OBSERVATIONS ON TERMITE INJURY TO LIVING PLANTS WITH SUGGESTIONS FOR CONTROL

by

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INTRODUCTION

Damage to living plants by subterranean termites (Reticulitermes spp.)[1] is an important entomological problem in Kansas. It confronts the commercial and government nurserymen, landscape specialists, orchardists, and home owners. Very little information on this problem has been published. Recommendations for control are both general and vague. During the growing season, several inquiries concerning this problem are received each week by Kansas State College. An examination of the United States Insect Pest Survey Volumes showed that 11 states have reported termite damage to living plants since 1921. These states extend from California to Massachusetts. The first report of such damage in the Pest Survey bulletins came from Michigan in 1921.

For a number of years, orchardists and some entomologists refused to accept the evidence that termites may cause primary infestations in plants. They assumed that the infestation was secondary, or that the termites had attacked the tree after it had been killed by other insects.

The erosion control programs that are under way at the present time in the great plains area, under supervision of federal and state agencies, have increased the importance of

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[1] Four species of the genus Reticulitermes have been recorded from Kansas by Kofoid (1934). The species are R. flavipes Kollar, R. tibialis Banks, R. virginicus Banks, and R. claripennis Banks.

this problem. Nursery stock is now concentrated; efforts are being made to keep every tree alive; drought conditions have made it necessary to water trees and the moist soil attracts termites; all of these factors tend to increase the number of infestations of termites in living plants.

The purpose of this study was to examine termite injury to living plants in Kansas and to develop if possible some effective methods of controlling the termites or preventing termite injury, without being detrimental to the plant.

REVIEW OF LITERATURE

The two most important works on termites and termite control are those by Kofoid (1934) and Snyder (1935). Both are very comprehensive. Kofoid dealt with the termites of the world, while Snyder's work covered the termites of the United States. Kofoid (1934) stated that in the more temperate regions termite attacks on living trees and plants are typically sporadic and local, and are not known to be of economic significance. In some cases such infestations result in injuries to trees, especially where there is little dead wood or the infestation is of long standing. Where dead wood is limited in extent, the termites eat close to the cambium and cause its gradual recession. Where the infestation is of long standing, the termites may tunnel the branches or trunk so extensively as to weaken the tree materially, making it incapable of withstanding a storm or crop weight. Such colonies, however, while apparently doing little damage at the time, are of potential economic significance, since they give rise at certain seasons to colonizing alates. They subject surrounding trees and nearby wooden structures to the danger of infestation and weaken the trees as they age.

Kofoid (1934) further stated that the damage resulting from such termite attacks could be prevented or reduced, and the degree of infestation limited to a negligible figure, by systematic removal of dead wood and the sealing or painting exposed injured areas to reduce the probability of entry of colonizing pairs; or by the injection of poisonous dust to destroy colonies, when the removal of infested parts is impractical.

Kofoid (1934) presented four other groups of characteristics into which fall the less numerous cases of damage by termites to living trees. (1) The attack from without, the termite colony having its origin and permanent centers elsewhere; (2) the attack is directly to the living portion of the tree; therefore, (3) it is potentially and in most cases actually more destructive, often resulting in the death of the tree, and (4) the damage is accomplished much more rapidly, in weeks rather than years, as in the other type of attack.

Kofoid (1934) listed only one species, the western subterranean termite, Reticulitermes hesperus Banks, which ranges widely in the United States, as attacking living plants. This termite attacks by eating into the root stock and trunk and finally girdling the cambium.

Banks (1920) stated that various species of the genus Reticulitermes have long been known to attack, more or less sporadically, living trees and shrubs, and even flowering plants and crops. Occasionally, they damage or kill the plants by tunneling the stalk. There seems to be reason to believe also that their attacks on roots are a drain on the vitality of the plants. Their attacks on trees are usually confined to dead portions, and the damage done is slight.

On occasion, according to Banks (1920), particularly in young, recently transplanted trees, these attacks may result in death. Careful examination of unsuccessful plantings of trees may show the number of such cases to be significant. It seems probable that such attacks will be found to be correlated with an exposure of dead wood in roots or rootstock at the time of transplanting.

In shade trees, according to Snyder (1935), the infestation may start locally at the base and extend more generally through the heartwood and sometimes to the top of the tree and through the branches. A wise preventive measure was the removal and prompt burning of all loose wood which may afford shelter to termites, such as prunings, dead and dying trees, untreated fence posts, and similar material. Care should be taken that trees do not become scarred near the base, in order to prevent heartrot and subsequent termite infestation. Scars and all pruned areas should be treated with a mixture of one-fourth creosote and three-fourths coal tar. This mixture should not be allowed to come into contact with the living tissues at the edges of the bark. Shellac may be applied to protect them.

Snyder (1935) reported that heavily manured soil will sometimes attract subterranean termites, since they can obtain food from the animal manure. Commercial fertilizers should be used in regions where termites are common in the soil. The stimulation of plant growth after injury, especially callus about scars, by any means such as soil fertilization will prove helpful in protection from further injury.

Snyder (1935) thought injury to nursery stock was likely to be serious on recently cleared land where decaying wood is abundant. He suggested that care should be taken not to allow the roots to dry out before planting, since weakened stock is especially susceptible to attack.

Subterranean termites can be killed in the soil, if it is moist and not too compact, by breaking it up near the tree and pouring carbon disulphide on the earth at a distance of about a foot from the trunk, then covering the liquid over with earth. The gas from this liquid will penetrate the subterranean galleries of the termites. Since it is somewhat dangerous to plant life, large doses should not be used. Carbon tetrachloride can be used in the same manner, but apparently is not as effective as the carbon disulphide (Banks, 1920).

Deep, late fall plowing was of value in breaking up the galleries and nests of subterranean termites on ground planted to field or truck crops. As a result of the frequent stirring of the soil, rotation of crops aided in preventing termites from injuring them. Plowing and fallowing were found to be more practical than the use of insecticides in preparing the soil to prevent termite injury.

Vaughn (1914) stated that termite injury to growing trees and plants was first reported in Kansas about 1908. Vaughn found that the subterranean termite had attacked elm, cherry, apple, honey locust, cottonwood and catalpa trees. In addition, injury was reported to strawberry, raspberry, and rhubarb plants and to corn, cowpeas, and wheat stubble. He also stated that a termite will eat its weight in wood every ten hours.

Vaughn suggested as control for living plants, a soap and cyanide solution--one-half pound of laundry soap in 20 gallons of water. Add seven ounces of potassium cyanide dissolved in seven gallons of water. Lastly, add two ounces of arsenic, shake, and pour near the roots. He reported that fields plowed in the fall were free from termites.

Smith (1938), in his work in Australia, found that the termites work on the plants just below the ground level, causing the leaves of the plant to turn yellow and the plants to lose their vigor. Fumigation with paradichlorobenzene was used as a control method with moderate success.

Headlee (1939) found that 0.05 pound of acid arsenate of lead per cubic foot of soil was effective in controlling termites (<u>Reticulitermes</u> <u>flavipes</u>) in the Lakewood sand region of New Jersey. The poison was sifted and mixed into the soil to a depth of four inches. There was no termite attack in the treated plots in five months, although the wood in the check plots was destroyed.

Termite control work in the far east was summarized by Beeson (1940). He suggested remedial measures for control of termites in seedlings and older trees. When young seedlings are observed to be dying in seed beds and nurseries, the rows should be systematically examined and the super layers of soil turned back and watered with a crude oil emulsion, or dusted with centrifuged napthalene, paris green, calcium cyanide, or sprinkled with paradichlorobenzene (liquid or crystals). The dry powders should be mixed with sand or ashes for distribution.

For older trees Beeson suggested two parts of quick lime slaked in as little water as possible, with one part of paris green or arsenate of lead.

GENERAL OBSERVATIONS

Possible Causes of Termite Injury to Plants

During the past six years, drought has been an important factor in the infestation of living plants by termites.[1] Drought means weakened trees, and it is an accepted fact by biologists that weakened trees are more susceptible to insect attack than are the vigorous plants. Watering of plants during the dry conditions attracts termites to the moist soils near the roots of the plants. This was noted during June and July in the experimental work at the college insectory. No termites were found in the top 12 inches soil of the experimental plots on July 2; whereas, when the plots were watered continuously, infestations appeared throughout the experimental plot by July 26. No termites appeared in the arid soil at the edges of

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[2]Stated orally by Professors George A. Dean, R. C. Smith, and H. R. Bryson, Department of Entomology, Kansas State College.

the plot.

That moisture is an important factor in termite infestation is shown by seven cases of active termite attack observed on the college campus during July of 1940. No infestations were reported in June, but one was found in August of that year. It was noted that during the dry period in July, the trees and shrubs on the campus were watered artificially, since the precipitation for July in Manhattan was .38 inches, whereas, in June and August the same year the precipitation was 4.06 inches and 4.72 inches respectively.

Observations on Termite Injury

Termite injury to plants falls naturally into two groups: the injury to seedlings and annuals, and the injury to the larger and more mature trees.

Termite injury to older and more mature trees usually originates in some injured part of the tree. The most common are mechanical injuries. Damage by lightning is a common form of mechanical injury. Quite often termites are secondary and not primary in infesting the older trees and shrubs. The termites were observed using the tunnels made by the flathead apple-tree borer in a small shrub by the College Auditorium. The death of the shrub was not due to termites, but to the borers that had girdled the trunk under the bark. It might be assumed that termites were also a factor, but undoubtedly they were not the primary cause of the death of the shrub.

The first stages of termite injury to seedlings and annuals can usually be observed by examining the foliage. The leaves at the tip of the branch or stalk are wilted, whereas the remainder of the leaves are turgid. This was noted in the Soil Conservation Service nursery south of Manhattan. Early in the morning the injured plants were easily detected. The few leaves at the tip had not regained their turgidity during the night, as had all of the other leaves of the plant. Later in the day, the other leaves would assume a wilted appearance and the injured plants were difficult to distinguish.

It was found that the termites worked near the surface of the soil unless it was dry, whereupon they would burrow deeper and remain in the moist soil. The plants were sometimes girdled or their root system hollowed out. If the top few inches of soil were dry this would cause immediate death to the plant.

In seedlings, as in older trees, the presence, number and kinds of insects must be considered. Likewise, the surroundings of the plants must be considered. The nearness of logs, old stems, stumps, boards, or any other concentrated amount of cellulose that might be the source of infestation is also an important consideration. Infestations sometimes can be checked by removing the source. Knowledge of the crops that had been grown on the soil before diagnosing the problems was helpful.

Relations of Agricultural Practices to Termite Infestations

According to Vaughn (1914), termites did not occur in fields which were in cultivation the preceding year. However, it was observed at the College insectary that corn plants were infested throughout a field which had been in cultivation the preceding year. It was noted in Brown County, Kansas, in 1938, that the corn along the edges of timber was damaged. The injury occurred only in the first six rows from an edge of the field that was bordered by a hedge. It seems probable that timber or hedges bordering a field would be a source of termite infestation. In small fields the infestation might extend throughout the field.

Small colonies or parts of colonies of termites were occasionally observed under cow dung in pastures near Manhattan. Snyder (1935) recommended that commercial fertilizers be used rather than barnyard manure, if the soil is infested. This removes the possibility of the cellulose material in the manure being a source of food supply for the termites.

In pastures near Manhattan iron-weed and living dock plants were observed containing infestations of termites. Both of the weeds were in vigorous condition, evidently withstanding the termite attacks.

Attempts to Infest Plants Artificially

Several attempts were made to infest plants artificially by bringing in large numbers of termites from colonies collected around buildings and in stumps near Manhattan. The best method of collecting termites for this purpose was to spread a piece of oil cloth, one square yard in size, as close as possible to a stump or log which was to be the source of supply. Then split or cut the stump or log open with a small axe. The oil cloth would catch the termites and wood particles that contained them as they fell from the log. The larger pieces of wood were then shaken over the oil cloth to dislodge the termites. As much trash as possible was then discarded.

Since the soft bodies of the termites were easily crushed, care was taken not to injure them while collecting. As soon as they were transferred to the new environment they dispersed rapidly and sought whatever shelter was available.

Stumps which had been dead about three years were the best medium for collecting large numbers of termites. The termite colony was usually found in the sapwood of the stump.

Three methods of placing the termites in the soil near the tree were used. One was to make a hole in the soil near the base of the tree and place the termites in it. The hole was then covered with pieces of cardboard or lumber. The second method was to place a number ten tin can (one gallon size), with both ends removed, near the base of the tree or plant. The can was then pushed down into the soil two-thirds of its height; the termites were then placed on the moist soil inside the can. The third method involved the use of tape boxes. These are small empty cylindrical pasteboard boses in which adhesive tape came to the College athletic department. One end of the box was removable. The opposite end was removed and this end buried in the soil near the base of the trees. Fifty to 100 termites were placed in each of the boxes through the upper end on June 6, and more termites on June 26.

Watering of the trees was started on July 15, and within ten days infestations occurred around 20 of the 28 trees that had been treated. Those treated by the second method, by putting the termites inside the tin cans, were not at all successful. Although the trees were not infested, the tape tubes and buried cardboard were infested. These were near the tree roots. There was no sign that the termites had worked in or near the tree roots.

Termites were placed in flower pots containing tomato plants. They were protected by covering the top of the pot with a small piece of cardboard into which a small opening had been made to allow the stem of the plant to pass. No infestation of the plants was obtained as a result of these attempts. Termites were found in the untreated tomato pots on the sixth day after they were placed in the pots. But the plants were not attacked.

From the observations, it would indicate that as long as there are other food materials in the soil, the termites will not attack healthy living plants. They are attacked either when the plants are in a weakened condition, or when the natural food supply of the termites has been exhausted in the immediate vicinity. Infestations will sometimes spread from trash and woody materials; the trash furnishes a place for the termite colony to become established. Once the colony is established and developed, there is the danger of infestation to all wood in the vicinity.

EXPERIMENTAL TESTS

Tests with Arsenate of Lead for Termite Control

Arsenate of lead appeared to be a safe and effective soil insecticide for termite control. It was used, as reported by Headlee (1939), in New Jersey for control tests with *Reticulitermes flavipes*. In his experiments he sifted the arsenate of lead into soil to a depth of four inches. His work indicated that as little as 0.05 of one pound of arsenate of lead per cubic foot of soil, or four ounces to five cubic feet, was an ample amount.

Chinese Elm and Apricot Trees Treated with Arsenate of Lead. Fleming (1937), in his work on the use of arsenate of lead in the control of the Japanese beetle larvae, found that in certain types of soils, it stunted the growth of the evergreen trees as much as 30 per cent, and concluded that it could not be effectively used.

In the present study applications of arsenate of lead were made around one-year-old trees, tomato plants, treated soil in jars, and in a solution near the roots of three-year-old fruit trees.

Eighteen trees of the two species, Chinese elm and apricot, were planted at the west insectary on April 30, 1940 (Table 1). They were planted in soil containing varied amounts of acid arsenate of lead. The amounts and the reactions of the trees are shown in Table 1. Tin casings made from number ten cans were placed around the trunks of the trees. These were sunken at least two-thirds of their heights below the surface of the soil. On June 6, 50 to 100 termite workers and soldiers taken from a tree stump and placed with a small amount of wood particles on the damp soil within the tins near the trees gave no signs of

Table 1. Trees treated with arsenate of lead for termite control, April 30, 1940.

Number	Kind of tree	Amount of lead arsenate per cu. ft.	Condition of tree June 1, 1940	Condition of tree July 28, 1940	Height of tree July 1	Height of tree July 28	Height of tree Aug. 20
1	Apricot	2 ounces	vigorous	vigorous	16"	22"	27"
2	Apricot	4 ounces	weak	dead, removed, no insect or arsenical damage to roots	11"	-	-
3	Apricot	check	vigorous	removed as a check	17"	22"	-
4	Apricot	6 ounces	fair	vigorous	16"	20"	24"
5	Apricot	8 ounces	vigorous	vigorous	21"	31"	37"
6	Apricot	check	weak	fair	11"	14"	20"
7	Apricot	10 ounces	dead, did not grow after transplanting	-	-	-	-
8	Apricot	12 ounces	vigorous	vigorous	17"	21"	25"
9	Apricot	check	vigorous	vigorous	17"	23"	40"
10	Apricot	1 pound	weak	dead, no effect on the roots	16"	-	-

Table 1. (concl.)

Number	Kind or tree	Amount of lead arsenate per cu. ft.	Condition of tree June 1, 1940	Condition of tree July 28, 1940	Height of tree July 1	Height of tree July 28	Height of tree Aug. 20
11	Apricot	2 ounces	weak, mechanical injury	fair	17"	24"	27"
12	Apricot	check	vigorous	vigorous	22"	34"	41"
13	Chinese Elm	4 ounces	vigorous	vigorous	24"	36"	48"
14	Chinese Elm	6 ounces	vigorous	vigorous	21"	36"	46"
15	Chinese Elm	check	vigorous	vigorous	28"	42"	50"
16	Chinese Elm	8 ounces	weak	weak	12"	21"	30"
17	Chinese Elm	12 ounces	vigorous	vigorous	26"	38"	45"
18	Chinese Elm	check	vigorous	vigorous	31"	42"	48"

damage or of infestation by June 21, at which time they were reinfested in the same manner. On July 1, 60 days after planting, four apricot trees were removed and examined. Two trees were living and two were dead. The examination was made to observe, if possible, any injury to the roots caused by the arsenate of lead. One of the living trees was untreated. The other had been in soil treated with four ounces of arsenate of lead per cubic foot. There was no noticeable difference in the root system. After drying ten days, no external difference could be detected among the four plants. This time was allowed to make a comparison of the roots of the live and dead trees. The heights of the trees were measured three times and no significant difference was observed between the treated and the untreated trees. There was no evidence of insect damage.

In as small a plot and with the few trees used, it would be impossible to make a definite statement as to the effect of the arsenate of lead on the plant growth. No difference was observed under the insectary conditions in the plot.

Potted Tomato Plants Treated with Arsenate of Lead. Twenty tomato plants were placed in pots that were set into two inches of soil. Five pots were treated at the rate of one ounce per cubic foot with arsenate of lead. Five were treated at the rate of two ounces per cubic foot and ten were left as checks. In each case the lead arsenate was thoroughly mixed into the soil before the soil was placed in the pots. The plants were kept moist and the top of the pot was covered with cardboard through which a small hole had been made to allow space for the stem of the plant. Two weeks after planting, each pot was infested with 25 to 40 termite workers and soldiers. Six days later they were examined for plant injury from both the insecticide and the termites, as well as the number of termites in each pot. Sixty-five termites were found in the untreated pots. One termite was found in the treated pots. In neither case was there any sign of termite damage to the tomato plants. The root system of the tomato plants in the five pots treated with arsenate of lead tended to be more bushy and had not spread as far through the soil as had those of the other pots. No differences were detected among the plants of the untreated pots and those treated with one ounce per cubic foot. From this it would appear that small dosages of arsenate of lead repel or kill termites which are in the soil containing this arsenical.

Effect of Arsenate of Lead on Termites in Jars. Six large battery jars were filled with soil and buried to within two inches of their tops in moist soil. There was no hole in the bottom of the battery jar, the only route of escape for the termite being over the top into the surrounding soil. The soil in three of the jars was treated with one ounce of arsenate of lead per cubic foot before it was placed in the jar. The soil of three jars was left untreated as checks. Small squares of dampened cardboard were placed in the bottom of the jars as food for the termites. Twenty-nine to 30 termites were placed in the soil in each jar. The soil was kept moist and approximately one-half of the surface was covered with cardboard.

At the end of six days, 16 termites were found in the untreated jars, while none was found in the treated jars.

Arsenate of Lead Solution Applied to Soil. The tape boxes previously described under the discussion of the artificial infestation of plants were noted on August 13, to be infested by termites. The bottom of the cylindrical boxes or tubes were within a few inches of the three-year-old fruit trees. The termites were in the soil near the tree. This soil was treated as it would have been had the tree been infested. An arsenical solution was prepared by mixing one-half ounce of arsenate of lead per gallon of water. This solution was applied in amounts of one-half gallon to each square foot of the soil surface near the tree. Holes were made with a one-fourth inch steel rod in the ground to the depth of one foot. The soil was loosened on the surface to permit better penetration of the solution.

The soil around one apple tree, four cherry trees and one plum tree was treated in the manner described. Three infested tubes were left untreated as checks. Few termites were found two days later in the treated soil, and they were not as active as those in the untreated checks. Six days after treatment the soil around the treated trees was free from termites. The check trees still had termites near them.

Three infested stakes and three pieces of lumber were treated in a similar manner. The termites were still active 48 hours after treating, but were gone five days later when another examination was made. Termites were still active about untreated stakes in adjoining plots after five days. This method of application gave a more uniform mixture in the soil than did the arsenate of lead when mixed into the soil as a dust.

These observations appear to indicate that termites were repelled or killed when they contacted arsenate of lead in the soil. Woodworth (1938) presented the idea that in wireworm control with arsenicals, only small amounts of the arsenical was ingested by the wireworms. The lethal dosages were obtained through the integument. If this is true in the case of wireworms, it is entirely possible that it is also true in the case of termites. If a termite dies, the body is devoured by the other members of the colony. In this manner, the arsenate of lead would be passed on to several individuals. Under laboratory conditions, Kofoid (1934) found that one termite dusted with an arsenical dust carried the poison to 249 other termites.

Tests on Tree Plots

The soil around the roots of two apple trees was treated with naphthalene flakes as the trees were transplanted (Table 2). Two ounces of flakes were scattered about the roots of one tree and four ounces about the other. Both trees died during the first summer after they were transplanted, from the effect of the chemical on their root systems. The check or untreated tree was killed by flatheat borers by October, 1939. The treated trees were not attacked by borers.

Naphthalene flakes were used above the roots of 12 fruit trees. Two ounces of the chemical was used around seven trees and four ounces was around the other seven. Care was taken to keep the chemical near the surface of the soil and away from the roots of the tree. No detrimental effects were noted on the trees. Termites were placed near the base of the trees, but an infestation did not develop. Six untreated trees used as controls were vigorous after 15 months growth.

Paradichlorobenzene crystals were used in two experiments. Two cherry trees were treated with the paradichlorobenzene, one ounce around the roots of one tree and two ounces around the other in the manner that the apple trees were treated with the naphthalene flakes. The trees showed no ill effects, and 15 months later the termites were in the soil around these trees.

Six forest trees were treated as they were transplanted (Table 3). The paradichlorobenzene was placed in two-ounce waxed salve boxes. Small holes were made in the tops of the boxes, which were placed upside down in the soil under the roots of the trees as they were transplanted. The boxes were used in this manner to keep much moisture away from the chemical and in this way possibly extend the length of time that it would still serve as an insect repellant.

In two experiments the termites could not be induced to remain near any of the trees during the first year, either the control trees or the ones that were treated.

Under the conditions of this study, the observations appear to indicate that paradichlorobenzene can be used successfully in large amounts as a repellant to termites around large trees. In the cases that were mentioned on page six, the odor of the chemical was still strong after 65 days. This same amount of chemical was applied to the soil around the roots of a small wood vine on a house that was being treated for termites and it caused the death of the vine. The more tender roots of the larger trees are far enough away from the chemical not to be harmed by it, but this was not true in the case of the small vine.

Paris green was dusted about the roots of two apple trees as they were transplanted. One ounce was used on one tree and two ounces on the other. Both of these treatments caused the death of the trees. The third tree, the untreated control, was vigorous at the end of the second season.

Two cherry trees and one plum tree were treated with quick lime as they were transplanted. The lime was scattered in the soil around the roots of the trees. One-fourth pound, one-half pound, and one pound were used, respectively. No change in the tree, as a result of the treatment, could be observed. Termites were introduced, but did not remain near the tree during the first year. Termites could not be found near the untreated control trees the first year.

A bait of sodium arsenite and sawdust was prepared by mixing one ounce of sodium arsenite into one pint of pine sawdust. The bait was scattered in the soil well above the roots of two plum trees. One quart was used on one tree and one pint of the bait on the other. The average height of the untreated trees was nine and one-half feet, 17 months after planting. The tree treated with one pint of the bait was only six and one-half feet in height. The tree treated with one quart of the bait was four and one-half feet in height. Nor further work was attempted with this chemical since sodium arsenite is soluble in water and

Table 2. Fruit tree plot. (Planted March 19, 1939)

Tree number	Species	Original treatment	Effect	Condition May 1, 1940
1	Delicious apple	untreated	dead, October 1939, borers	removed
2	Delicious apple	2 ounces Naphthalene	killed by naphthalene, October, 1939	removed
3	Delicious apple	4 ounces Napthalene scattered about roots of tree	killed by naphthalene, October, 1939	removed
4	Delicious apple	untreated	----	vigorous
5	Rome Beauty apple	untreated	----	vigorous
6	Rome Beauty apple	untreated	killed by borers and sunscald, October, 1939	dead
7	Rome Beauty apple	untreated	----	vigorous
8	Jonathan apple	2 ounces Paris green scattered about roots	killed by Paris green, Oct., 1939	dead
9	Jonathan apple	4 ouncws Paris green scattered about roots	killed by Paris green, Oct., 1939	dead
10	Jonathan apple	4 ounces Paris green scattered about roots	----	vigorous
11	Early Richmond cherry	untreated	----	vigorous

Table 2. Fruit tree plot. (cont.)

12	Early Richmond cherry	untreated	----	vigorous
13	Early Richmond cherry	1 ounce paradichloro-benzene	----	vigorous
14	Early Richmond cherry	untreated	----	vigorous
15	Early Richmond cherry	2 ounces paradichloro-benzene	----	vigorous
16	Montmorency cherry	untreated	----	vigorous
17	Montmorency cherry	untreated	----	vigorous
18	Montmorency cherry	untreated	----	vigorous
19	Montmorency cherry	1 pound quicklime	----	vigorous
20	Montmorency cherry	$\frac{1}{2}$ pound quicklime	----	vigorous
21	Juanita plum	$\frac{1}{4}$ pound quicklime	----	vigorous
22	Juanita plum	untreated	----	vigorous
23	Juanita plum	untreated	----	vigorous
24	Juanita plum	untreated	----	vigorous
25	Juanita plum	1 pint sodium arsenate bait	tree growth stunted. Height $6\frac{1}{2}$ feet. Average $9\frac{1}{2}$ feet.	----
26	Juanita plum	1 quart sodium arsen-ite bait	tree growth stunted. Height $4\frac{1}{2}$ feet.	----

Table 2. (concl.).

27	Juanita plum	untreated	----	vigorous
28	Juanita plum	untreated	----	vigorous
29	Juanita plum	untreated	----	vigorous
30	Juanita plum	untreated	----	vigorous

Table 3. Shelterbelt tree plot, April 21, 1939.

Number	Kind of tree	Treatment	Condition of tree, September 15, 1940
1	Ponderosa pine	paradichlorobenzene	dead
2	Ponderosa pine	naphthalene (2 ounces)	dead
3	Ponderosa pine	naphthalene (4 ounces)	dead
4	Ponderosa pine	check	dead
5	Ponderosa pine	check	dead
6	Apricot	paradichlorobenzene	vigorous
7	Apricot	naphthalene (2 ounces)	vigorous
8	Apricot	naphthalene (4 ounces)	vigorous
9	Apricot	check	dead
10	Apricot	check	vigorous
11	Catalpa	paradichlorobenzene	vigorous
12	Catalpa	naphthalene (2 ounces)	vigorous
13	Catalpa	naphthalene (4 ounces)	vigorous
14	Catalpa	check	vigorous
15	Catalpa	check	vigorous
16	American elm	paradichlorobenzene	vigorous
17	American elm	naphthalene (2 ounces)	vigorous
18	American elm	naphthalene (4 ounces)	vigorous
19	American elm	check	vigorous
20	American elm	check	vigorous
21	Walnut	paradichlorobenzene	dead
22	Walnut	naphthalene (2 ounces)	dead
23	Walnut	naphthalene (4 ounces)	dead
24	Walnut	check	dead
25	Walnut	check	dead
26	Honey locust	paradichlorobenzene	vigorous
27	Honey locust	naphthalene (2 ounces)	vigorous
28	Honey locust	naphthalene (4 ounces)	vigorous
29	Honey locust	check	vigorous
30	Honey locust	check	vigorous
31	Cottonwood	paradichlorobenzene	vigorous
32	Cottonwood	naphthalene (2 ounces)	vigorous
33	Cottonwood	naphthalene (4 ounces)	vigorous
34	Cottonwood	check	vigorous
35	Cottonwood	check	vigorous

Note: A large number of termites were placed around each tree during June, 1940, and in June and July, 1941.

it was assumed that it leached down to the root systems, thus stunting the growth of the trees.

Stakes Treated with Nicotine Sulphate

Five of seven stakes which were infested by termites were treated with the common spray solution of nicotine sulphate mixed at the rate of one large tablespoonful per gallon of water. One-half gallon of this mixture was poured around the five infested stakes. When examined six days later, all of the stakes were infested by termites.

In a series of four infested stakes, three were treated in the manner described above. When examined 24 hours later, all were infested. Nicotine sulphate probably destroyed a few termites when first applied, but it did not appear to be a useful insecticide for the control of termites.

Test of Dichloroethyl Ether as a Control for Termites

Dichloroethyl ether was used in the College greenhouse to kill the termites which were infesting tomato plants. The plants were killed by termites, so the soil was treated where they had been located. To one gallon of water 10 cc. of dichloroethyl ether were added and the two liquids mixed. One-half gallon of the mixture was poured on the soil where each of the four plants had been. Two weeks later live plants were placed in the treated soil. The amounts of this chemical which remained in the soil evidently reduced the metabolism of the plant, which retarded the growth to a point where the metabolism was barely enough to keep the plant alive. These plants were removed one month after they had been set out. They had grown only two inches in height by that time. Other plants were more than 24 inches in height by this time.

This reaction of the plant to that concentration of this particular chemical is contrary to the results obtained when it was used by Campbell (1926) in the control of crambus larvae. No damage to the fertility of the soil was noted at that time.

Since this unfavorable reaction was obtained, the use of dichloroethyl ether was abandoned as a prospective termite control.

Application of Ethylene Dichloride Emulsion on Seedlings

On July 19, termite injury to sand cherry and seedling ash was noted in the beds near the Kansas River. The damage was noted in early morning before the sun had had time to cause all the leaves to wither. Examination of the roots revealed that the termites had cut the tap root usually near the middle of the root, and the plant could not support itself in the dry top soil. This type of injury is shown in plot one. Usually only two or three termites were working on a plant at the same time. Sometimes the roots of the plants were girdled immediately below the surface of the soil. Other times they were tunneled almost the entire length of the root.

The infested trees were marked early in the morning and treated later in the day with ethylene dichloride emulsion in the same proportions that it was used by Snapp (1939) in treating for the control of the peach tree borer. The stock solution of the emulsion was prepared by mixing one pint of fish oil soap with nine pints of ethylene dichloride, and then adding ten pints of water. One and one-half pints of the stock solution was then mixed with eight and one-half pints of cold water. Small holes were made in the soil near the infested trees and one-eighth pint of this solution was poured into these holes. The uninjured trees on both sides of the infested trees were treated also. In all, there were treated nine infested and 18 uninfested trees. These were examined 48 hours after treatment, at which time no damage from the insecticide was noted on the uninfested trees. The nine trees that were infested were dead and three of them contained live termites that were feeding on the roots.

Snapp (1939) recommended using only one-eighth of a pint of the solution per tree in the control of the peach tree borer. He cautioned the users that greater strength would cause injury to the plants. Termites were alive and feeding on the roots of the treated plants 48 hours after the chemical was applied. The insecticidal action of ethylene dichloride emulsion was immediate, so 48 hours would be ample time for the experiment. No further tests were made with this chemical

SUMMARY AND CONCLUSIONS

Termites attacking living plants constitute one of the more important entomological problems in the Great Plains area. Attacks on living plants by subterranean termites (<u>Reticulitermes</u>

spp.) in Kansas was first reported in 1908. Complaints of termite damage to living plants have come in annually since this time, from commercial orchardists, landscape specialists, greenhouse operators, and home owners. The literature mentions only incidental observations, which are largely unsupported by experimental results. Carbon disulphide has been recommended as a chemical method of control, but its effects are temporary and too strong a concentration endangers the life of the plant.

The purpose of this study was to observe the conditions under which termites attack plants; the nature and appearance of the injury; and if possible, to suggest effective and economical methods of prevention and control.

Observations indicate that termites are attracted to the moist soil of watered plants and also to dead wood materials. Plants are likely to be attacked when the other food supply of the vicinity is exhausted. The roots of seedling and annual plants are both girdled and tunneled by termites. Injury in older trees usually starts at a point of mechanical injury to the tree. Termite attacks are less frequent in land that had been cultivated the year preceding.

As many observations as possible were made in the field during 18 months of the study. Seventeen different insecticides were used, either alone or in combinations, in the control tests. One hundred three plants, consisting of 47 fruit trees, 36 shade trees, and 20 potted tomato plants were used in this study.

Four different chemicals were mixed into the soil around the roots of two-year-old fruit trees as they were transplanted.

Paris green and naphthalene flakes each caused the death of two trees the first summer. Sodium arsenite bait caused two trees to be severely stunted in growth in 18 months. The reaction of lime on tree growth was not noticeable. Two ounces of paradichlorobenzene had no noticeable effect on the plants, but large amounts, as much as one pound per plant, caused the death of the small ones. Attempts to infest the trees artificially by introducing termites into the soil near the base of the trees were made once during the first summer of experimental work, and twice during the second summer. The attempts were unsuccessful, as the trees were not attacked.

Eighteen trees, six Chinese elm and 12 apricot, were used in an experiment to determine the effect of arsenate of lead on both the trees and the termites. Six of the trees were left as checks, and the soil into which the remaining 12 were transplanted was treated with arsenate of lead in amounts varying from two ounces to one pound per cubic foot of soil. No differences in the heights and vigor of the trees were observed four months after they were transplanted. This indicates that small amounts of arsenate of lead in the soil does not impair the growth of trees. Artificial infestation was attempted on these trees and again it proved unsuccessful.

Five of 20 tomato plants were treated with arsenate of lead mixed at the rate of exactly one ounce per cubic foot of soil, and five others were potted in soil treated with two ounces of arsenate of lead per cubic foot of soil. Ten plants were left in untreated soil as checks. Two weeks after planting, 25 to

40 termite workers were placed in each pot. Six days later 65 termites were found in the untreated soil, while only one termite was found in the treated soil. This indicates that the termites were either killed or repelled by the arsenate of lead in the soil.

Cardboard boxes near the fruit trees became infested with termites. The boxes and trees were treated with a mixture of one-half ounce of arsenate of lead per gallon of water. This mixture was poured in holes near the base of the trees at the rate of one-half gallon per square foot of soil surface. The termites left the treated soil and boxes while they remained in or near the untreated boxes when observed periodically for one month. These experiments dealing with arsenate of lead mixed into the soil indicate it may be a possible means of control for termites without being too dangerous to the life of the plant.

Solutions of nicotine sulfate, ethylene dichloride emulsion, and dichloroethyl ether, at the strengths recommended for the control of other insects all proved ineffective as a control measure for termites, as live termites were found in the soil two days after treatment. Since these chemicals are fumigants, their effectiveness is soon lost.

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