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# Arsenical Poisoning of Fruit Trees

BY

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# The Agricultural Experiment Station

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# ARSENICAL POISONING OF FRUIT TREES.

WM. P. HEADDEN.

I was called upon at one time to investigate the cause of the death of some shade and ornamental trees, and the bad condition of the property in general. The claim was advanced that arsenic and lead were the cause, more particularly the former. The assertion was made that animals had died as the result of feeding upon the grass growing on the premises. Examination of the grass, the bark of the trees, the soil, and the dust which had collected in unused portions of the buildings, all showed an abundance of arsenic, lead and copper.

In connection with the preceding facts, the probable cause of the death of the trees seemed apparent and yet certain considerations led me to be cautious in insisting upon the arsenic present as the cause. For instance, calcic arsenite was at that time being used on our fruit trees to destroy the codling moth—the whole tree from the outermost twigs to the very base of the trunk was, I well knew, literally bathed with this arsenical preparation several times in the course of a season. The whole of this arsenic sooner or later found its way to the soil. I had not, at that time, proved by direct experiment, nor learned that any one claimed that the fruit trees had been injured by this arsenic. This seemed to me so strong an argument against the too ready assumption that arsenic was really the cause of the death of the trees, that I felt obligated to caution the attorneys that it was not clear to my mind, that neglect had not contributed more to the condition of the property than the causes complained of. Still the facts were well established, i. e., the trees were dead and arsenic was present, also lead and copper, and in spite of the fact that our apple and pear trees were being sprayed, a number of times annually with arsenical preparations and no injury reported, except in cases where the arsenic had been applied in a soluble form, I was quite fully convinced, that the arsenic had contributed largely to the death of the vegetation on this property.

The protection against arsenical poisoning in the case of our orchard trees is the insolubility of the arsenical preparations used in spraying and further that these preparations shall not be changed or become soluble in the soil. In the case referred to, it would have been judged that the iron and especially the lime present, both as carbonate and sulfate, was sufficient not only to render the arsenic insoluble but also to prevent its being brought into solution again, still it was my opinion that the arsenic was really the principal cause in the destruction of the vegetation in question.

While the conditions met with in the case of this property were not identical with those obtaining in orchard culture, they had enough in common with them to convince me that there were but two conclusions to draw, either that I was in error in regard to the agency of the arsenic in this case, or that there would come a time, and that soon, when the arsenic applied would eventually find its way into the soil, and prove a source of danger to the trees. I was, at that time, going on four years ago, so fully convinced that the arsenic would become a source of grave danger, that I ventured to express this veiw to the orchardists of the State and cautioned them that the probability of injury from this cause was imminent.

Prof. Gillette, who, as an Entomologist, is interested in the control of insects injurious to the fruit crops of the State, has repeatedly suggested that I should take up this line of investigation, Prof. Paddock, also, who, as a Horticulturist, is interested in the diseases of the trees—has made the same suggestion. 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.

I will add before leaving these introductory paragraphs, that this work in my Department is directly an outgrowth of my attempts to study the alkalies of this State, but I deem it both just to the interests of the State and wise to segregate it, and present it at the earliest advisable time, irrespective of the rest of the work.

It will appear in the proper place how the injuries herein described and explained are influenced by the alkali, indeed, the orchardists themselves have repeatedly suggested this by such questions as: Has our strongly alkali water any effect on our spray material, specifically upon the lead arsenate?

While the suggestions of danger were made so long as three years ago, no observations of any trouble were officially made public until January 1907, when Mr. O. B. Whipple in his report as Field Horticulturist of the Western Slope Fruit Investigation, calls attention to certain difficulties under the title of Root Rots. I give the whole of his report touching upon this subject taken from Bulletin 118 of this Station:

### ROOT ROTS.

"Two apparently distinct forms of root rot are found. One form, which is proving the least destructive of the two, seems to show no preference for varieties, and confines itself to that part of the tree below the ground. The other seems to work exclusively on the Ben Davis and Gano, and the trunk as well as the roots are affected. The disease often extends upward into the large branches. The first indication of the disease is the appearance on the trunk of spots of a chocolate color. When peeled off the bark has a peculiar marbled appearance, the diseased portions standing out in sharp contrast to the healthy tissue. The disease soon kills the bark and it dries down to the wood, taking on a dark brown color. Two seasons are required for the disease to kill the trees. 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. (See Plate I., lower figure). Trees showing an early bronzing of the foliage are generally found girdled by this disease. The second season the tree starts into leaf as the normal tree, generally setting fruit, and dies in mid-summer, the fruit and leaves clinging. (See Plate I., upper figure). The disease seems to be infectious, as the trees appear in groups, and in many cases it appears as though it were carried by water. When a diseased tree is found, several more are generally found in the same row. However, other varieties besides the Ben Davis and Gano may stand in the same row with diseased trees on either side and show no sign of contracting the disease. The fact that Ben Davis and Gano are very tender as regards the application of arsenical sprays has suggested to my mind that the trouble may be due to arsenic collecting about the crown of the tree and killing the bark. However, the fact that trees sprayed with arsenate of lead and arsenite of lime are alike affected, seems to be contrary to such a hypothesis.

"Prompt removal of the trees affected seems at present to be the only treatment that can be suggested. Reports indicate that the disease has only been in the orchards two or three years at the most. Soil conditions seem to have no relation to the disease, as it is found on all kinds of soils."

The description of the affected trees as given by Mr. Whipple is, I believe, entirely reliable as he has been in this field for several years, and has had opportunity to observe these trees at all stages of the affection. I can, in fact, corroborate his statements as Mr. Whipple was kind enough last Autumn and again this spring to point out a number of these trees at different stages in the process of dying. While the appearance of brown spots on the trunk of the tree are observable early in the progress of this trouble, they are not the seat of the trouble, which beginning on the crown of the tree has by this time advanced to the trunk. Whether it ever begins on the roots below the crown is not at present known. It is not to be wondered at that Mr. Whipple, without a definite knowledge of the cause of the trouble, states that the disease seems to be infectious. He pointed out to me a row of Ben Davis trees, four of which were already dead. with leaves and fruit still clinging to them. In the adjoining row was another tree which was likewise dying, as I now recall it—this tree stood at a point where the irrigation water crossed from the row of four dead Ben Davis trees and passed close to this one, seemingly justifying Mr. Whipple's inference that the disease is infectious and also the further statement, "and in many cases it appears as though it were carried by water." My explanation of this is a different one as will appear in a future paragraph.

Mr. Whipple in the next sentence, calls attention to an important fact, i. e.—that the two varieties, Ben Davis and Gano, are very sensitive to arsenical sprays, and suggests the possibility that the trouble may be due to arsenical poisoning, but seems to dismiss this as an untenable hypothesis. Another point in Mr.

Whipple's very brief account of this disease is that the disease had been noticed for only two or three years. Information which he and I have since gathered corroborates this statement; the earliest observation of the affection of the trees of which we were able to learn was in 1904 and trees have been dying in certain orchards annually since that date.

### VARIETIES AFFECTED.

The varieties affected in this way are by no means confined to the Ben Davis and Gano. The following varieties are also affected: Spitzenberg, Early Harvest, Wolf River, Lawver, Blacktwig, Baldwin, Jonathan, Grimes Golden, and Pewaukee, and without doubt, other varieties might be added if search were made to find every variety affected in this way. The trouble also extends to pear trees, but I have studied apple trees mostly.

### AREA INVOLVED.

At this writing I am not prepared to give any territorial limits to the trouble. I have observed it from near Fruita almost to Palisade and in the neighborhood of Delta. I am further credibly informed that the same condition of the trees has been met with in the neighborhood of Canon City. If this latter statement is correct, our principal orchard growing sections are involved and the importance of definitely establishing the cause and if possible, a correction for the trouble, becomes very great.

### THE NUMBER OF TREES AFFECTED.

This would be very difficult to determine and I have no data on which to base even a rough estimate, but an idea may be obtained from the following facts. One man stated that in the last few years, he had lost 50 per cent of his Ben Davis. Another stated that he began pulling up a few trees four years ago and this year he had removed nine trees and there were others which he should have removed; another man had removed twelve and still another the same number. The four Ben Davis trees in the row that I saw last October, together with others had been removed this Spring and there were still other trees in this orchard which were affected. I visited one orchard in which there was a large number of affected trees—in other orchards, there are only a few. The total number of affected trees in the orchards of the Western Slope, is already unfortunately large.

### THE PROBABLE CAUSE OF THE TROUBLE.

I have already clearly indicated my conviction that the cause of the trouble is arsenical poisoning; that there are some trees suffering from other causes is quite certain but the cause of the greater portion of the trouble is the arsenic which has accumulated in the soil. The expression of this conviction is not a hasty one, for I am fully alive to how much it means to this state and all other orchard growing states where similar soil conditions prevail, but it is for the best interests of orchardists that they should know the facts pertaining to the death of their trees and the conditions of their soil.

## THE ACCUMULATION OF ARSENIC IN THE SOIL.

The spray material used in combating the codling moth is either a calcic arsenite or lead arsenate. The number of sprayings applied vary from two or three to nine during the season. I do not think that this Station has ever recommended more than three sprayings during the season, but many orchardists apply more. The amount of lead arsenate used is from four to six pounds to each 100 gallons of water. The average orchardist does not consider the amount of arsenic thus applied to a single tree a very large quantity, and he cannot be expected to consider the nature and possibilities of the material that he is applying, so in many cases he applies, as he thinks, wisely, a liberal quantity, sometimes using eight to ten pounds of lead arsenate to 100 gallons of water, and applies eight or ten gallons of the turbid liquid to the tree. If six pounds of pasty lead arsenate be used to 100 gallons of water and ten gallons of the mixture be applied to a tree we have six-tenths of a pound of the pasty arsenate, or in round numbers, three-tenths of a pound of dry lead arsenate.

Practically the whole of this eventually finds its way into the soil. If this be repeated three times during a season we have 1.8 pounds of pasty lead arsenate or 0.9 pounds of dry arsenate applied to each tree, or considering that the dry lead arsenate contains 25 per cent of arsenic acid, we have 0.225 pound of this substance per tree and allowing 80 trees to the acre, we have 18 pounds of arsenic acid to each acre of the orchard. If this amount of arsenic acid were evenly distributed through the first foot of soil, it would correspond to four and a half pounds of arsenic acid for each million pounds of soil, or 4 1-2 parts per million. This arsenic is, however, not evenly, but very unevenly distributed, as the spray mixture runs down the trunk of the tree and accumulates in the soil at its base. It is not done one year only, but every year, unless there should be no fruit. Some of our orchards have already been sprayed for eight or ten years and a few of them for even a longer period, so that we would expect to find a considerable accumulation of arsenic in the soil, especially in the soil at the base of the trees. This corresponds to the facts as found by analysis. In one sample taken beneath the head of a twelve-year-old apple tree, and representing the soil to the depth of five inches, I found arsenic corresponding to 30.6 parts of arsenic acid to each million parts of the soil; in another, soil 25.5 parts; in another 26.0 parts; in another 38.2 and in still another, 61.3 parts per million. The sample giving 38.2 parts arsenic acid per million was taken at the base of the tree and to a depth of one foot, the last sample, giving 61.3 parts arsenic acid per million, was taken at the base of the tree and to the depth of four inches. All of the samples were taken either in the Spring of the year or at least some time after the last spraying, so that they ought to fairly represent the orchard soils. We find in fact, what was from the beginning patent, namely that the arsenic does accumulate and is already present in our orchards in dangerous quantities, if it, by any means, should become soluble.

### THE ARSENIC IS TAKEN UP BY THE TREES.

It is altogether correct that the spray material applied is a compound of arsenic either difficulty soluble or insoluble in water as calcic arsenite or lead arsenate. It is also true that literally hundreds of trees have already died or are sick, as I believe, beyond hope of recovery. The symptoms are the same. The duration of the tree after showing the first early ripening of its foilage is about one year; the attack of the disease is at the same point, and progresses in a uniform manner. Mr. Whipple describes its course as follows:

"The first indication of the disease is the appearance on the trunk of spots of a chocolate color. When peeled off the bark has a peculiar marbled appearance, the diseased portions standing out in sharp contrast to the healthy tissue."

"The disease soon kills the bark and it dries down to the wood, taking on a dark brown color. (Plate II., Fig. 1). Two seasons are required for the disease to kill the trees. The first season the trunk is girdled and the foilage drops early. This early ripening of the foilage is often the most prominent symptom and diseased trees can be easily picked out in the early fall. Trees showing and early bronzing of foilage are generally found girdled by this disease. The second season the tree starts into leaf as the normal tree, generally setting fruit and dies in mid-summer, the fruit and leaves clinging."

I have seen no tree in which the trouble has advanced to that stage indicating its death during the following summer, but that some of the roots, in fact, most of them in nearly every case, had been attacked, the bark destroyed to a greater or less extent, the woody tissue stained brown and the bark at the base of the trunk severely attacked just below the ground. It is from this point that the trouble seems to take its start. Some facts, however, particularly the condition of some of the roots, they being entirely dead, while others standing in just as close a connection with the diseased crown are in much better condition, suggest that the attack may not be confined to the crown. The condition of the crown produced by this trouble is shown in Plate II., Fig. 2, also the stained or discolored condition of the tissue. This is a photograph of a stump of a Ben Davis tree which was removed this spring, and would have died this summer. Plate III., Fig. 3 is that of another Ben Davis tree from another orchard and shows how the woody tissue is stained. The notch shows where a portion of the stump was removed for the purpose of examination. This tree was in bloom when dug up. It was perfectly representative of a number of other trees in the same orchard which had already been dug up or had been marked for removal. Many trees in this immediate neighborhood are affected in the same manner. The trouble is not confined to one orchard. In this case we found it in four, we might say, contiguous orchards. I have taken portions of at least 14 different trees. They were from a considerable variety of soils and were trees that had just been removed or which we removed ourselves, or are still standing in the respective orchards. So far as I could learn, only two of these trees failed to show some life this season and one of these was a pear tree which we dug up ourselves. This tree had been cut back severely in 1907 and had thrown out a few shoots, some of which had made a fair growth. None of them were trees which had died and remained standing and had had an opportunity to absorb arsenic as dead trees. As stated, some of the trees represented by our collection are still standing and were in full bloom at the time we removed the roots and branches. The condition of the roots and bark, however, was that produced by the long continued action of the poison.

The conditions found are as follows: The bark at the base of the trunk and just beneath the ground is destroyed and the damage extends up the trunk sometimes even into the limbs. (see plate II.) This damage is shown on the trunk by the bark being brown and sunken. On the roots, the bark is disintregated as is well shown by Plate IV., Fig 1, a sample taken and photographed by Mr. Whipple. Often, in the advanced stages of the trouble, the bark is almost charred and the wood itself is even blackened. The tissue is strongly attacked and yields to the rasp like wood charred sufficiently to destroy its fibre. It looks and acts like wood acted on by a dilute acid, sulfuric acid for instance, only the darkening is not, as a rule, so intense as would correspond to the same degree of disintegration by this acid.

The limbs and branches of trees affected in this way usually, but not invariably, present a case of "black heart." The interior portion of the branch is strongly discolored with a margin pronouncedly darker than the rest of the interior. (Plate IV., Fig. 2; also Plate III., Figs. 1 and 2). This condition is usually attributed to another cause, freezing at some time or other, but we have pretty direct proof that in these cases, it probably has been caused by the poisoning of the tree. It is a rule that branches of healthy trees show this difference to a very small extent, they being usually white from the center to the circumference. Even in Fort Collins, where we have severe changes in the temperature, this seems to be the case. A branch from a neglected tree in my garden is white throughout (Plate IV., Fig. 4). The age of this tree is not less than 15 years, and has to my knowledge been subjected to temperatures ranging as low as -40 degrees F., and often below -18 degrees F. I do not know the early history of this tree, and do not wish to give more weight to the fact mentioned than is due. I have not examined pear trees as carefully as I have apple trees, but the few branches that I have observed were not discolored in this manner. Plate IV., Fig. 3 represents a section of the trunk of a pear tree, killed by arsenic, and shows the manner in which the wood is stained.

Another effect of this trouble is to cause the bark to split and the wound to bleed. (Plate V., Figs. 1 and 2). This result may be partly and possibly wholly induced by another cause. Mr. Whipple suggests that the splitting open of the bark may result from the girdling, but this will certainly not apply in many cases, though it may in some. I have in mind two orchards in which this cracking and bleeding occurs to such an extent that any person whether he were accustomed to orcharding or not would take notice of it. One of these orchards is today rated as a very fine one.

With these general statements concerning the manifestations of the difficulty, I will give the facts on which the statement rests, that the arsenic is not only in the soil but has been absorbed by the trees.

I have taken samples from fourteen trees, eleven apple and three pear trees. These samples consist of roots, stumps, one trunk and branches. I should add to the above two samples of the deposit formed by the bleeding referred to in a preceding paragraph. On these various samples, thirty tests for arsenic were made and its presence was established in every instance. I did not attempt to make quantitative determinations except in a few cases which showed from 1.25 parts to 12.77 parts of arsenic per million of the woody tissue. I found the reaction for arsenic stronger in the roots and crown of the trees than in the branches, but could not with certainty distinguish any difference in the amount of arsenic present in the green or natural colored portion of the limb and the discolored portion.

I do not wish to weary the general reader with technical details, but it is proper that he be assured that the arsenic reported as having been found in these thirty different samples, was not contained in any or all of the reagents used. The proof of this was obtained by using a piece of oak wood and carrying it through as though it were a sample of an apple tree when a negative result was obtained showing that both the wood and the reagents were free from arsenic. This was not the only precaution, for four blank tests were made during the work to make sure that no error should arise from this source. The care taken was in all ways as circumspect, so far as the analytical work was concerned, as though the examination of human viscera were in my hands. Another source of error lay in the danger of getting some particles of spray material with the bark of the sample. This was obviated by removing the bark from both the roots and branches, before taking the sample for analysis.

In one case, that of a pear tree, the bark was examined; in this case the bark was smooth and sound enough to permit of its being washed with a stiff brush. It gave a fainter reaction for arsenic than the wood which it covered.

With these statements it may fully suffice if I give the details of only two samples a little more fully.

One taken from the trunk of a small pear tree ten years old. Section cut out 30 inches above the ground, bark entirely removed, wood quite generally stained but not deeply so like the roots or central portion of many of the branches of the apple trees. This section is shown in Plate IV., Fig. 3. The wood is hard but rasps easily. I took 60 grams, almost exactly two ounces, destroyed the wood by means of sulfuric and nitric acid; collected the arsenic as arsenate of Iron; dissolved in sulfuric acid and introduced it with proper precautions into an active Marsh apparatus and obtained arsenic corresponding to 2.55 parts of arsenic acid per million. Owing to unavoidable losses, the arsenic obtained is too low.

The second one is a sample of a stump. I cleaned it thoroughly by paring off all bark and soiled portions and rasping it. I took two ounces as before, proceeded in exactly the same manner and obtained arsenic corresponding to 12.77 parts of arsenic acid per million. Every sample was proceeded with in just as careful a manner as these two, and arsenic was easily proven to be present in the tissue of every sample, whether it was taken from the central, the intermediate or exterior portion of the root or limb.

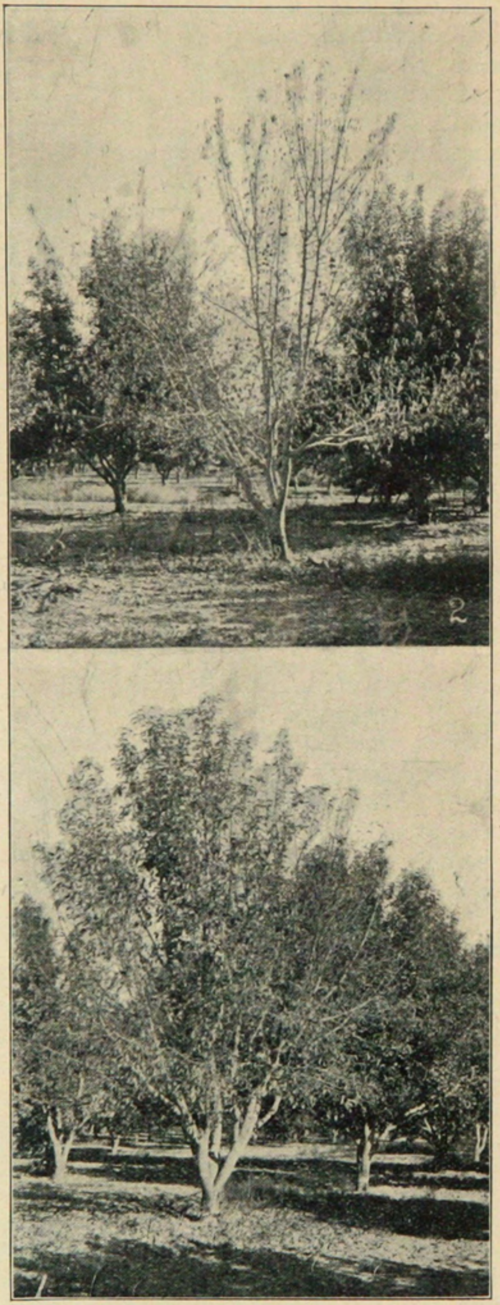
We have seen that the arsenic is accumulating in the soil, having already reached as large an amount as 61.33 parts of arsenic acid in a million of soil.

I have stated in Mr. Whipple's words, the manner in which the trees are affected and have given the description of what I myself found.

Further we have shown that in these dying trees arsenic is present in the roots, the trunk and branches varying up to 12.77 parts per million.

## ARSENIC IS THE CAUSE OF DEATH.

So far the question, Is the arsenic really the cause of the corrosion of the bark beneath the ground, the killing of the bark on the trunk, the killing of the roots and the staining of the wood, in short is it the cause of death? has not been answered. I have stated



Colo. Ag. Expt. Sta.

PLATE 1.

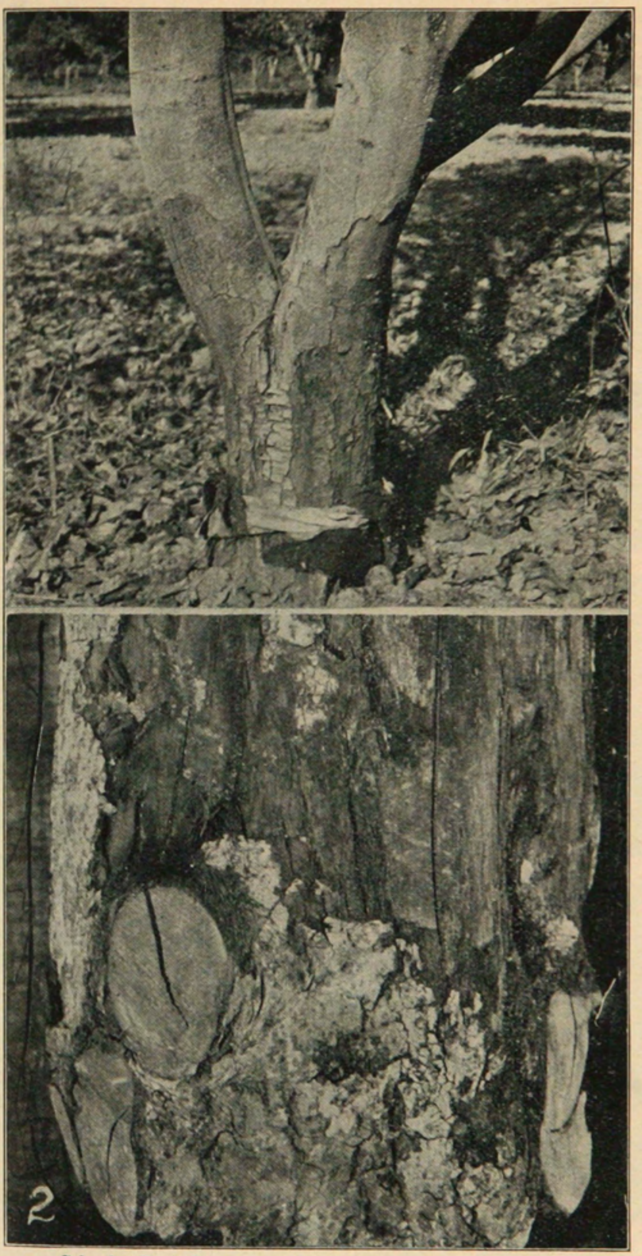



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PLATE 2

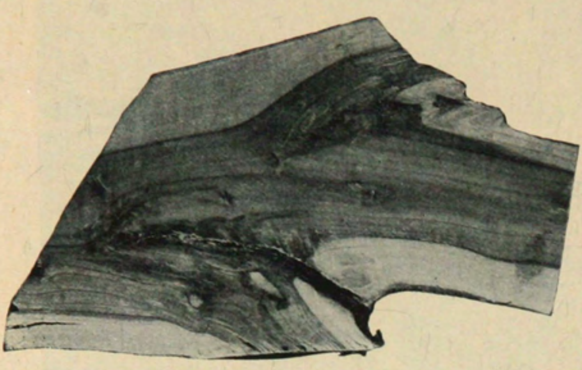

Fig. 2

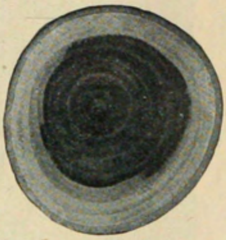

Fig. 1

Colo. Ag. Expt. Sta. Fig. 3

PLATE 3.

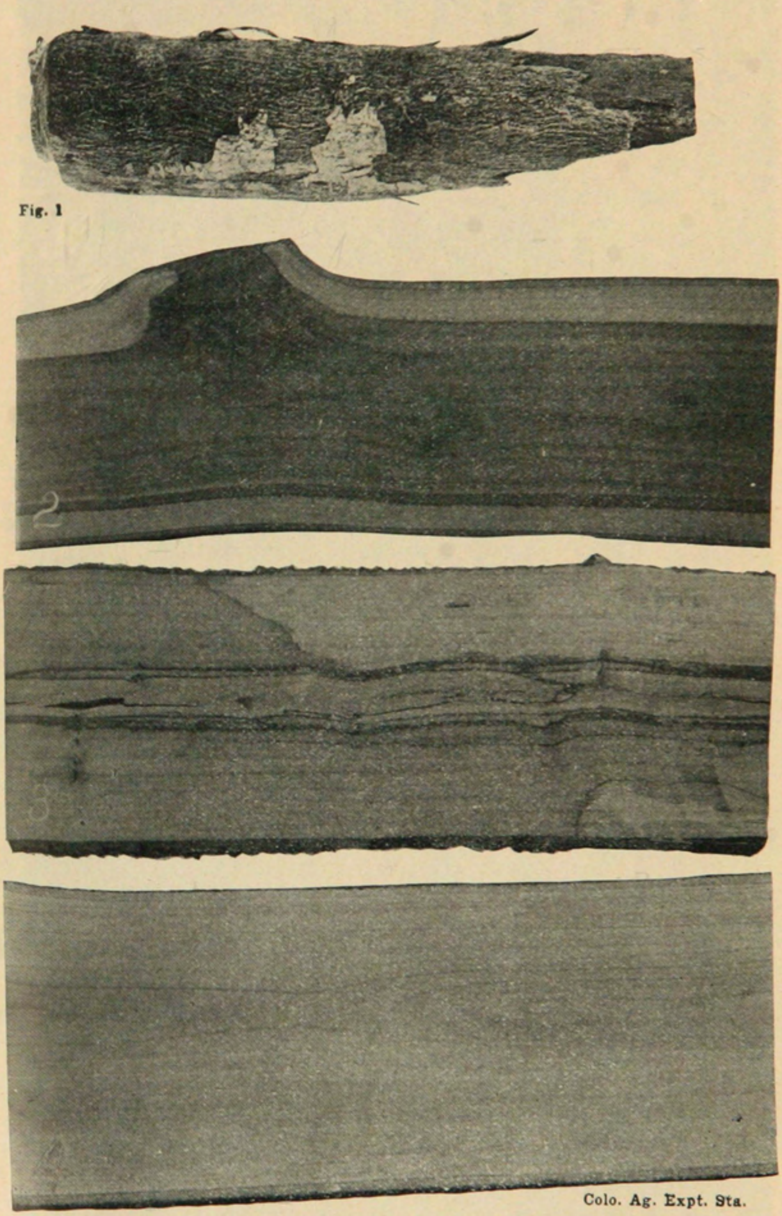

Fig. 1

Colo. Ag. Expt. Sta.

PLATE 4.

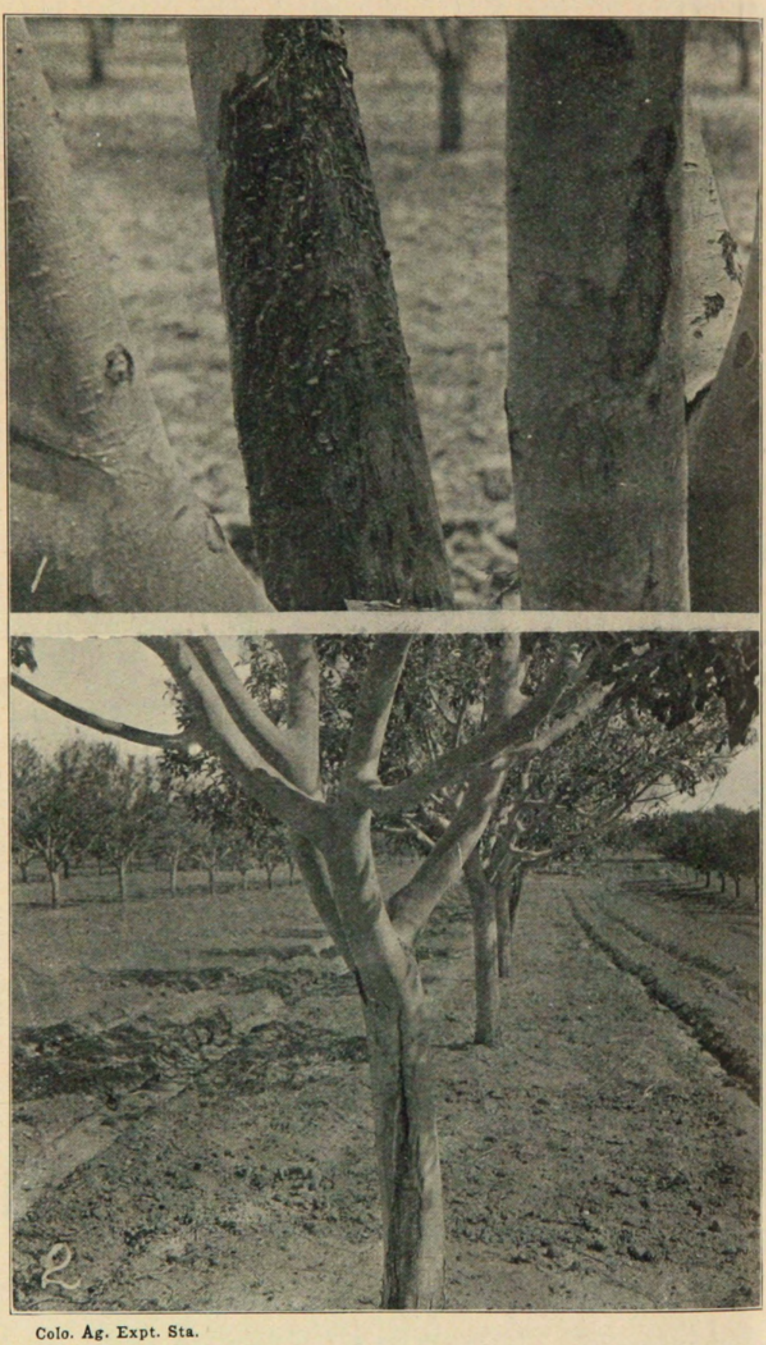

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PLATE 5.

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PLATE 6.

Fig. 3

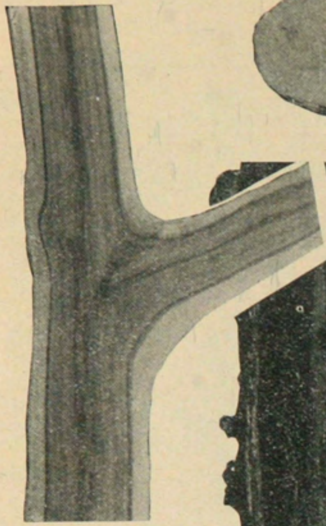

Fig. 1-A

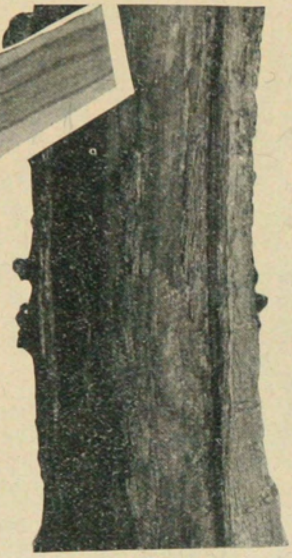

Fig. 4

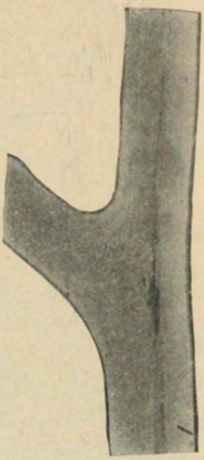

Fig. 1-B

Fig. 2

Fig. 1

Fig. 2

Colo. Ag. Expt. Sta.

PLATE 7.

my conviction that many trees have been killed by arsenic and that others are hopelessly sick. I will give some reasons for my belief. First, it is a well-known fact that soluble arsenical compounds will kill plants. It has been found that Herbicide, a preparation found on the market, is essentially a solution of an arsenical compound. Both white arsenic and arsenic acid have been shown by various experimenters to be deleterious even when present in very small quantities, one part per million in solution. Second, I took some greenhouse plants, coleuses, daisies and geraniums in two and a quarter and three inch pots and added from 0.05 to 0.5 grams, approximately from 3-4 of a grain to 7.5 grains, of sodic arsenite and the smallest amount used sufficed to kill the plants. Third, I know of two trees, one killed outright, at least this is the testimony of the owner, there is nothing but the stump left at the present time, and the other partially killed. It was my good fortune to see this tree in October last when the affected limb was still on the tree with the dead and blackened leaves clinging to it. Inquiry elicited the statement that it had been killed by arsenic as the other tree had. In the case of the tree that had died and been removed, they had made arsenite of lime under it or near it and had probably spilled the arsenite of soda. In the case of the tree, one limb of which was dead, they had been more careful with their sodic arsenite, having some left over they determined to get rid of it and emptied it into the irrigating ditch near the tree; this was one day in June—two days later the limb was sick. I saw it in October when the limb was dead and had the appearance of having been dead for some time, and again in April last. In the meantime the limb had been cut off but was still lying beside the tree as shown in Plate VI. Mr. Whipple and I measured the distance from the trunk of the tree to the irrigating ditch shown in the foreground of Plate VI., and found it to be 12 feet. An examination of this tree showed that a section of the bark from the base of the trunk up into the big limb was brown, sunken and in appearance like the bark in the trunks of the affected trees. The wood beneath this bark was dead and colored brown, well shown in Plate VII., lower Fig. 2, which shows that nearly the whole section of the limb was involved, and that the bark was sunken and dead. The condition below the surface of the ground was even still more striking for the bark was destroyed and the little that remained was very dark, in places, black. We dug out this root, following it to the irrigating ditch, to the point where the sodic arsenite had been emptied. Two or three feet from the ditch, the root had divided into five branches or rootlets. These were black and brittle. Following these toward the trunk, we could trace the effect of the arsenite by two sections of the bark, one on the upper and the other on the lower side of the root, which had been destroyed and the wood beneath them killed and blackened. The other two sections of the root were still of a natural color. The roots, two in number which were thrown off to the left of the main root presented a condition contrasting very sharply with the five rootlets and the two sections of the main root for they were apparently entirely normal while the others were black and dead. The condition of this root is shown in Plate VII., Fig. 1, which represents a section of the root taken close to the trunk of the tree—again in Plate VII., Fig. 4, which represents a view of the under side of a piece of this root. The side root was apparently healthy (Plate VII., Fig. 3). The killing of the bark and woody tissue was in this way traced from the point at which the sodic arsenite was introduced into the ditch through the small roots into the large one, thence into the trunk, the limb, and even into the branches. The course was direct and the flow of the poisonous solution was confined to a comparatively narrow channel. The darkened area, "black heart," in the case of these branches is shown in Plate VII., Fig. 1-a and upper Fig. 2, which shows the central discolored area, which is not symmetrical with the annual rings or contour of the limb, and also the border of deeper stained tissue. I am not concerned about any theory of sap circulation, but am simply tracing the discoloring effect of the arsenic through the root into this portion of the branches. We see that the discoloration extends through the root, trunk and central portion of the branch. In this instance, death may be said to have been sudden and it may be assumed that a portion of this effect may be a post mortem one.

We have not simply assumed that the placing of sodic arsenite in the ditch and the dying of this branch of the tree two days later are wholly conclusive as to the cause of death. I have examined the wood of the branches and the root and find an abundance of arsenic in both. In this case, I recovered the largest amount or arsenic found in any sample, namely from the discolored portion of the root, in which I found arsenic corresponding to 34.5 parts of arsenic acid in one million parts of the tissue.

The other portions of this tree were apparently in good condition when I last saw it. An examination of the branches from the unaffected portion failed to show any such case of "black heart" as the affected limb (Plate VII., Fig. 1-b). In fact, they showed nothing which could be classed as a darkened center, though I recall one branch which was clouded more or less.

I have given this case in some detail because I believe it to be as conclusive proof as can possibly be adduced that soluble arsenic compounds not only produce death when introduced into the circulation of the apple tree, but will produce the effects which we find preceding the death of our apple and pear trees. In both cases, we have the killing of the bark, the staining and destruction of the tissue, and the killing of the trees. The "black hearted" condition is only incidental but in the case of our trees, I believe it to be a very suspicious condition.

I have now given the reasons for my conviction that the arsenic which has accumulated in our soil from the use of arsenical sprays used in combatting the codling moth and other fruit, leaf and bark eating insects is the cause of this trouble. To restate them succinctly, we find the arsenic already accumulated in the soil to an extent far beyond the danger line for solutions as established by competent experimenters. We find it also in the tissues of the plant where it is not normally present; we have proven both in the case of herbaceous and woody plants that soluble arsenical compounds will cause their death.

I regret that I can see no other conclusion than that the corroding of the crowns, the killing of the bark, the staining and final destruction of the woody fiber, the early dropping of the leaves presaging the early death of the tree and its final death a few months later are caused by arsenical poisoning.

### SOLUBLE ARSENIC IS PRESENT IN THE SOIL.

In preceding paragraphs, I have made two statements which will help us to explain but in no wise to remedy the trouble. One statement is that the only protection against arsenical poisoning of our orchard trees is the insolubility of the arsenical preparations used in spraying and that their continued immunity from poisoning requires that these arsenical compounds shall not be rendered soluble by any agent in the soil. Again, also in an introductory paragraph, I state that from the standpoint of my own department, this subject was really approached through the study of the effects of the alkalies.

It is certainly true that it is possible that in time, these arsenical compounds might accumulate in the soil to a sufficient extent to enable the feeding roots of the tree to bring enough arsenic into solution to be dangerous to the life of the tree by systemic poisoning. It is useless, however, to dwell upon this possibility when there are known conditions, amply sufficient to explain all the facts. Our soils, especially near the surface, contain from 0.20 of one per cent to upwards of one per cent of alkalies, from 8,000 pounds to upwards of 40,000 pounds of alkalies in an acre foot. A few small areas may be practically free from these salts, but the rule is that they are present. It may be accepted as essentially correct that these salts consist of sodic sulfate and sodic chlorid. There is almost always a small amount of sodic carbonate present, but it is sometimes absent, as is the case in one of the soils in question.

### ALKALIES RENDER ARSENIC SOLUBLE.

These so-called alkali salts, sodic-sulphate, carbonate and chloride or to call them by their more common names, Glauber's Salt, Sal Soda, and ordinary kitchen salt, are capable of bringing the arsenic into solution, even when it is present as lead arsenate. It has often been asked at meetings of these orchardists whether it was a safe practice to use their surface alkali water in applying the lead arsenate and I have stated that it was not a good practice, for one could easily conceive of conditions under which the whole of the lead arsenate could be converted into sulfate of lead and sodic arsenate be formed in the solution. This statement never seemed to be an acceptable one. I have in this case not depended upon any chemical laws, however, evident their adequacy might be, but took well washed lead arsenate, a sample which we found by rigid test to be free from soluble arsenic, suspended one gram of it in 2,000 times its weight of water and added two grams of Glauber's salt, allowed it to stand three days, filtered off a portion of it, concentrated by evaporation and tested it for arsenic. I found that the arsenic had gone into solution in very considerable quantities. A parallel experiment was carried out with salt in which only one gram of salt was used to the 2,000 grams of water. This was not allowed to stand quite three days when 1,500 grams were filtered off, concentrated and tested for arsenic. This concentrated solution was found to be so heavily charged with arsenic, that only a small part of it gave an unmanageable amount of arsenic when brought into an active Marsh apparatus.

A similar series of experiments was made with the lime arsenite. We included in this experiment the salts above mentioned and also distilled water; the lime arsenite was prepared by precipitating a solution of calcic chlorid containing an excess of the lime salt with a solution of arsenite of soda, filtering and washing it. This precipitate was probably the pure normal arsenite of lime. One gram of this lime arsenite was suspended in 2,000 times its weight of distilled water, another gram in a like quantity of water containing two grams of Glauber's salt and a third gram in a like quantity of water to which had been added one gram of salt. The calcic arsenite seemed almost completely soluble in each of the three trials.

We have then direct proof that the alkali salts in the soil are capable of bringing the arsenic, even when present as arsenate of lead, into solution and consequently making it a source of danger.

In regard to the arsenite of lime, there would seem to be but little to be said. I remember having years ago tested the clear solution remaining after the lime and arsenite of lime had settled and as I now recall it, for I have no note on it, the solution was free from arsenic. If this is correct it may have been due to the great excess of lime present.

LIME SALTS IN THE SOIL DO NOT PREVENT THE SOLUTION OF ARSENIC

The idea expressed in the last sentence has persistently presented itself in another form, namely would not the lime salts occurring in our soils, especially gypsum which is notably soluble in water, serve to prevent the solution of arsenic. The answer to this is unquestionably no. For when 500 grams of soil, rich in sulfate of lime, were suspended in 2,000 grams of water and allowed to stand, some arsenic went into solution. This experiment was made three times and the results showed the presence of soluble arsenic so decidedly that there was no reason to seek even for cumulative evidence on this point. It does not, of course, matter where the alkalies came from, whether they were already in the soil or whether they are brought to the soil by the water used for irrigation, some of which I know to be rich in alkali.

### CANNOT DISTINGUISH THE SOURCE OF ARSENIC.

I do not know the history of the samples of soil examined whether they contained the arsenic as lime arsenite or lead arsenate, nor does it appear to me to be a matter of importance in which form the arsenic was present in the soil. The experiments with the alkalies, Glauber's salt and ordinary kitchen salt, indicated in my judgment, the greater solubility of the lime salt, but it would be difficult perhaps, aside from the deportment of the lime salt, to prove directly that the arsenic found in the tree had been derived from the lime arsenite for the ash of the tree contains some lime and there is scarcely an orchard soil which has not received both the lead and lime salts. It is impossible to tell which one has contributed more largely to the damage done, but owing to the length of time it has been used and the greater readiness with which it appears to go into solution, it would seem probable that the lime preparation has up to the present, contributed more largely to bringing about the trouble than the lead salt.

It is, on the other hand, easier to obtain direct proof that the lead arsenate has been the source of some of the arsenic for lead is not a normal constituent of woody tissue and the presence of a trace of it suffices to prove that the lead arsenate has been the source of the arsenic. I tested only six of the samples for lead but as lead was found in each of them this number of tests is deemed sufficient. The lead was obtained in the metallic form and its identity established beyond doubt.

The significance of this is not only that lead arsenate has been the source of the arsenic but that the ordinary kitchen salt present in the soil is probably an active agent in bringing it into solution, for the lead chlorid which would be formed by the interaction of the lead arsenate and salt is more readily soluble than the sulfate, the product of the interaction of Glauber's salt and lead arsenate. In this case too, it seems beyond question that both salts, Glauber's salt and ordinary kitchen salt, contribute to the damage done. The amounts of these salts in the soil and in some water used for irrigation, particularly the Glauber's salt, is more than ample to bring about the solution of the arsenic.

### TWO KINDS OF ARSENICAL POISONING.

So far I have not mentioned the character of this arsenical poisoning whether it is a general systemic poisoning or a case of acute irritant poisoning. That the former class of poisoning may occur seems very probable as in the case of one of the pear trees studied but all the rest of the cases with which we have met so far, seem clearly to belong to the latter class. The possibility of the occurrence of the former, however, is a matter for serious concern, for if the soil becomes sufficiently rich in arsenical compounds to enable the roots to appropriate the arsenic as they do the general sustenance of the tree then the poisoning of the tree becomes a question of its ability to tolerate the poison. I fear that we have some cases in which our statement that the beginning of the trouble is at the crown of the tree, is not applicable, though this, as a rule, seems to be the case. Still it is suggestive, as elsewhere indicated, that often the dead roots are not as intimately connected with the affected areas of the crown as those which still retain a little life.

The lead and lime with which the arsenic is combined in the sprays may be appropriated by the tree to its injury. The amount of lime, however, added to the soil as lime arsenite would be wholly insignificant in comparison with the lime already present in nearly all of the soils with which we are concerned in this bulletin unless it were taken up as arsenite of lime.

There are really three substances which might act as poisons to the trees, namely, arsenic, lead and lime.

### ARSENICAL POISONING.

I have already discussed the question of arsenical poisoning so far as the purposes of this bulletin demand.

### LEAD POISONING.

The question of lead poisoning is a permissible one for discussion, but while lead, as it was found in every sample tested for it, is probably present in all of the samples and may have some influence, the action of the arsenic appears so clearly the important one that the action of lead may be dismissed with this brief mention.

### THE EFFECT OF LIME.

This question is one which cannot justly be left wholly without mention. As indicated above the lime and arsenic may be taken up in combination, or it may be simultaneously but not in combination and it would be difficult to distinguish their separate action. There are, however, other questions which involve the case still further. It is stated on good authority that marly soils are unfriendly to a number of plants. Many of our soils are rich in carbonate of lime and others are underlaid by a stratum of marl, carbonate of lime, sometimes acquiring a thickness of two feet or more. It is a serious question in my mind whether this is not a bad feature. My attitude toward this subject is exactly the same as that toward the one or arsenical poisoning, i. e., that the subject should not be mentioned without good and forcible reasons for doing so. Why mention this then at all?

I have called attention to the fact that many trees, evidently in an unhealthy condition, are bleeding freely from old wounds, stubs, where limbs and branches have been cut off and from cracks in the bark (Plate V., Figs. 1 and 2). This sap is heavily laden with salts of some kind, dries quickly, and deposits a yellowish white crystalline mass. This mass when fresh possesses, at least sometimes, a disagreeable taste; the thoroughly dried salt has not a particularly unpleasant one. I have seen this juice dripping from a crack in the bark and building a veritable stalactite of this material Mr. Weldon, our Field Entomologist, and I gathered a quantity of this material, avoiding as far as possible the scraping of the bark, lest we should get some of the spray material. The conditions exposed our sample to contamination in this manner and by dust, which might contain arsenic, being blown into it, but I think that the results obtained from this sample may be accepted as, in the main, reliable. This material was very rich in arsenic and contained 25 per cent of calcic oxid. I do not believe that the splitting or cracking of the bark and the bleeding are specific characteristics of arsenical poisoning but are attributable to other causes which in these cases may act conjointly with the arsenic. The destruction of the bark by the arsenic is an entirely different thing from this cracking or splitting of the bark.

Having found that this dried sap was an interesting subject, we gathered a second sample. The preceding sample was gathered before the first spraying of the season had been made, but the second was taken subsequently to it. Lead arsenate was used in the spray and might have gathered in this dried juice which forms rough masses on the limbs and trunk of the tree. In order to remove as far as I might be able, such arsenic as might be present as lead arsenate, dust and other impurities, I dissolved the dried sap in as little warm water, not boiling, as possible and used only the aqueous solution in making the test for arsenic which was very abundant indeed.

This sample of air-dried material gave 24.93 per cent of lime, $CaO$; it contained a little magnesia and alkalies. I have made no attempt to determine the acid combined with the lime, but lime being practically the only base, it seems probable that the mass is essentially a malate of lime which would require 25.7 per cent of this substance, calcic oxid. These trees do not present the symptoms described for the arsenical poisoning, though arsenic is very abundant. The question is—Are these trees suffering from systemic arsenical poisoning, lime poisoning or both? 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 have no remedy to suggest for either condition. Preventive measures are so far as I can see, our only recourse. Those which suggest themselves to me are: to remove the arsenic laden soil from about the crown of the tree and replace it with fresh soil; to use the standard brands of lead arsenate in preference to the arsenite of lime or white arsenic, sal soda and lime; to use as little lead arsenate as possible. I have been told that good results have been obtained by using 2 1-2 and even 2 pounds of pasty lead arsenate to 100 gallons of water, but the spraying must be done thoroughly. Spray no oftener than is absolutely necessary. If I am not mistaken Prof. Gillette has found that 95 per cent of the effect of the whole season's spraying was obtained by the first spraying when thoroughly well done. Some device should be used to prevent the spray material from running down the trunk and collecting at its base or it would be still better to make provision for gathering the whole of the drip. Water rich in alkalies should not be allowed to flow close enough to the tree to permit of the deposition of the alkalies in the soil about the trunk of the tree. Concentrated lye, if used to kill the woolly aphis, should not be applied to the soil at the crown of the tree or permitted to flow down and collect there.

## SUMMARY

First: There is a large number of fruit trees in the State which are suffering from an affection of the trunk and root.

Second: This trouble begins, in by far the greater number of cases, at the crown of the tree and subsequently involves both trunk and roots.

Third: The first marked symptom is an early ripening of the foilage usually followed by death about midsummer of the ensuing year.

Fourth: The crown of the tree is found to be girdled, the bark on portions of the trunk dead and sunken and most of the roots dead, their bark destroyed and the woody tissue discolored, usually a light shade of brown and sometimes exteriorly blackened.

Fifth. Soluble arsenical compounds will effect the destruction of the bark, the staining of the wood, the production of the so-called "black heart" and the speedy death of the tree.

Sixth: Arsenical sprays have been used in these orchards for a number of years.

Seventh: These arsenical compounds have accumulated in the soil.

Eighth: The accumulation of arsenic in the soil in an insoluble form has already passed far beyond the limit of danger for arsenic in a soluble form.

Ninth: The insoluble arsenical compounds are being converted into soluble ones in the soil.

Tenth: The alkalies are the agents effecting the solution of the arsenic. By alkalies, I mean, sodic carbonate, sodic sulfate and sodic chloride.

Eleventh: The lime salts, viz. the sulfate, gypsum, and the carbonate do not effectively protect the arsenical compounds from the solvent action of the alkalies.

Twelfth: Systemic poisoning may take place, probably does, by absorption of the arsenic with the nutritive solutions taken up by the feeding roots but the greater portion of the trouble appears to be from local irritant poisoning.

Thirteenth: The arsenical poisoning is, in all probability, in many cases, complicated by lime poisoning.

Fourteenth: The arsenic in the arsenite of lime is more readily brought into solution than that of the lead arsenate.

Fifteenth: It is probable that the lime or marl in the soil and subsoil is also an agent acting conjointly with the arsenic in producing some of the trouble.