rotted off. Some of the remaining trees were pulled up and a few of the roots were found to be in this condition. It is my opinion that the color of this orchard is mostly due to starvation but this forms a part of another study, and is mentioned to dissipate any idea that some might get that this reddish color is diagnostic of arsenical poisoning. This color is not due to sunburning. I have considered this, but there are some facts very hard to explain on this theory, for instance this color is only a little more intense on the south side of the limb than on the north side and all of the trees of an orchard may show this color.

Almost any tree in some of these orchards might be used as an example to illustrate and introduce the discussion of systemic arsenical poisoning.

I have stated that the subject of the action of lime and arsenic might have been included under this caption and the first example is a Jonathan; the tree is small for its age, about 14 years old, the bark is somewhat yellowish and it represents a case of moderate bleeding. The deposit formed is rich in arsenic. I cut off a limb of the tree; the interior portion of it was strongly discolored, the discoloration was not confined to the annual rings. An examination of this wood showed the presence of arsenic. Both of the preceding tests were repeated with a confirmation of the results. The crown of this tree is not corroded. We evidently have in this case an instance in which both the lime and arsenic are present and it is difficult to judge whether the arsenic, independent of the lime, is the cause of the bad condition of the tree.

The next case is that of a Spitzenberg. The tree was small for its age, crown was good, bark very yellow, foliage during the preceding season small, scanty and of a bad color throughout the season and ripened too early. This tree was dug up in the spring of 1909 because of its bad condition. The wood from the center of the tree outward for nearly an inch was brown but not deeply colored as the Johathan just described. This tree showed no bleeding. A limb of this tree was taken for examination and the woody tissue showed as strong a mirror as some of the trees which had corroded crowns. The mirror was weighed and corresponded to 2.19 parts arsenic acid per million of wood.

The soil sampled to the depth of one foot at the point where the tree had been pulled up showed the presence of 138 parts of arsenic acid per million of soil. This soil also showed that there was 1.345 parts of arsenic acid per million of soil soluble in cold water.

In investigating further it has been shown that the leaves of apple trees which had, during previous years, been regularly sprayed from two to four times, but had not been sprayed this year, contained arsenic equivalent to 2.628 parts of arsenic acid per million parts of the dried leaves.

I have examined a number of samples of apples and pears from Colorado and other states, namely, from California, Michigan, New York, Pennsylvania, Ohio and Illinois, and found them all to contain arsenic. Some of these samples were bought in market, but for others I am indebted to the officers of the respective Experiment Stations and it is a pleasure to acknowledge my obligations to them. I may state in this connection that the above fact is not the only one indicating that other states where spraying has been diligently practiced are suffering as we are but not to the same extent.

I have stated above that the fruit of seven states, as found upon the market or furnished me by their Experiment Stations, contain arsenic. I have weighed and calculated the arsenic as arsenic acid in a few cases, and the results are per million parts of fresh apples as follows: 0.51, 0.68, 2.30, 0.52, of pears 0.52. The total number of samples of fruit examined is twelve. These were either known to have been grown on sprayed trees or supposed to have been. It is possible that the sample showing 2.3 parts per million ought to be left out of consideration but I know of no reason why it should be except that it is very much higher than the other results. These samples were washed and pared and the calyx cup and ovary cut out; no greater care than this could be exercised to avoid getting any spray material into the sample. I further met this possible error by obtaining fruit from trees not sprayed this year and I found that this, too, contained arsenic.

As the ability of the tree to take up arsenic from the soil is an important factor in systemic poisoning, I have endeavored to ascertain whether trees which had never been sprayed take up arsenic. We have presented several cases in which the application of sodic arsenite to the soil, within the feeding area of the roots, was followed by the almost immediate taking up of the arsenic and death of a portion or the whole of the tree. I have mentioned in all eight instances of this sort, one instance of an apple tree within a few feet of which the spray tank containing arsenate of lead was emptied followed by the death of one limb of the tree, and further the case of the elm tree has been given somewhat fully. It would seem that these cases would suffice to prove that trees will take up enough arsenic from the soil to injure them, even when the arsenic has been applied in a difficultly soluble form, as in the cases of one apple tree and that of the elm tree. To add to the force of these samples, I have examined peach trees which had not been sprayed but which were growing in land already rich in arsenic and these too contained arsenic though two of them were only five years old. The elm tree and the peach trees could not have gotten the arsenic except through the activity of the roots. If further proof is needed the presence of arsenic in the juices forced out of a fresh wound and in the leaves and fruit which had never received any spraying certainly indicate that the arsenic is carried with the sap of the tree. It can certainly make no difference whether the arsenic is originally in the soil or has been added, but the proofs are not wanting that this arsenic comes from the spray materials put upon the soil for it is associated in many cases with both lead and copper, as much as 0.003 per cent of lead having been found in one sample. These facts establish this, i. e., that the trees do take up arsenic from the soil together with lead and copper.

One of the effects of the arsenic on these injured or partially killed trees is to stunt them. This is especially noticeable in those parts which we know to have been affected by sodic arsenite.

Other causes for the unhealthy condition of these trees, their small size, the unnatural color of their bark, the early yellowing of the leaves, the small size and exceedingly high color of the fruit, have suggested themselves. Among these are insect injuries, atmospheric conditions, soils, etc.

We can, I think, dismiss insect injuries, these having been carefully watched for and guarded against, and also atmospheric agencies, including smoke, electricity, etc., and turn our attention to the soil conditions. The average depth of the soil is stated to be from three to three and one-half feet. I think that this is too high for the whole apple orchard, but if the soil is two and one-half feet deep it is quite sufficient for the sustenance of healthy apple trees. There is, however, scarcely a healthy apple tree in the orchard or at most only a few of them.

Whatever our views may be regarding the injurious properties of alkalis we cannot satisfactorily explain the trouble on the theory that they are injuring the trees, for the total water soluble portion of the soil amounts only to 0.22 of one per cent, whereas we have healthy orchards in soil containing a much larger quantity of alkalis than this.

There can be no question of seepage for this is as high as any land in the neighborhood and there is no source from which seepage can come.

There can be no question of ground water for it is necessary to sink wells to a depth of seventy-five feet to obtain water. On the other hand there can be no question regarding the supply of good irrigation water for this is abundant.

This orchard has received intelligent care, neither has labor nor money been spared to make it a good orchard.

These considerations eliminate the questions of neglect, seepage, alkali, the lack of water or the irrational use of it as agencies in producing the present conditions, but they do not eliminate the question of an unfertile soil. If it were not that I know that some very competent persons consider this point seriously as the possible cause in this case I would not discuss it.

Personally I have but little confidence in the results of a soil analysis as criteria whereby to judge of the fertility of our soils. An analysis may have some value, especially if it shows an absolute deficiency in some of those elements which we have found to be essential to the development of plants.

The following analysis, made to answer, if possible, the question in regard to the lack of plant food in this soil, shows its composition:

ANALYSIS OF AN ORCHARD SOIL.

Insoluble	60.966
Silicic acid (sol. in sodic carbonate)	16.228
Sulfuric acid	0.247
Carbonic acid	1.739
Chlorin	none
Phosphoric acid	0.091
Lime	3.176
Magnesia	1.651
Ferric oxid	3.697
Potash	1.240
Soda	0.423
Aluminic oxid	3.746
Manganic oxid (br)	0.644
Moisture	2.070
Ignition (organic matter etc.)	4.412
	100.330

Additional Determinations.

Nitrogen	0.098
Copper	0.0058
Lead	0.0009
Arsenic acid	0.0011

According to this analysis we have an abundant supply of potash, a fair supply of phosphoric acid, more than an average supply of nitrogen for our soils and no possible deficiency except it be of chlorin, which is apparently absent; an aqueous extract of the soil, 25 grams, gives a faint reaction for chlorin, which simply means that it is present in very small quantities. This sample represents the surface foot of soil taken at the place from which a dead tree had been removed. The determination of the water soluble portion. 0.22 per cent. does not indicate an excess of soluble salts. The history of this land shows that it is productive. A portion of it was at one time used as a vegetable or truck garden and produced well. The suggestion that the truck garden might have been heavily fertilized and thus forced into productiveness suggested itself at once and I urged it. The answer was the trees then should show where the truck garden was but they are neither better nor worse than in other portions adjacent to it.

We have no proof that starvation due to the infertility of the soil does in any measure account for the present conditions of the trees.

Another question somewhat more serious than the preceding is in regard to the presence of other poisonous substances besides those of the spray materials. This includes lead and copper. There is only one present which might possibly exercise a deleterious influence and that is lime. I have pointed out elsewhere that apple trees do well in limestone soils, at least they do not show the distress exhibited by the trees under consideration. We have no justification in fact, so far as I know, for assuming that lime as carbonate is injurious to apple trees and still less ground to assume that lime as a silicate is injurious, but a casual inspection of our analysis shows that the lime was probably present in both of these forms and possibly to a slight extent as sulphate.

So far neither the analysis of the soil nor the information received in regard to the garden crops grown give us the least reason for attributing the condition of the orchard to the infertility of the soil nor to any poisonous substances other than the spray materials or possibly to the simultaneous action of arsenic and lime, as has been pointed out under the latter subject.

The depth of the soil has been stated as given to me, but I doubt whether the soil is quite so deep as three to three and a half feet. I dug down to the bottom of the soil at some points and found it about two feet and then a marly subsoil.

I think it safe to assume that there is not lime enough in the soil to do any harm; further, I think it safe to assume that the depth of the soil is amply sufficient to grow healthy trees, provided that the subsoil is not in some way injurious.

I have tried to find out what is probably the greatest depth at which our apple trees feed, and judging by the depth at which I have found the fibrous roots under what I considered the most favorable conditions I would judge that depth not to exceed two and one-half feet. This depth of soil, then, would ordinarily be ample and I believe it is. If this be correct, the character of the subsoil lying below this depth, provided it was pervious to water, would probably not be of as great importance as we, at first glance, might think, for even if it contains arsenic, and I have strong reasons for believing that it does, this arsenic is at best difficulty soluble in water and lies below the feeding ground of the trees. The question is an entirely different one when the subsoil is within 8 or 12 inches of the surface or the material constituting the subsoil is mixed with the soil to such an extent that it constitutes more than an eighth of the soil, as we sometimes find to be the case. We have in the analysis of this soil 1.739 per cent. of carbonic acid (CO_2) enough only to form a little less than 4 per cent. of calcic carbonate. This leaves a slight excess of lime to combine with the other acids. I have assumed this form of lime to exist in the soil as I take it that this is probably the most injurious form of lime usually met with in soils to which no arsenite of lime has been added or in which this salt does not exist. We do not positively know that carbonate of lime in such quantities is in the least injurious.

The trees in this orchard are sick. A few of the trees have corroded crowns. This feature is on the increase. Some trees have already been killed. There are some cases of bleeding and the deposits, like the others of this kind, are rich in arsenic and lime. The trees not affected in either of these ways are small for their age and are not thrifty though the crowns are perfect. These trees have not suffered from fungi or insects or blight. There is no excessive water, nor is the soil in such condition as to produce suffocation. Neither Prof. Paddock nor Prof. Whipple was able to detect any cause for the condition of the orchard and tentatively suggested that it might be due to starvation. The small size of the trees, the color of their bark and the small annual growth justify the general conclusion that the trees lack in proper nutrition, but this does not explain whether this lack is due to an insufficient supply of food in the soil or an inability on the part of the tree to take up and assimilate the food. In so far as an analysis gives us any adequate information on this subject, this soil is fairly well provided with the various elements of plant food and if the trees are starving it is not because the supply of food within the reach of their roots is inadequate but because of some other reason. I believe that the trouble is due to the action of arsenic, either alone or in conjunction with the lime. This orchard has been well cared for and diligently sprayed for a number of years, using at first Paris green, next, lime, sal soda and arsenic, and of late years arsenate of lead.

I have shown that the soil, especially about the trees, is very rich in arsenic, as much as 138 parts arsenic acid per million of soil being present; also that distilled water dissolves out of this soil about 1.34 parts of arsenic acid. The rest of the soil is certainly heavily charged with arsenic, the sprayings having been frequent and heavy, placing it within reach of the feeding roots of the trees. That the trees may take up enough arsenic in this manner to do them injury is shown by the case of the elm tree and others which have been cited and there are still others which might have been mentioned. In addition we have two very significant facts, first that the trees are sick, second, that the wood of these trees contains arsenic, the one in which it was determined 2.19 parts per million of woody tissue, as much as is usually found in other dying trees. In cases where arsenic is known to have been the cause of injury one of its effects has been to check the growth of the affected parts, in fact to almost prohibit it. These trees are small for their age, and make but little annual growth. All of the observed difficulties may be caused by arsenic and we find no other causes to which we can with any degree of reasonableness attribute the difficulty. We therefore conclude that systemic arsenical poisoning is very probably the cause of the unhealthy condition of these trees and in some cases of their death.

It is difficult to tell what part, if any, the lime may be playing in producing this specific trouble. I have stated that while it is well known that apple trees do well in limestone soils and that lime in the soil as carbonate of lime, this is the composition of our marls, is not per se injurious to the apple tree, yet the composition of the deposits formed by the bleeding described in Bulletin 131, and again in this, indicates strongly that lime, in some way, participates in producing it. Leaky spots in trees do not ordinarily, so far as my observation goes, give rise to such incrustations or form stalactites as we find on these apple trees. I have been unable to find an analysis of the ash of the apple tree juice and I have been unable to collect the juice in order to make one myself. I have, then, no data pertaining to this subject to serve for comparisons and can only present the facts.

In default of any knowledge concerning the composition of the juice of the apple tree, the best available subject from which to obtain some light would appear to be the ash of the wood on which there seems to be almost no data. I was able to find but one analysis of the ash of this wood and that is an old one, quoted by Adolph Mayer from the compilation of E. Wolf. This analysis shows the presence of over 36 per cent of silicic acid and can scarcely be considered as a typical ash. Dr. E. W. Allen was kind enough to call my attention to the analyses of apple tree ashes published in the report of the Director of the New York Experiment Station for 1891, page 164.

The trees subjected to investigation were young trees. The object in view was to determine the amount and character of the mineral constituents of plant food removed by nursery stock. The trees were probably not more than three or at most four years old. The trees discussed in this bulletin are of various ages, mostly from fourteen to eighteen years old. While I know nothing about the influence of the age of the tree upon the amount of ash in the wood and its composition, I will use these analyses for comparison for I have no others. Again the influence of the soil is a question which must be passed over. Another unavoidable condition which may affect the results is the necessity which compelled me to use small limbs one and a half to two inches in diameter to represent the living trees whereas I cut off a limb fully five inches in diameter at the trunk of the tree to represent the dead one. These are all weaknesses in our data but these data are the only available ones.

The soil in which two of the Colorado trees grew is represented by the analysis given under the caption "Analysis of a Marly

Soil." The third tree grew in a sandy loam, an alluvial soil, along the Gunnison river. The lime dissolved out of this soil by acetic acid was equivalent to 3.547 per cent of calcic carbonate. The subsoil is sandy and there is no marl present in the sense that we speak of its occurring in and beneath the mesa soils. In the former case, that of the soil in which the two trees grew, there is more than nineteen per cent of calcic carbonate and a still more marly subsoil, as against 3.5 per cent calcic carbonate and a sandy subsoil in the latter case. This is as marked a contrast in the character of the soils as is likely to be found in any county in Colorado, waste lands excepted. The localities from which they were taken are about four miles apart, so that the general conditions, climate, etc., are comparable. The trees taken for examination are of the same variety, the Jonathan. This variety was chosen because it seems to be the one which is most subject to these troubles.

The results of an examination of the quantity and composition of apple tree ashes given in the Report of the Director of the New York Station, Geneva, 1891, are as follows, taking the average for three varieties, Haas, Golden Sweet and Hurlburt:

	Branches	Trunks	Roots
Silicic acid	2.30	3.65	26.74
Phosphoric acid	5.89	4.94	7.11
Chlorin	0.68	0.43	0.37
Sulfuric acid	3.18	4.19	4.17
Carbonic acid	28.23	28.65	10.12
Ferric oxid	0.21	0.00	3.36
Calcic ox'd (lime)	41.94	43.76	28.39
Magnesic oxid	6.99	6.38	8.17
Sodic oxid	4.86	2.57	5.28
Potassic oxid	5.71	5.43	5.76
	99.99	100.00	100.01

The percentage of ash in these trees was as follows: in the Hulburt 1.6, in the Haas 1.8 and in the Golden Sweet 1.2 per cent.

It was not feasible for us to obtain wood from the trunks of of the tree. These samples were taken on the 10th of February, moved in pruning. This was branches varying from one and a half to two inches in diameter. In the case of a dead tree I took a large branch, at least five inches in diameter where I cut it from the trunk of the tree These samples were taken on the 10th of February, 1910. The percentages of ash in the samples as received at the laboratory without drying were as follows, dead tree 0.964 per cent; living trees on marly soil, 2.00 per cent; and living trees on sandy loam on river bottom, 1.17 per cent. The dead tree had died during the early part of the preceding autumn. There were many leaves and nearly if not quite full grown apples still hanging on the tree. There were other trees of the same variety and in the next row presenting the same conditions. These conditions are mentioned because the ash constituents of the wood, such of them as are soluble, may have been used up in the effort of the tree to mature the crop of fruit. There is no way of telling how long the tree had been drawing on this source of supply. The end result is all that we can definitely establish and this shows the presence of 0.026 per cent of ash. The trees growing on the river bottom, sandy loam soil, appear to be perfectly healthy. The growth is vigorous and the bark has a normal color. There are almost no signs of unhealthiness in this orchard that I saw or to which my attention was called. The orchard had been sprayed but not as regularly and persistently as the preceding one. The living trees from the preceding orchard are certainly more nearly comparable to these trees than the dead tree is because they are living trees and because the parts of the trees were of the same size and approximately of the same age. We find that the limbs of the trees growing on marly soil contain 2.00 per cent of ash while those growing on the sandy loam carry only 1.17 per cent. The average percentage of ash in the young trees grown at Geneva, N. Y., is 1.55 while the percentage in Colorado trees assumed to be normal is 1.17 per cent. The dead tree grown on marly soil contains a less percentage and the living tree a larger pencentage of ash than either the New York trees or the Colorado trees grown on a sandy loam soil. The New York trees were taken for examination early in the spring before the buds were well developed. They ought, therefore, to be comparable in this respect.

We see that the living trees on the marly soil contain 1.7 times as much ash as the trees growing on the sandy loam and 1.3 times as much as the young trees grown in New York. I have separated the bark from the wood and the statements of my further results are not directly comparable.

Wood of the dead tree, marly soil, 6464 grams, percentage of ash, 0.453, amount of ash obtained 29.28 grams. Bark from the wood of the dead tree, 624 grams, percentage of ash, 7.854, amount of ash obtained 49.00 grams. The percentage of ash in the bark is 17.3 times as great as in the wood. The percentage of insoluble ash in the bark is 18.35 times and that of the soluble ash 11.6 times as great as in the wood.

Wood of living trees, marly soil, 8760 grams, percentage of ash 0.539, bark 1516 grams, percentage of ash 10.452. Amount of ash obtained from wood, 47.22 grams, from bark 158.45 grams. The percentage of ash in the bark is 19.39 times that in the wood; that of the insoluble ash in the bark is 28.4 times and that of the soluble ash 6.5 times that of the wood.

Wood of healthy trees, sandy loam, 6794 grams, percentage of ash 0.389, amount of ash obtained 26.34 grams, bark 878 grams. percentage of ash 7.21, amount of ash 63.30 grams. The percentage of ash in the bark is 18.53 times that in the wood; that of the insoluble ash 24.93 times, and that of the soluble ash 6.18 times as great as that in the wood.

A comparison between the quantities of ash in the living trees from the marly soil and in those growing in a sandy loam shows a decidedly higher percentage, both in the wood and bark in the former case than in the latter. The composition of these ashes is even more striking than their quantities. The ashes were prepared with great care and yet there was water present in some of them and there is a deficiency of carbonic acid. One of the samples was analyzed four times to be sure that no mistake had been made, the excess of bases and the presence of water could not be altered. The ashes had been treated with a solution of ammonic carbonate and subsequently heated to 210° C. with the addition of dry ammonic carbonate. The carbon, sand, and water have been deducted and the analyses stated on the basis of 100.

	Living tree Sandy Loam		Living tree Marly soil		Dead tree, Marly soil	
	Wood	Bark	Wood	Bark	Wood	Bark
Silicic acid	0.837	0.944	0.807	0.774	0.604	0.552
Phosphoric acid	5.094	3.170	4.524	1.500	3.170	1.234
Chlorin	Trace	0.195	Trace	Trace	0.406	0.135
Sulfuric acid	1.884	0.554	1.821	0.449	1.474	0.396
Carbonic acid	29.549	36.615	33.826	35.467	34.970	39.395
Lime	26.000	49.141	35.920	54.320	41.264	53.697
Magnesia	9.289	3.189	7.574	1.408	8.073	1.125
Ferric oxid	0.105	0.212	0.199	0.184	0.130	0.182
Manganic oxid	0.147	0.101	0.143	0.175	0.149	0.127
Potash	26.621	5.264	14.298	5.200	4.999	1.730
Soda	0.474	0.615	0.888	0.523	4.761	1.407
	100.000	100.000	100.000	100.000	100.000	100.000

As already intimated we do not know whether any of these analyses can justly be considered as representing the quantity and composition of the ash of a perfectly normal apple tree. The New York trees were young and the bark and wood were evidently taken together. The object that that station had in view did not require the examination of these parts separately.

We have seen that the limbs of the Jonathan trees growing on a marly soil contain 2.00 per cent of ash whereas the limbs of trees growing on a sandy loam, the bark included in both cases, contain only 1.17 per cent. We notice further that the wood of the trees growing on the marly soil is high in lime and low in potash compared with that grown on the sandy loam, the ash of the former contains 36 while the latter contained 26 per cent of lime; in regard to the potash the relative quantities are reserved, i. e., the ash of the former contains 14.3, that of the latter 26.6 per cent. The phosphoric acid of these ashes is much more nearly equal, 4.5 per cent in the wood grown on marly soil and 5.00 per cent in that of wood grown on a sandy loam. We find that the ashes of the barks also vary, that of the trees growing on the marly soil being very rich in lime, 54.3 per cent, while that of the trees grown on sandy loam contains 48.2 per cent. The phosphoric acid is twice as great in the ash of the bark from trees grown on sandy loam as on the marly soil. The results obtained for the quantity of ash present in the wood and bark of the dead tree and its composition seem to show mostly the extent to which the tree used up its ash constituents in dying.

The analyses of the ashes given in the New York report are of young trees which may make some difference, but they are similar to ours only in containing a high percentage of lime. The potash in them is only a few tenths of one per cent higher than we find in the ash of our dead tree. I have no analysis of the Geneva soils though some were published in Bulletin 56, old Series.

The effect of the marly soil seems to be to increase the percentage of ash in the, wood and bark, to lower the percentage of potash present and to increase that of the lime. This marly soil has been sprayed regularly and heavily. The results give no conclusive answer to the question had in mind when the work was undertaken, but the following facts present themselves. The trees grown on the sandy loam are thrifty and healthy so far as we are able to judge. The trees on the marly soil on the other hand are not thrifty. We find no bleeding in the case of the trees on the sandy loam while it is quite common in the trees on marly soils. The ash of the trees grown on the sandy loam contains much less lime and more potash than that of trees grown on marly soil. The deposits made by exuding juices of the bleeding trees contain 25.0 per cent. of lime and 49 parts of arsenic acid per million. These facts perhaps may not amount to satisfactory proof to some but they certainly point directly to either the lime or the arsenic or to their joint action as the cause of the unhealthy condition of the trees. As lime alone has not been observed to produce these results, confined almost exclusively to these marly soils, we are justified in attributing the trouble to their joint action.

I cut off the, limb of a Jonathan tree on the 8th of April and on the 12th of May I removed 2.2 grams of a deposit. The aqueous solution of this deposit gave a very satisfactory test for arsenic. The trunk through which the juice had to pass was very short and the arsenic could scarcely have been gathered from the woody tissues of the tree. The elm root, taken at least six feet from the trunk, was quite rich in arsenic. No doubt can reasonably be entertained but that this arsenic and also the lime had been gathered by the roots. The cases mentioned are by no means isolated ones. In some orchards cases of bleeding are numerous and severe, in others they may be absent. The orchards in which this occurs usually have a marly subsoil at a shallow depth. This bleeding is not confined to wounds made by trimming but frequently takes place from cracks in the bark as previously described. Some instances of this are met with in many of the orchards to which reference has been made.

Healthy trees do not bleed in this manner and their juices do not form such deposits. Trees killed by irritant arsenical poisoning do not bleed in this manner, nor have I seen any deposit of this sort on trees injured by arsenic accidentally applied to them. This condition is not attributable to arsenical poisoning alone. This deposit is, however, rich in arsenic and lime and I infer from these facts that we have in these cases a systemic poisoning by lime and arsenic.

It has been observed by orchardists that certain shallow soils underlaid by marl produce a yellowing of the leaves on apple trees;

this has been attributed to the lime. I have held in these cases that it was starvation rather than poisoning but this cannot be admitted in the case of the soil, an analysis of which has been given on a preceding page, without denying the evidence of this analysis and the actual productiveness of the soil.

I have intentionally permitted these two subjects, the systemic poisoning by arsenic and the effects of lime, to merge into this broader form, because I believe that this form of the trouble is primarily due to arsenical poisoning modified by the presence of lime which exists in the soil in large quantities in the form of calcic carbonate and often forms, beneath the soil proper, a layer from two or three inches to two or more feet in thickness.

I have shown on a previous page that these limey, virgin soils and also these marls contain arsenic, about one-tenth as much as the average orchard soil examined.

To restate the case briefly. We have well cared for trees which are extremely small for their age. Their general condition is bad; some of the trees have died, these trees had no disease of the crown or roots and were not suffering from any recognizable, known disease; the wood is stained a light brown, an effect produced by arsenic; they make but little growth, another effect produced by arsenic; arsenic is present in the woody tissues of these trees and even in their fruit. Some of the trees have corroded crowns, a sufficient cause to account for the death of the particular trees. These cases are not considered in this place. It will be recalled that in discussing irritant arsenical poisoning I pointed out that some of the arsenic found was probably gathered by the roots. Some of the trees show the splitting of the bark and bleeding, forming deposits rich in arsenic and lime.

The arsenic is gathered from the soil by the roots as is shown by the peach trees and also by the elm which were never sprayed. This fact is again shown by the presence of arsenic in the fruit and leaves grown on trees which have not been sprayed this year. This arsenic is evidently carried to the leaves and the fruit from the soil by the solutions passing through the tree. The final question is how much arsenic can a tree tolerate and how long can it endure the amount that the roots gather and pass into the tree. These are questions to be solved. I am convinced that many trees have already reached the limit of their endurance and that this is the cause of their bad condition. I said in Bulletin 131, in reference to this subject of systemic poisoning and the action of lime as distinct from irritant arsenical poisoning, "These trees do not present the symptoms described for arsenical poisoning, though arsenic is very abundant. * * * These soils are marly or have a subsoil of this material and the presence of 25 per cent of lime in the dried sap seems to me to be a very suggestive fact."

I add to this that the presence of arsenic in these soils equivalent to from 26 to 138 parts of arsenic acid per million of soil, and of arsenic equivalent to 49 parts of this acid to each million parts of this dried juice are more suggestive and that the presence of arsenic in leaves which have received no application of spray equivalent to 2.19 parts of arsenic acid per million of dried leaves and in the fruit equivalent to from 0.51 to 2.3 parts of arsenic acid per million of fresh fruit, are still more suggestive, if not satisfactorily conclusive, that systemic arsenical poisoning is really the cause of the small size, the bleeding and the death of some of our fruit trees.

Before I state the conclusions of this bulletin it is proper that I should express my appreciation of the helpful, kindly interest and willing assistance rendered me by the officers and others connected with this station and also to officers of other stations and states.

Throughout Bulletin 131 I tried to make it as plain as language could possibly make it that I fully appreciated the fact that the subject matter of the bulletin was of the most serious character and of very great importance. I told the public that my colleagues had urged me to take up the investigation and used this language: "These statements are not made to devolve any responsibility upon these professors, but to show that this view has not been hidden from the people or my colleagues and the presentation of this bulletin is not a hasty resolve or a thing done without a very keen appreciation of its importance not only to the orchardists of Colorado, but to all orchardists." The same is true in regard to this bulletin.

It is true that the presence of arsenic in apples from California, Michigan, New York, Pennsylvania, Ohio, Illinois, and Colorado show that fruit grown on sprayed trees contains arsenic and further that this is a general fact, but there is no reason at all for alarm for either the health or life of persons eating such pears or apples. Two of my assistants and I have tried it, one of us eating nearly eight pounds of apples by weight, in twelve hours. The apples from Illinois, Ohio, and New York were just as rich in arsenic as those from California or Colorado. I repeat that so far as the public is concerned there is no reason at all for the least concern. At present it seems possible that we may use the sulfid of arsenic with less danger than accompanies the use of lead arsenate and we will certainly use very much less arsenic than in the past. It has been demonstrated that if everybody will give his orchard one thorough spray at the time now recommended, using one or one and one-fourth pounds of pasty lead arsenate to fifty gallons of water, four to four and one-half pounds to the 200 gallon tank, we will have fairly clean apples. The preceding statement applies only under favorabe conditions. There can be no doubt but that excellent results have been and may be obtained from one spray but there are conditions under which one spray will not suffice to supress the injury by the codling moth even to a reasonable limit. It seems that the first brood may be so long in making its appearance that one may find unhatched eggs and pupated specimens representing the first brood on the same date.

The growing apples present a comparatively large amount of surface entirely free from the arsenate of lead and consequently not protected against the attack of late hatching individuals. These are not theoretical considerations but facts as they have been observed in the orchard were may be found, in some sections, many apples which the worms of the first brood have entered from the side. In such cases one spraying would mean a wormy crop. On the other hand the results obtained with one spraying have been excellent, especially in cases where the orchard was not subjected to subsequent infection from adjacent, unsprayed, or very poorly sprayed orchards.

Summary

While many trees, both apple and pear, have been damaged, even killed, by the action of arsenic collected about the crown or collar of the tree, other causes of death are not excluded. It is shown in Bulletin 155 that nitre in the soil may kill apple trees, but the crowns and roots are not attacked by this agent as they are by arsenic.

The total number of trees affected is large. It is seldom that more than a few affected trees occur together, usually they occur singly, scattered throughout the orchard.

Trees killed by nitre usually occur in blocks, sometimes only a few trees, 12 to 20, but in other instances they occur by the acre.

The arsenical preparations used for spraying are supposed to be insoluble in water, this is not correct. Well washed arsenate of lead will yield arsenic acid to pure water, about, 0.3 per cent. of its dry weight.

The addition of sodic sulfate, sodic chlorid or sodic carbonate, even in small quantities, to the water materially increases the amount dissolved. This is especially true of the sodic chlorid and sodic carbonate .

In Bulletin 131, I attached considerable weight to the action of these alkali salts which are present in all of the soils of the semi-arid regions in a greater measure than in the soils of some other sections. I do not doubt but that they have some influence upon the solubility of the arsenical compounds, but as much as 1.38 parts of arsenic acid per million soluble in water has been found when the total water-soluble portion amounted to only 0.22 per cent. of the air dried soil. Again I have found weighable quantities of water soluble arsenic in soils which were free from alkali. The alkalis in our soils may increase but they are not the only cause of the solubility of the arsenic.

Three forms of this trouble are recognized, corrosive arsenical poisoning, systemic arsenical poisoning and arsenic-lime poisoning. The last form is consdered as being produced by the joint action of lime and arsenic, because we do not find this trouble present on limestone soils in general nor is it characterstic of arsenical poisoning produced by soluble arsenic preparations, sodic arsenite for example.

Corrosive arsenical poisoning attacks the tree at the crown, below the surface of the soil and usually involves the large roots also. The attack is from the outside and causes the disintegration of the bark, the cambium is not destroyed until the corrosion has perforated the bark which is not loosened. Pear and apple trees are affected; the pear tree is, at least, as susceptible to the action of the arsenic as the apple tree. Some varieties of pears, as well as apples, seem more susceptible than others, but this is true only in a general way. The age of the tree at the time the first applications were made seems to have some effect upon the resisting power of the bark. The variety of soil may have some influence but it is not pronounced enough to be recognized with certainty. Very many, if not the greater part of our soils, contain arsenic. This is true of our virgin soils as well as of our cultivated soils. Our orchard soils now contain from 10 to 28 times as much arsenic as our virgin soils.

No other agency known to us produces the observed results, but arsenic when applied in soluble form produces similar effects quickly.

The first sign of trouble in the apple tree is an early ripening of the leaves, at least, one year before the death of the tree; in pear trees the foilage ripens early and assume a deep purple color.

The amount of arsenic present in the destroyed bark and in the woody tissues of such trees is as great as in cases in which it is known that arsenic was the cause of death.

The trouble is very general throughout the state and occurs in all kinds of soils which fact eliminates the question of seepage and, to a large extent, that of alkalis.

While the alkalis may in some instances be present in the soil in sufficient quantities to produce a perceptible effect, we cannot, owing to the wide range of localities and the great variety of soils in which we meet the trouble attribute very great importance to their action. Their presence, however, in soils undoubtedly tends to make the arsenic more readily soluble.

In the case of trees which have not been sprayed but which have been grown as fillers in sprayed orchards, the wood contained arsenic. This is true, too, of young trees grown in soil which contains arsenic. This shows that the arsenic may be and is taken up with the nitrient solutions. The fruit grown on such trees, apples and pears, contain arsenic and also the leaves. The fruit and leaves grow and are shed each season this is not the case with the woody portions of the tree.

Systemic poisoning is produced by this arsenic distributed throughout the tree, interfering with nutrition and growth of the tree and in some cases causing its death.

The bleeding met with in trees on marly soils is probably due to the combined action of lime and arsenc. A study of the ash constituents contained in the wood of trees grown in marly soil and in a sandy loam shows a remarkable difference in the amount of ash, 2.00 per cent. against 1.17 per cent. of the wood and a very much lower percentage of potash, 14.298 per cent. against 26.621 per cent. of ash. The deposit produced by this bleeding is very rich in arsenic as it contains 49 parts of arsenic acid per million of the dried deposit.