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University of Tennessee Agricultural Experiment Station

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THE UNIVERSITY OF TENNESSEE
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Two-year-old apple infested with the woolly aphis

KNOXVILLE, TENNESSEE

THE UNIVERSITY OF TENNESSEE
AGRICULTURAL EXPERIMENT STATION
Knoxville

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THE WOOLLY APPLE APHID IN TENNESSEE*

By S. Marcovitch

INTRODUCTION

The woolly apple aphid (*Eriosoma lanigerum* Hausman) is a well-known pest wherever apples are grown. The elm, quince, pear, hawthorn, and mountain ash are also subject to attack. This insect is sometimes very abundant in southern nurseries, causing the roots to become swollen and covered with nodules, which finally decay. Fifty per cent of the trees in the nursery may often be seriously infested. Such trees have to be discarded because of the weakened root system and the chances of spreading the aphis to the newly set orchard. Bearing trees in the orchard may also be infested, although the injury is not so apparent. This investigation was originally started for the purpose of finding out more about the woolly aphid in the nursery, where the problem is most serious.

CHARACTER OF THE INJURY

Beneath the white cottony patches are reddish-brown sucking lice. Aerial colonies may be found in the axils of the twigs, on branches, or on scars, and even on the fruit itself. In the absence of parasites, and under favorable conditions, the insects may almost cover the whole tree, giving it a whitish appearance. No doubt a toxin is injected into the tissues, for where the aphids feed, swellings or protuberances are produced. According to Staniland (1924), the galls are produced by abnormal production of cambial cells. In Oregon the woolly aphid has been found to be associated with the spread of perennial canker (Childs, 1929).

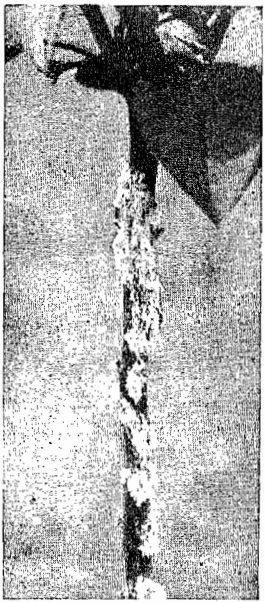

Fig. 1—A cluster of woolly aphis on apple

This insect also lives on the roots of the apple, but the root form, although identical with the aerial form, looks more reddish because the woolly secretions are not so dense. With us in the United States the root form is much more serious, especially on nursery stock. Most frequently it is located on the crown, just beneath the surface of the ground. The continuous feeding causes the roots to become badly knotted and swollen. Such roots

*The author desires to acknowledge the valuable assistance of Mr. M. V. Anthony in these experiments.

Fig. 2—The work of woolly aphis on apple root

finally decay and often result in poor growth. In Virginia, Alwood (1904) found the woolly aphid a most serious pest in the nursery. When only slightly infested, young trees may outgrow the injury and make normal growth (Schoene and Reppert, 1919).

In Europe, where the insect is supposed to have been imported, and is known as the "American blight," the aerial form is often the most injurious, and very little is said about the root form. This condition seems also to prevail in South America, New Zealand, and Australia.

LIFE-HISTORY

ON THE APPLE

The woolly aphid is capable of spending the entire year on the apple. In a mild season it may be found early in the spring, but after a cold winter it does not become conspicuous until June, when the spring migrants from the elm have established colonies. Reproduction takes place agamically, with from 2 to 28 young produced by each female per day. These become full-grown in from 8 to 20 days. Thus, a single female may produce 117 young within 29 days. As soon as aerial colonies are well established, the young crawl down or fall to the ground, where they enter through cracks and produce colonies on the roots. As many as 18 generations may be produced in Tennessee in a single summer. Generally only the wingless aphids are observable. At the approach of autumn, a winged dark-colored form appears among the wingless forms. This is known as the fall migrant. It leaves the apple, to be carried by the wind to the American elm, where the beakless, sexual forms are produced. In Europe a migrant is said to be occasionally produced that gives rise to young with a proboscis, which feed on apple.

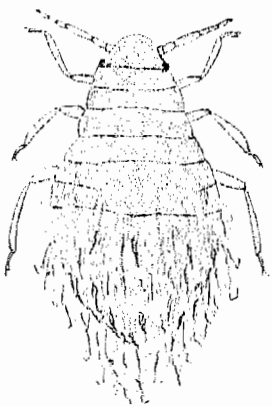

Fig. 3—Female of the woolly aphis, full-grown, as it occurs on the apple
Enlarged about 12 times.

Comparatively few of these migrants are produced. Their presence seems to coincide with the shortening of the day as the fall months are approached (Marcovitch, 1924). In 1925, the first fall migrants were observed on September 14. Others were observed as late as November out of doors. In the laboratory, where young apple trees were given only 6 hours' exposure each day, these migrants were produced in large numbers.

ON THE ELM

That the elm is the primary host of the woolly aphis was first observed by Miss Patch (1913). If elm trees (*Ulmus americana*) are near, and the aphids happen to alight on them, these migrants will give birth in a few days to young aphids, half of which are true males and the other half true females. The true sexes are wingless and beakless and do not feed. The females are small, oval in shape, reddish in color, and only about 1/20 inch in length. The males are somewhat smaller and not as plump-looking. Soon after mating, one large egg becomes visible, which seems to occupy the entire body (Fig. 7). The egg is laid in the crevices of the bark. The winter is thus passed in the egg stage on the elm. The young that will hatch out the following spring are known as stem mothers.

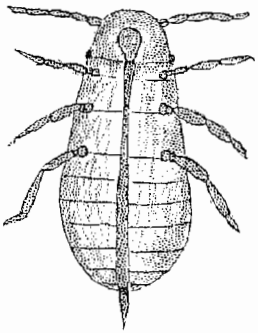

Fig. 4—Ventral view of first-stage nymph of the woolly aphis, showing the presence of a long beak

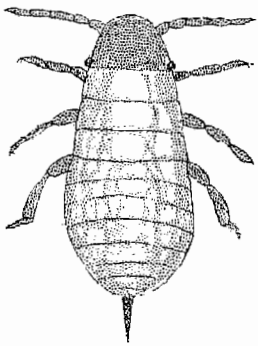

Fig. 5—Dorsal view of the first-stage nymph of the woolly aphis

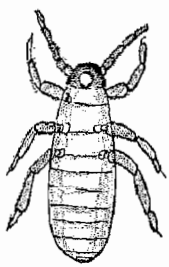

Fig. 6—Male of the woolly aphis Enlarged about 20 times.

HATCHING OF THE EGGS

In 1924, stem mothers in the first and second instar were found as early as January 31. Doubtless the eggs hatched the latter part of January. This month was 3° F. below normal in temperature, so that the early hatching of the eggs can hardly be attributed entirely to temperature. The increasing length of day, on the other hand, may be an

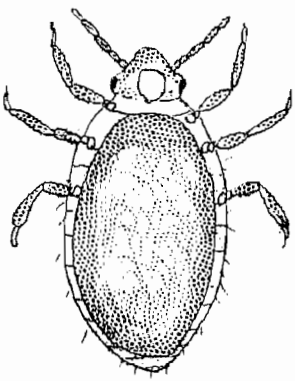

Fig. 7—Fertilized female of the woolly aphis, showing egg within. Note the absence of a beak
Enlarged about 20 times.

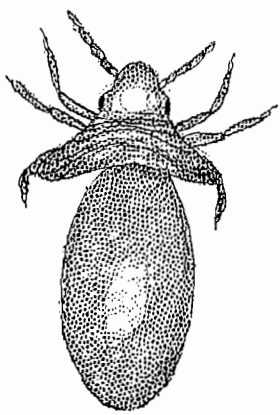

Fig. 8—Fertilized female, showing the process by which the egg is extruded

important factor, as has been shown in the case of the formation of the sexes in plant lice.

In 1923, stem mothers in the second and third instar were observed as early as March 2, located at the base of the terminal buds, which were noticeably enlarged. Normally the buds do not begin to swell until April, but that year by March they had grown considerably and were very conspicuous. The stem mothers remain at the base of the bud with their setae deeply inserted until the first leaves appear. Full-grown stem mothers were observed March 29, and were giving birth to the second generation. As soon as the buds burst, the first leaves become curled and thickened to form a rosette. In this stage the stem mother may be found on the inside of a twisted leaf. Normally a rosette results from the stimulation caused by a single stem mother, but occasionally several stem mothers may be found on one rosette. Baker (1915) records as many as 299 young produced by a single stem mother.

Fig. 9—Rosettes of the woolly aphis on elm

Examination of buds in April revealed large numbers of molted skins of the stem mothers that had disappeared. It is likely that many perish and that not all are successful in forming rosettes.

Full-grown forms of the second generation were present out of doors on April 16, while pupae of the third generation were observed as early as April 24. The third generation acquire wings and leave the elm to make their abode on the apple. In Tennessee, winged forms become numerous the first week in May, and may be found as late as June 10.

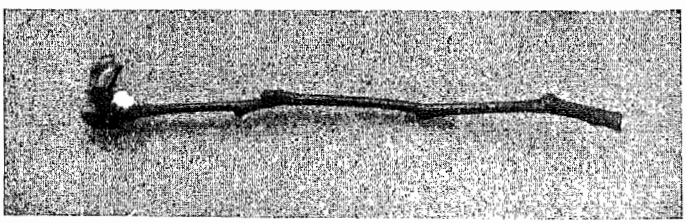

Fig. 10—A stem mother situated at the base of a terminal bud, showing the early stages of rosette formation in March

It is probable that some of the spring migrants form colonies on other elms, for in July large colonies of a woolly aphis were observed on the terminal leaves of small elms. These were identified by Miss Patch as *Eriosoma lanigerum*. An attempt was made to transfer the winged forms on apple, but they failed to establish colonies.

On April 27 winged individuals from rosettes kept in the laboratory were placed on apple seedlings. Young were deposited by some

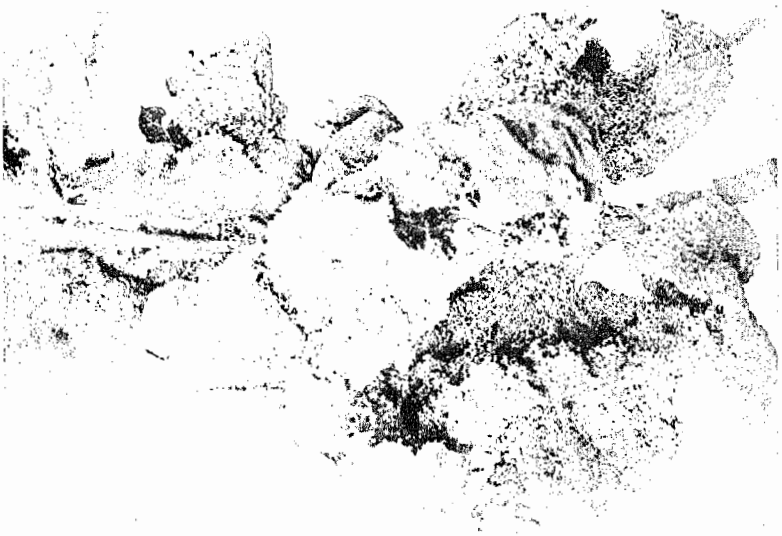

Fig. 11—A single rosette on elm caused by the woolly aphis (*E. lanigerum*), containing migrants that fly to the apple in May

of the females at once, and in a few days flourishing whitish colonies were noticeable. The individuals developed entirely on the apple, and on May 9 were full-grown.

HIBERNATION

In Tennessee the woolly aphid passes the winter in the wingless agamic form on the apple. In a mild season, such as that of 1923, aerial and root forms were present throughout the winter. In December, 1930, a sudden cold snap developed, the temperature dropping to 8° F. The twigs with woolly aphis were completely covered with ice, and when brought into the laboratory the lice became active. A greater survival was noticed among the younger and smaller nymphs. In the northern states the woolly aphid passes the winter on the apple in the first instar only.

WOOLLY ELM APHID

Eriosoma americana, also a woolly aphid, inhabits the elm. It may be distinguished from *Eriosoma lanigerum* in that it is grayish in color, it produces a leaf curl but not a rosette, and its eggs hatch later. The first leaf roll was observed April 23, 1933, with the stem mother nearly full-grown. April 30, several were found to be full-grown and depositing young. It is a curious fact that the stem mothers are unable to live on a normal, uncurled leaf.

The first winged forms became mature on May 15, and when placed on apple would not deposit young. This species migrates to

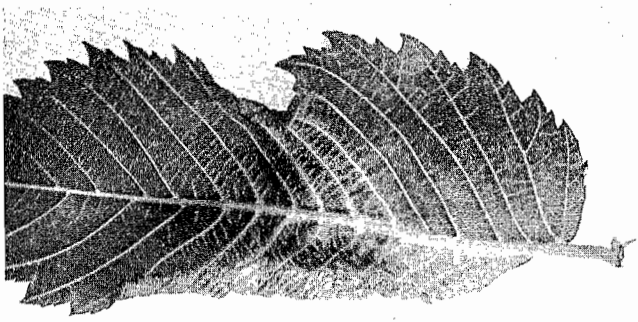

Fig. 12—Elm leaf curl caused by the woolly elm aphid (*E. americana*), containing migrants that fly to the juneberry

the juneberry (Patch, 1915). When winged forms were placed on juneberry leaves, they crawled to the underside and deposited young. Within a few minutes, one female gave birth to 18 young in a row. As soon as the young became dry they crawled to the roots of the potted seedling.

October fall migrants of *Eriosoma americana* were observed in abundance settling on the American elm.

EFFECT OF TEMPERATURE ON GROWTH AND DEVELOPMENT

Often during the summer months no aphids could be found of either the aerial or the root form, even though heavy infestations were observed in the early summer or spring months. Since this disappearance seemed to occur especially during hot, drouthy summers, a study of the temperature requirements was undertaken.

METHODS USED IN REARING

Seedling apple trees one or two years old were placed in jars of water. Transfers were made to these seedlings, which were then placed in the cabinets at various temperatures. At 30° C. only one or two generations could be reared before the trees died. A simple method of making the transfers was to start with a bearing female. After the first young were produced, the adult female was removed.

STUDIES AT CONSTANT TEMPERATURES

The optimum condition for growth and development seems to be near 20° C. (table 1). At this temperature the maximum number of young, 119, were produced by each female, over a reproductive period of 18.5 days. Reproduction began at 14.5 days. At 25° the average number of young produced was 93.5.

At 30° C. only 6.6 young were produced over a period of 9.2 days. Obviously this temperature is not very favorable for development. Difficulty was experienced in rearing them, and large numbers perished.

MORTALITY AT 100° F. AND VARIABLE HUMIDITIES

At a constant temperature of 100° F. and 80 per cent relative humidity, young aphids lived only 4¾ hours and half-grown ones lived 7 hours. At 50 per cent relative humidity the young survived for only 40 minutes, while older ones lived 75 minutes. A relative humidity of 100 per cent was also unfavorable, for the aphids survived but 2½ hours.

SOIL TEMPERATURES

Practically every summer high temperatures prevail, ranging from 90° to 98° F. In a series of observations July 30, 1931, a maximum of 113° was recorded in the gravelly loam soil of the nursery at a depth of 2 inches, while at 6 inches the temperature was 102°. The air temperature 24 inches above the soil was 102°.

The data from the temperature cabinets indicate that temperatures of 85° to 100° F. are highly unfavorable for development. Since these temperatures occur frequently each summer, it is easy to understand why we have the almost complete disappearance of the woolly aphid during the summer months. A few individuals, however, survive these unfavorable conditions, for as soon as cooler weather prevails, accompanied by rain, the woolly aphid becomes evident. Two-year-old trees are always more heavily infested than the small one-year-old trees, perhaps due to the heavier shade produced by the larger trees.

TABLE 1—*Record of reproductive capacity at constant temperatures*

Temperature		No. of adults used	Average age first young were produced	Reciprocal	Mean reproduction period	Average total number of young	Average number of young per day
°C.	F.						
15	59	15	22.7	4.40	29.3	117.6	4.0
20	68	17	14.5	6.89	18.5	119.0	6.4
25	77	20	8.8	11.49	18.1	93.5	5.2
30	86	16	14.7	6.80	9.2	6.6	0.7

TABLE 2—*Showing* 100 *per cent mortality in hours, produced by a temperature of* 100° *F. and variable relative humidities*

Age of aphids	No. of aphids	40 per cent R. H.	No. of aphids	80 per cent R. H.	No. of aphids	100 per cent R. H.
1 or 2 days.....	76	2-3/4	22	4-3/4	19	2-1/2
Half- to full-grown	333	1-1/4	142	7	371	2-1/2

NATURAL ENEMIES

The woolly aphis has several natural enemies that help to keep it in check, especially above ground. The minute chalcid *Aphelinus mali*, when present, is often capable of wiping out all of the aerial forms. This parasite has been imported with beneficial results into Australia, South America, and several European countries. Two Syrphidae, *Syrphus americanus* Wied. and *Pipiza radicum*, were also reared. Unfortunately, the work of these useful insects is partially

Fig. 13—A cluster of woolly aphis, showing parasitism by *Aphelinus mali*

nullified by the action of other parasites, such as *Pachyneuron syrphi* Ash., which was reared from *P. radicum*. A capsid bug, *Deracocoris aphidiphagus* Knight, predacious on the woolly aphis, was also observed. The two ladybirds *Scymnus ceryicaulis* and *Coccinella 9-notata* are also listed as predators of the woolly aphis (Marlatt, 1897).

REMEDIAL MEASURES

RELATION TO THE ELM

The first conspicuous infestation of the woolly aphid occurs in June soon after the migration from the elm. It is hard to conceive how the nursery can become infested if no elm migrants are present, unless the nurseryman uses infested scions or roots. One year we actually found woolly aphids on roots shipped in from Kansas. If precautions are taken to free the roots and scions from aphis, the only source of infestation is the progeny resulting from the elm migrants.

In Tennessee a large number of apple nurseries are located at Winchester. In 1925 small elm trees were found grown as nursery stock beside a block of one-year-old apple trees. Three large rosettes were present on these elms in April and contained thousands of aphids and migrants ready to fly to the apple. Interplantings of this nature offer ideal conditons for the multiplication of the pest.

A survey also revealed a large elm tree covered with rosettes in a creek bottom on the farm of Mr. Vanzant. This elm was less than a quarter of a mile from an apple nursery. It is needless to say that one badly infested elm may supply enough migrants to infest an entire locality where apple trees are grown.

Elm trees infested with rosettes containing the woolly aphids should be removed, especially if near an apple nursery. It goes without saying that the American elm and the apple should not be grown together in the nursery. Where one does not wish to remove a valuable elm that shows the presence of woolly aphids, the rosettes may be removed before the migrants leave. Generally the migrants appear the last week in April. It would therefore be best to remove

the rosettes about the middle of April. In some years, when March is warm, the rosettes grow rapidly and become very conspicuous before the leaves come out. In a cool spring, however, the leaves put out soon after the rosettes form, making it difficult to locate the rosettes.

Underhill (1925), in Virginia, found that delaying the setting out of nursery stock until the migrants had all left the elm reduced the infestation in the nursery to practical proportions. When the grafts were set out June 5, less than one per cent were infested. However, the trees did not make a normal growth, due to the short season, and averaged 2 inches less in height.

HOST RESISTANCE

The Northern Spy is said to be resistant to the attacks of the woolly aphis. The attempt to utilize this fact is fraught with many difficulties. Stock grown from seeds of the Northern Spy are not uniform in possessing the resistant qualities, according to results obtained by our Horticultural Department.

Fluke (1930) showed that scions of the Northern Spy had no influence on susceptible stock so far as woolly aphis resistance is concerned.

Staniland (1924) found that resistant varieties, such as French Paradise, were associated with 80 per cent of Sclerenchyma in the circumference of the stem.

TABLE 3—*Insecticide tests for the control of the root-form woolly aphid of two-year-old trees*, 1929

Material used	Strength	Date of application	Rate of application	Soil type	Degree of infestation Nov. 1
Nicotine	1-4000	Oct. 7	3 pints per sq. ft.	Clay loam	Slight
Penetrol	1-200				
Nicotine	1-2000	"	"	" "	"
Penetrol	1-200				
Paradichlorobenzene		Oct. 17	½ oz.	" "	None
"		"	¼ oz.	" "	"
Carbon disulphide emulsion	1-50	Nov. 1	½ pint	Sandy loam	"
" " "	1-50	"	1 pint	" "	"
" " "	1-100	"	¾ pint	" "	"
" " "	1-100	"	1 pint	" "	"
" " "	1-100	"	1½ pints	" "	
" " "	1-200	Oct. 9	½ pint	Clay loam	Slight
" " "	1-200	"	1 pint	" "	"
" " "	1-200	"	1½ pints	" "	"
" " "	1-200	Nov. 1	1½ pints	Sandy loam	None
" " "	1-200	"	2½ pints	" "	"
" " "	1-200	Oct. 7	3 pints	Clay loam	Slight
" " "	1-400	Oct. 8	3 pints	" "	"
" " "	1-400	Nov. 1	3 pints	Sandy loam	None

INSECTICIDES

Like other aphids, the aerial form of the woolly aphid readily succumbed to nicotine, 1-1000, and soap, 3 pounds to 100 gallons of water. The root form represents a much more difficult problem, and nicotine at the rate of 1-2000 with penetrol, when 3 pints per square foot was used, did not seem to be thoroughly effective.

Paradichlorobenzene seemed to destroy the aphids when as little as ⅛ ounce per tree was used. Because of the thin bark on apple, however, paradichlorobenzene is apt to cause injury to the tree under certain temperature conditions. In California, Essig (1926) found that paradichlorobenzene did not injure nursery trees. As little as 1/16 ounce of paranitrochlorobenzene killed the aphids but was injurious to the tree.

Cory (1923) and Schoene (1922) used 5 and 8 per cent solutions of pine-tar oils successfully. Our tests with these materials gave variable results. Other remedies recommended in the past, such as tobacco stems and kerosene emulsion, have been found worthless.

Carbon disulphide, ½ ounce to 4 gallons of water, applied at the rate of ¾ gallon per square foot, will control the root form of the woolly aphis (Leach, 1918). More recently a carbon disulphide emulsion has been used very successfully for the larvae of the Japanese beetle. In our work we used an emulsion supplied by I. P. Thomas Company, of Philadelphia, at a cost of about 20 cents a pound. The emulsion is a mixture of carbon disulphide, castor oil, potassium hydroxide, alcohol, and water, and is said to be stable.

Against the woolly aphid this carbon disulphide emulsion seemed to give the best control. When it was applied at the rate of ½ pint, diluted 1-50, or 1½ pints, 1-200, the aphids disappeared in the sandy soils. Heavier soils or dry soils require more material for good results.

Because of the cost and the large amount of water required, carbon disulphide emulsion would not be practical in the nursery. Material to treat one acre of a nursery would cost $130.00. For the newly set orchard, it may be of value whenever a heavy infestation warrants treatment.

Caution.—Carbon disulphide is inflammable and must be used with caution.

FUMIGATION

In 1922 live aphids were found on apple seedlings shipped in from Kansas. It was also observed that the woolly aphids can live and multiply when in storage if they are present on the trees at digging time.

The easiest way to remove the lice prior to shipment is to fumigate with hydrocyanic acid gas, using 1 ounce of sodium cyanide to 100 cubic feet of space. This treatment will also destroy the San Jose scale.

INFLUENCE OF SOIL TYPE ON INFESTATION

In 1922, apple grafts were grown in the greenhouse for observation of the woolly aphis. Although aerial forms were plentiful, no root forms could be found. The absence of lice on the roots was puzzling. In order to account for this condition, if possible, a study of the moisture and character of the soil was made.

Experiments with different degrees of soil moisture revealed no decided difference in the degree of infestation. In another set of

experiments, in the greenhouse, the grafts were grown in sandy soil, sandy loam, clay loam, and clay soil. Eight per cent of the trees in the sandy soil showed root aphis, while in the clay soil 92 per cent were infested.

In order that the character of the soil under outdoor conditions might be studied, trenches in every other row were dug in the nursery, some being filled with a sandy loam and others with a clay soil. The residual soil varies from silty to gravelly loam. Some of the trees were also mulched with a 3-inch layer of sand.

TABLE 4—*Influence of character of the soil on the abundance of the root form of the woolly aphis*

Soil type	No. of trees	Per cent infested	Degree of infestation
Clay	31	96.7	Heavy
Silt loam	115	89.5	"
Clay and gravelly loam	149	43.0	Moderate
Clay loam mulched with sand	93	14.5	Slight
Sandy loam	33	3.0	"

Fig. 14—Two-year-old apple tree, heavily infested with the woolly aphis, dug from a clay soil

Migration of the aerial forms to the roots is facilitated by the cracks in the clay soil in dry weather.

As shown in table 4, the highest infestation, 96.7 per cent, was present in the clay soil. The residual silt loam, which also cracks badly in dry weather, showed 89.5 per cent infestation; a residual gravelly loam 43 per cent. The latter soil when mulched with 3 inches of sandy loam showed only 14.5 per cent infestation. In the trench filled with a sandy loam, only one tree, or 3 per cent, was infested, and that but slightly.

As is well known, clay soils crack badly, and it therefore appears that the aphids enter the soil through the cracks and become established on the roots. It was observed in the laboratory that a clay or silt soil will, in the process of drying, crack over an eighth of an inch away from the roots. This, in turn, gives the aphids more room to move about than would be possible in a sandy soil.

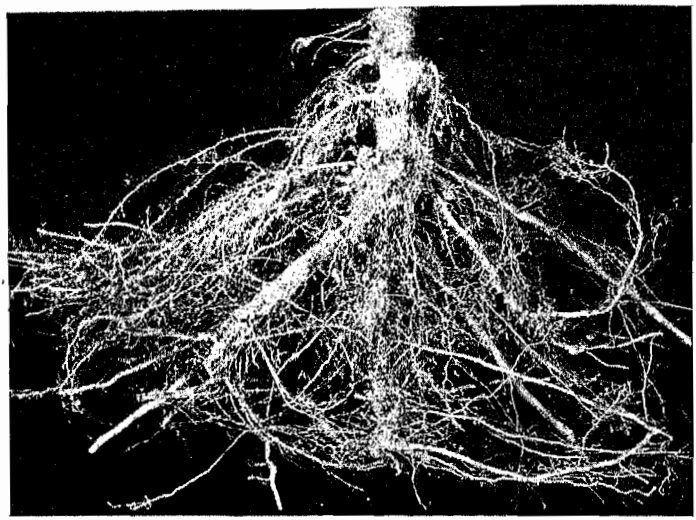

Fig. 15—Tree grown in sandy soil, showing freedom from infestation

In 1913, Woodworth called attention to the desirability of preventing the migrating of the lice from the roots, and recommended that a few shovelfuls of soil be removed around the tree and replaced with sand.

Mordvilko (1927), working in Russia, observed that the phylloxera cannot live on the roots of vines in sandy soils. In the few cases where the vine aphis was found on the roots, Mordvilko observed that heavy winds, by agitating the aerial portion of the tree, caused cavities near the trunk, by means of which the aphis entered the soil. He also explains the presence of the *Eriosoma lanigerum* on the roots as due to wind pressure and the formation of cracks.

In California, Nougaret and Lapham (1928) likewise observed that phylloxera infestation is most frequent on soils of heavy texture, which bake and crack when dry. They point out that heavy soils, by cracking, afford more crevices and interstices for free movement of the insect. On the other hand, the Madera, Oakley, and Fresno sandy loams are free from phylloxera infestation and practically immune.

The same phenomenon for the woolly aphis is mentioned by Newcomer (1933). He points out that the aphis is unimportant in the

sandy areas of the Northwest, whereas deformities in the roots are found on trees growing in heavy soils.

SUMMARY

1. The woolly apple aphid (*Eriosoma lanigerum*), a native American insect, is an important pest of the apple in Tennessee, especially on nursery stock.

2. Where the woolly aphid is present, the roots become knotted and finally decay. Trees with badly knotted root systems are not salable.

3. Both aerial and root forms may be found on apple throughout the year. In September, a fall migrant is produced that deposits the true sexes on the American elm.

4. The winter is passed in the egg stage on the elm. Stem mothers hatch out in early spring, or sometimes as early as January, and produce a rosette on the terminal buds. Three generations are produced within the rosette, the last becoming winged and taking up its abode on the apple. The resulting progeny form the clusters of the well-known woolly aphid of the apple.

5. *Eriosoma americana* produces a leaf curl on the American elm, with the juneberry (Amelanchier) as its summer host.

6. A constant temperature of about 68° F. seems to be near the optimum for growth and development. At a constant temperature of 100°, and 40 per cent relative humidity, the young survived only 40 minutes. Since soil temperatures often reach 100° or over, the mortality produced in the summer is high. During hot, drouthy summers the root forms seem to disappear almost entirely.

7. Several natural enemies keep the woolly aphis in check, but not in complete control.

8. Since elm trees are the principal source of infestation, they should be destroyed when present near nurseries. If this cannot be done, the rosettes should be removed before April 20.

9. Among the different insecticides used, paradichlorobenzene, paranitrochlorobenzene, nicotine, pine-tar creosote, and carbon disulphide emulsion, the last seems to be the most promising, and practical only in the newly set orchard.

10. Root infestation seems to take place by the migration of the aerial forms through cracks in the soil. Trees grown in sandy soils, which do not crack, are comparatively free from root trouble. Mulching with 3 inches of sand also effectively reduced the number of woolly aphids on the roots and should be a practical measure for the newly set orchard.

LITERATURE CITED

Alwood, Wm. B. Circular in relation to some injurious insects and plant diseases. Va. State Crop Pest Com., Cir. 45. 1904.

Baker, A. C. The woolly apple aphis. U. S. Dept. Agr. Office Sec., Rpt. 101. 1915.

Childs, L. The relation of the woolly apple aphis to perennial canker infection with other notes on the disease. Ore. Agr. Exp. Sta., Bul. 243. 1929.

Cory, E. N. Experiments on the control of the woolly aphis. Md. Agr. Exp. Sta., Bul. 252. 1923.

Essig, E. O. Paradichlorobenzene as a soil fumigant. Calif. Agr. Exp. Sta., Bul. 411. 1926.

Fluke, C. L. The influence of resistant apple scions on the susceptibility of non-resistant stocks with relation to woolly aphis attacks. Jour. Econ. Ent., Vol. 23: 741-743. 1930.

Leach, B. R. Experiments in the control of the root form of the woolly apple aphis. U. S. Dept. Agr., Bul. 730. 1918.

Marcovitch, S. The migration of the Aphididae and the appearance of the sexual forms as affected by the relative length of daily light exposure. Jour. Agr. Res. Vol. 27: 513. 1924.

Marlatt, C. L. The woolly aphis of the apple. U. S. Dept. Agr., Cir. 20. 1897.

Mordvilko, H. A. Sur la biologie du phylloxera dela vigne. Comp. Rend. Acad. Science, France. 1927.

Newcomer, E. J. Orchard insects of the Pacific Northwest and their control. U. S. Dept. Agr., Cir. 270. 1933.

Nougaret, R. L., and Lapham, M. H. A study of Phylloxera infestation in California as related to soil types. U. S. Dept. Agr., Tech. Bul. 20. 1928.

Patch, E. N. Woolly aphid of the apple. Me. Agr. Exp. Sta., Bul. 217. 1913.

————Woolly aphid of elm and juneberry. Me. Agr. Exp. Sta., Bul. 241. 1915.

Schoene, W. J., and Reppert, R. R. Growth of apple trees injured in the nursery by crown gall and woolly aphis. Va. State Crop Pest Com., Quart. Bul. Vol. 1, No. 2. 1919.

Schoene, W. J. Notes on woolly aphis studies. Va. State Crop Pest Com., Quart. Bul. Vol. 4, No. 1. 1922.

Staniland, L. N. The immunity of apple stocks from attacks of woolly aphis. Bul. Ent. Res., Vol. 15: 157. 1924.

Underhill, G. W. Woolly aphis investigations. Va. State Crop Pest Com., Quart. Bul. Vol. 7, No. 1. 1925.

Woodworth, C. W. The woolly aphis. Calif. Agr. Exp. Sta., Cir. 102. 1913.