A study of the life history and control of the Euonymus scale, Unaspis euonymi (Comst.).

A STUDY OF THE LIFE HISTORY AND CONTROL OF THE EUONYMUS SCALE, UNASPIS EUONYMI (COMST.)

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A STUDY OF THE LIFE HISTORY AND CONTROL OF THE EUONYMUS SCALE, *Unaspis euonymi* (Comst.)

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TABLE OF CONTENTS

	PAGE
INTRODUCTION	1
Economic Importance	
History	
Host Plants	
MORPHOLOGY	9
TAXONOMIC RELATIONSHIP WITH OTHER SCALES	13
LIFE HISTORY	16
Egg Stage	
Nymphal Stage	
Adult Stage	
SEASONAL HISTORY	33
CONTROL	37
Dormant Spray	37
Summer Spray	41
Biological	49
Cultural	52
SUMMARY	53
BIBLIOGRAPHY	56

INTRODUCTION

This thesis is a further study of the euonymus scale, Unaspis euonymi (Comstock), continuing and complementing the work done by Warner (1949). Very little is added to Warner's studies as far as morphology and taxonomic relationships are concerned.

There have been several different ideas regarding the life history of the scale. Westcott (1946) states that, "the eggs winter under female shells and hatch in late spring -- after a second generation in late summer." Britton (1923) reports overwintering as a partly-grown female, and Felt and Bromley (1931) report hibernation as an almost mature female -- having three generations a year. In Connecticut, Felt (1933) also reported three generations per season. Pyenson (1941) found the scale overwintering both as partly-grown and fully-grown females. The number of instars a generation was first determined by Warner (1949), but this writer cannot agree with his finding of three instars per generation for both sexes. Thus the need may be seen for a more complete knowledge of the biology of this insect.

While several studies have been made of the life history, surprisingly few have been made, recently, to determine the most effective control. One of the most primitive recommendations was to smear the stems of the plant with carbolineum during the winter and spray in the spring with an emulsion of crude linseed oil (one pound of soap in about two gallons of water, to which are added thirteen and one-half parts of the oil) -- Morzechi (1913).

Metcalf (1911) recommended a sixty percent kerosene emulsion or Scalecide 1-10 as dormant sprays and Scalecide 1-25 as a summer spray. Sanders (1928) found one gallon of Sunoco Dormant Oil to twenty gallons of water applied in the late dormant stage gave good control if thoroughly sprayed. Chapman, Parker and Gould (1931) corroborate Metcalf's findings that Scalecide 1-10 gave good control but they reported plant injury. They also tried fumigating with hydrogen cyanide, using one ounce and one-and-a-half ounces per hundred cubic feet for an hour. They obtained a hundred percent control. To the writer's knowledge, this latter method was never tried again. The reason is likely because of the great danger

in using this gas and the fact that it could not be applied by the average homeowner.

Bongini (1935), in Italy, found that four percent mineral oil as a dormant spray reduced the infestation. It is to be doubted that this material would produce effective control. In 1940, Paillot reported a mixture of sixty percent paraffin oil and two percent dinitro-ortho-cresylate as giving excellent control. Pyenson (1941) and Warner (1949) found that by using two percent Elgetol (dinitro-ortho-cresylate) alone, one hundred percent control was obtained. The oil and D-N treatments referred to are used as dormant sprays only unless otherwise stated. It is noted by this writer that although various authors of entomological texts report complete control with various chemicals, the only material found effective and safe by several investigators was dinitro-ortho-cresylate.

The few attempts to devise a control for the scale have not been in proportion to the damage caused by the scale. If this scale grows unhindered on any of its thirty odd hosts, as recorded later, it will eventually cause the death of the plant.

Following infestation the first damage is evidenced as a yellowing of the leaves, due to the

abstraction of the plant juices, then the leaves become grey and necrotic, and finally drop. As the population builds up and the stem and leaves become nearly covered by the scale, so much of the nourishment is taken from the plant, that the death of the stems, main branches and eventually the whole plant results. This would mean the loss of these attractive and popular ornamental plants.

It is difficult to determine the economic importance of this scale, for as indicated by Warner (1949) the loss of these plants cannot be measured in dollars and cents, but if they are to be taken care of by the homeowner or a commercial company, a certain amount of money must be spent to maintain the aesthetic value of these plants. For no matter where the hosts are located in the United States, they have a good chance to become infested, as the scale has spread throughout the nation since its initial discovery in Norfolk, Virginia in 1880.

According to Ferris (1937) the scale came to this country from the Orient. Following its appearance in Norfolk, the scale was next reported by Fernald (1903) to have been found in New Jersey,

Virginia, Georgia and Ohio. Sanders (1907) noted its spread to Massachusetts, Pennsylvania and Delaware, (Metcalf, (1911) said it was very destructive in 1909); Merril (1923) found the scale in Florida, California and Texas; and in 1935 Herrick reported the scale as being found throughout the nation. Westcott's (1946) observation on the scale's location and abundance is that, "It is said to be more abundant and injurious in warmer parts of the country but limited personal observations make me believe it is less a pest in California and the deep South than from Massachusetts down through the mid-South."

The scale has also been reported from other parts of the world by Nikoskii (1936) from Russia, by Ripper (1916) from Austria, by Balachowsky (1930) from France, by Morzechi (1913) from Yalta, by Benlloch (1936) from Spain, by DesSantis (1941) from Argentina, by Fernald (1903) from England and Whitney (1927) reported the interception of the scale on a shipment of plants coming from Japan.

This dissemination on plants and plant parts is the predominant means of spread of this organism, as the motile stage of the insect can crawl but a few inches. Therefore the spread of the scale must

be due to other than its own activity. The cases reported of a previously uninfested plant becoming attacked may be due to the dissemination of the motile first instar form by rodents, birds, other insects or possibly man, or to poor previous observations made while the population is building up.

Although this insect is called the "euonymus scale", the mistake should not be made of believing that it feeds only on Euonymus species. It has been noted on various plants, including: Syringa vulgaris (L.), Celastrus scandens (L.) and Prunus pissardi (Koehne) by Felt (1905); and on Lonicera perichymenium (L.), Prunus cerasifera atropurpureus (Jaeg.) and Burcus by Underhill in 1943; and on Pachysandra terminales (Sieb. and Zuec.) by Britton (1923). This last species was found to be a very favorable host by the author. It has also been found on Hibiscus by Herrick (1935); and on Jasminum in Italy in addition to the many susceptible species of euonymus. A new host Pachystima canbyi was discovered in 1949.

The species of Euonymus found infected by Warner (1949) are as follows:

Euonymus americanus (L.)

Euonymus bulgaricus (Velen. Bots.)

Euonymus bungeanus (Maxim.)

Euonymus europaeus (L.)

Euonymus europaeus aldenhamensis (Gibbs)

Euonymus europaeus chrysophyllus (Chem.)

Euonymus europaeus coccineus (Hill.)

Euonymus europaeus intermedius (Gaud.)

Euonymus europaeus nanus (Todd.)

Euonymus fimbriatus (Wall.)

Euonymus fortunei (Lusey.)

Euonymus fortunei coloratus (Rehd.)

Euonymus fortunei granlis (Reg.)

Euonymus fortunei minimus (Simon-Louis)

Euonymus radicans (Sieb.)

Euonymus fortunei reticulata (Reg.)

Euonymus fortunei vegetus (Rehd.)

Euonymus hians (Koehne.)

Euonymus japonicus (L.)

Euonymus latifolius (Scop.)

Euonymus maachii (Rupr.)

Euonymus macropterus (Rupr.)

Euonymus niroensis (Nahai)

Euonymus obovatus (Nutt.)

Euonymus phellomanus (Loes.)

Euonymus semi-exertus (Koehne.)

Euonymus verrucosus (Scop.)

Euonymus yedoensis (Koehne.)

The masculine endings are used here instead of the feminine as used by Warner (1949) because the masculine is used by Kelsey and Dayton (1942) in Standardized Plant Names. This book is considered to be the final authority on the names of economic plants.

Warner (1949) found no scales on Euonymus alatus apertus (Loes.) and Euonymus alatus compactus (Adams) and three others. On the former two he tried to raise the scales, but they soon died after being put on the plant. The writer confirmed these results with similar experiments.

MORPHOLOGY

"The egg of the euonymus scale is elongate, smooth, orange-yellow and measures 0.22 mm. by 0.11 mm." - Chapman, Parker, and Gould (1931). Most of the eggs are orange-yellow but variations are found ranging from a honey-colored to a white egg.

From this egg emerges the motile first instar form, the "crawler". The color of the crawler resembles that of the egg from which it hatches, and varies as much. It is an oval, flat form possessing a pair of antennae (see plate 1-A), three pairs of legs and at the caudal end of the body, two filaments at least as long as the crawler's body, which can be seen only under the high power of the binocular microscope (about 75X), with proper side lighting.

From the crawler develops the second instar form, which has a translucent exuvium possessing a median ridge and smaller lateral ridges derived from the median one. After the second instar the structures vary according to sex. The male will be considered first. In the third and fourth instars of the scale, three white lobes appear at the caudal end of the scale and fuse.

They continue to increase in length until the white lobes are three and one-half to four times as long as the second instar exuvium. The total length of the scale is then about 1.5 mm. The fourth instar is characterized by two purple figure eight shaped areas, one on either side of the head region. This purple area can be seen in the mature male. The fifth instar male undergoes no changes in exuvial growth, the changes being concerned with the insect itself. Antennae, eyes, wings and a caudal appendage become visible. These structures may be seen on the adult male which is a pale orange, two-winged, poorly flying insect.

During the third instar of the female nymph, a circular white exuvium, which later turns greyish-brown, is secreted around and behind the insect. Another such layer is secreted behind the first, in the fourth instar. Following the secretion of the second exuvium, the insect is mature. Craighead (1950) refers to the female scale as varying from a dirty grey to brown or to nearly black. The writer did not observe any brown scales and the only nearly black scales observed were from dead females at least one year old.

Britton (1923) described the scale of the female as follows: length about 2 mm.; dark grayish-brown; broadly pyriform, convex, thick and firm in texture. He described the female terminalia as: median, second and third lobes pointed and serrulate. Median group of circumgenital gland orifices, 4-6; anterior lateral, 5-9, posterior lateral, about 4. See plate I-H and I.

Legend for Plate I

(Plate from Lewis (1937))

A - Antenna and cephalic margin of first stage.

B - Habit.

C - Antenna of adult female.

D - Anterior spiracle of adult female. This spiracle has been chosen for illustration, since if any distinctive arrangement of pores is developed in connection with the spiracle it is here, rather than in the posterior pair.

E - Pygidium of second stage female.

F - General features of adult female.

G - Pygidium of adult female.

H - Dorsal aspect of detail of pygidial margin of adult female.

I - Ventral aspect of detail of pygidial margin of adult female.

Unaspis euonymi (Comstock)

TAXONOMIC RELATIONSHIP

The euonymus scale is a coccid insect of the subfamily Diaspinae, tribe Diaspini. It was described as Chionaspis euonymi by Comstock in 1880. Ferris (1937) placed it in the genus Unaspis, described by MacGillivary (1921) in his book "The Coccidae". In 1948 Unaspis was accepted as the official generic name by the American Association of Economic Entomologists. There are four species assigned to this genus now. They are Unaspis yanonensis (Kuw.), found in Japan; U. acuminata (Green), found in Ceylon; and U. citri (Comst.) and U. euonymi (Comst.) found in the United States.

Britton (1923a) gives the following key to separate the subfamilies of Coccidae:

1a. Females without abdominal spiracles; males with simple eyes 2

b. Females with abdominal spiracles; males with compound eyes; adult females active, with waxy secretion in form of white larvellae ..... Orthoziinae

2a. Adult female without scale or armor; usually with legs and without pygidium 3

2b. Adult female covered by a separate scale or armor; without legs; abdomen terminating in a compound segment or pygidium; oral orifice without hairs ..... Diaspinae

3a. Adult female with deep cleft at posterior extremity; oral orifice closed above a pair of triangular plates ..... Coccinae

b. Triangular plates absent.. Dactylopiinae

The following key to separate the Diaspinae is adapted from Warner (1949):

1a. Scale of female circular to oval, exuviae central to marginal .. Aspidiotus

b. Scale of female elongate, narrowed at cephalic end, exuviae terminal 2

2a. Scale of female white ..... Chionaspis

b. Scale of female brown 3

3a. Scale of female usually dark brown; scale of male similar to that of female but smaller ..... Lepidosaphes

b. Scale of female greyish brown; scale of male small, elongate, sides nearly parallel, white felted, usually .. Unaspis

According to Ferris (1937) the American species of Unaspis differ as follows:

U. euonymi (Comst.) - presence of fine small groups of perivulvar pores and the lack of sclerotization of the derm of the thorax and first abdominal segment.

U. citri (Comst.) - absence of perivulvar pores - sclerotized thorax and first abdominal segment do not show definite transverse rows.

LIFE HISTORY

In late April, Chapman, Parker, and Gould (1931) found females containing sixty to one hundred fifty-seven eggs, with an average of ninety-eight eggs per female scale. Warner (1949) recorded eighty-one eggs in one female scale and eighty living offspring from one scale were observed by the writer. None of the scales observed by the writer had as large a number of eggs as reported by Chapman, Parker and Gould. This may have been due to the scale's greater fecundity in warmer Virginia, where Chapman, Parker and Gould did their work, or because the writer started the project late in the spring.

The eggs seem to fill the entire body cavity of the female scale, before oviposition begins. This is due to a greatly distended and a highly active ovary. After oviposition, the eggs usually remain under the female until they hatch, but at the height of the activity usually several eggs are pushed out because of the pressure of other eggs being laid.

The writer tried to determine the incubation period of the egg by removing newly laid

eggs, i.e. those still attached to the female, from the scale and putting them in vials placed in the shade with a moist and with a dry atmosphere. In no cases did the eggs hatch. The eggs may be very sensitive to handling or may hatch only within a narrow humidity range. These, or some unknown factors, may explain why eggs failed to hatch away from the mother scale.

At the end of the incubation period, the crawler emerges from the egg. These crawlers usually wander about for twelve to thirty-six hours before settling, but the writer noted one crawler which was put on a stem and immediately crawled straight upward for six and three-eighths inches and soon settled. Its traveling time was about five minutes. Upon settling, the mouthparts are inserted into the plant tissue. Removing the insect results in its death, likely due to starvation. Very likely the adult male scale, upon emergence, leaves its mouthparts in the plant tissue, but, to the writer's knowledge, no one has determined this point.

To determine the distance the crawlers can travel, crawlers were put on two Euonymus vegetus plants. On one plant, the crawlers were put near

the base of the plant, but on succulent tissue; on the other plant, the crawlers were put on the tip of the uppermost leaf. The distance from where the crawlers were put on the leaf to where they were found was measured by the shortest route they could have taken. Because of their wandering, the crawlers covered a longer distance than measured.

TABLE I. DISTANCE MOVED BY CRAWLERS BEFORE SETTLING.

Crawlers put on top of leaf	DISTANCE CRAWLED (IN INCHES)	DIRECTION CRAWLED
	1/4	Remained on top of leaf
	1/4	" " " " "
	5/16	" " " " "
	1/4	" " " " "
	7/16	" " " " "
	3/8	" " " " "
	3/8	" " " " "
	3/4	" " " " "
	3/16	" " " " "
	1/8	" " " " "
	1/4	" " " " "
	1/2	" " " " "
	5/8	" " " " "
	1/4	" " " " "
	5/8	" " " " "
	7/8	" " " " "
	1 1/4	On underside of top leaf
	1 1/4	" " " " "
	1	" " " " "
	1 7/8	Down and up
	3 1/8	" " "
	2 5/8	" " "
	2	" " "

Average 0.85 inches

TABLE I (Cont.)

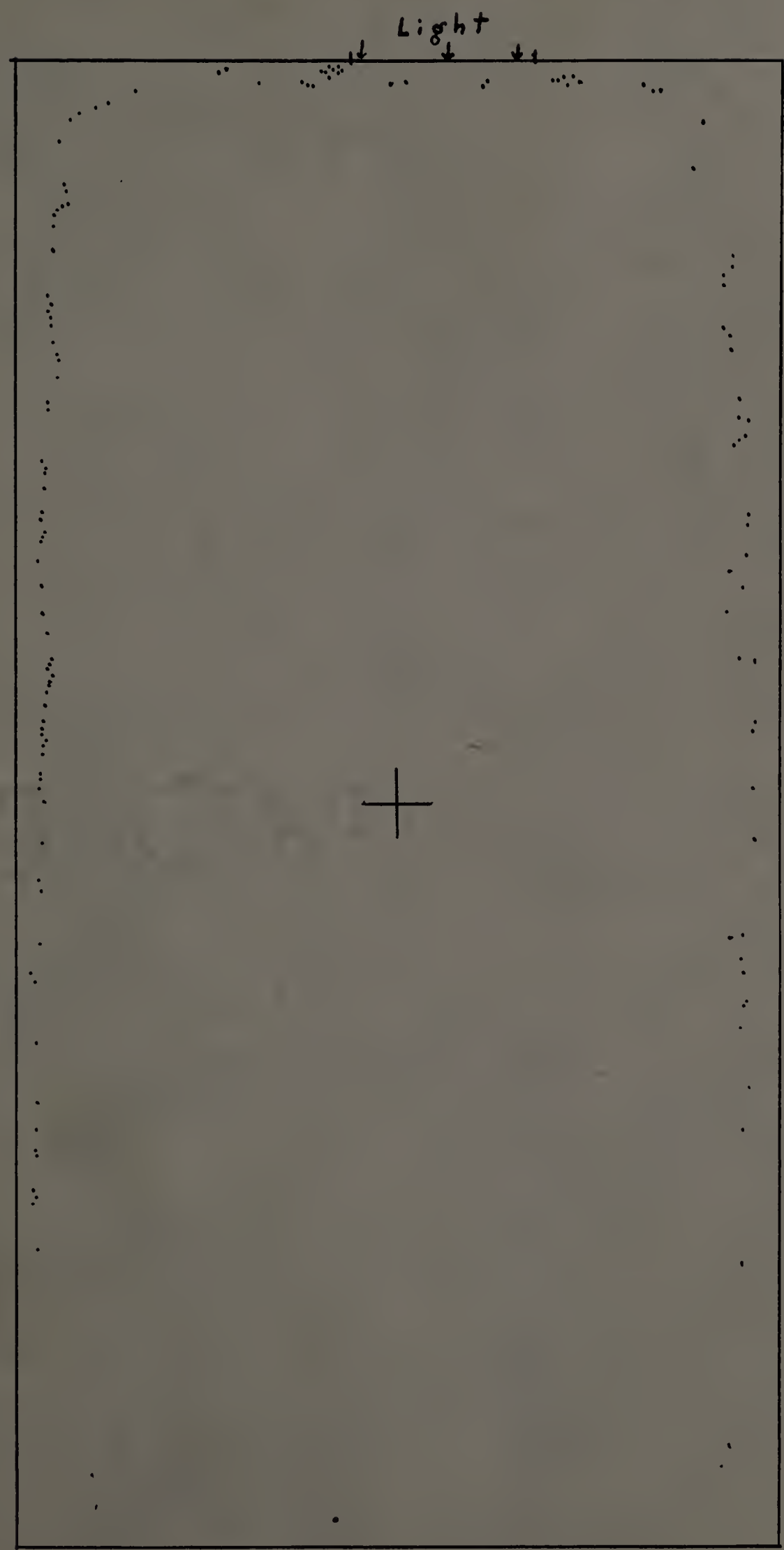
Crawlers put near base of stem	DISTANCE CRAWLED (IN INCHES)	DIRECTION CRAWLED
	3/8	Down
	3/8	"
	3/8	"
	3/8	Up
	1/4	"
	5/8	Up and across
	8 1/4	Up
	7	"
	14 1/4	"
	14 1/2	Down and up
	2 1/2	Up
	4 1/4	"
	12 1/8	"
	7 1/2	"
	4 3/8	"
	16	"
	1 3/8	Up and across
	4 1/2	Up
Average distance crawled	5.53	

Table I shows that the scales are negatively geotropic and so an infestation recently established on the ends of the branches likely can be eliminated by cutting out these infested tips and contiguous areas without affecting the appearance of the plants. One crawler was noted that went down over dead bark, i.e., non-succulent tissue. This insect crawled 14 1/2 inches with about eight inches of the distance over such bark. Therefore, old stems will not prevent migration of crawlers and occasionally the scale will go down for some distance. The potted plants on which the crawlers had been put were left in a shaded insectary so light would not be a factor possibly affecting the insects. In the insectary uniform light came from the opened sides.

To determine the effect of light on the crawlers, they were scattered inside a rectangle of tanglefoot over which was placed a cardboard box cover that fitted the rectangle. This box cover had a one-inch square hole cut in one end. An electric bulb was placed at that end so the direct light would shine for about one inch onto the paper where the crawlers were located.

This test was run at night so daylight would not be an influencing factor. Another test was run identical with the first except that the crawlers were funneled onto the exact center of the rectangle, whereas, in the first test they were scattered throughout the rectangle. A one-inch line was drawn parallel to the box opening along the edge of the tanglefoot, and the distance from the crawler to the nearest point on the line was measured. The crawlers were not attracted to the direct light at the opening, but definitely preferred the area along the side of the box which would receive the brightest light. Possibly the heat from the bulb repelled them. It is also possible that the bright light repelled them and that actually they were attracted to the warmth of the bulb. Because the measurements are of little significance, they are not given here, but a chart of the location of the scales is given (see Figure 1). If this is positive phototropism it would cause the crawlers to go from the stem if it was located in the usual heavy growth of euonymus, outward and upward toward light, where the more desirable food is to be found. If this

FIG. I. PHOTOTROPISM TEST.
(Dots represent Crawlers)



is an attraction to heat it would cause the crawlers to go from the cooler, moist environments of the interior of the foliage, toward the exterior of the shrubbery where the warmth of the sun is most felt. Three adult male scales, from a total of four, were obaseved caught in front of the opening. A reaction to approach bright light or substantial heat and thus be subjected to air currents would well distribute the males and thus insure fertilization of all nearby females.

Thus there are two, and possibly three, factors, positive phototropism and/or thermophilism a nd negative geotropism, that are instrumental in getting the crawler to its food and in aiding the spread. It would be interesting to see if the two sexes react differently to the various intensities of light and heat. This could be discerned by having the crawlers go to plants instead of to tanglefoot, with different plants bordering on different intensities of light and making observations when the scales mature.

Attempts were made to determine the sex of the crawlers by their color and by the presence or absence of two caudal filaments. Several

crawlers much lighter than the rest were put on a potted plant but both sexes developed from these crawlers. Using the darkest crawlers might have produced more positive results. After applying crawlers apparently with and without caudal filaments to potted plants, the writer came to the conclusion that with high power (about 75X) and with proper light, these filaments can be discerned on all crawlers, although on some they might have broken off. Male scales developed on both plants to which these crawlers were applied. Therefore, no method was developed by which the crawlers could be separated according to sex.

Apparently, heavy rains do not knock the crawlers off the plant as a rain of 0.65 inches in three hours did not reduce their number. Using a garden hose at full force might temporarily slow down the scale's spread if applied when the crawlers are most active, but it would create new foci of infestation with each female that was knocked uninjured onto an uninfested twig.

After stopping at the chosen spot, the crawler inserts the stylets of its mouthparts into

the plant. From this time on, the development varies with the sex, the female euonymus scale having four instars and the male having five instars, including a pseudopupa. "Pseudopupa" is used by the writer to describe the stage of changing from nymph to adult. It is very similar to the pupal stage of holometabolous insects but is not identical because the male scale is feeding at this time as can be demonstrated by breaking the stylets which results in the death of the scale.

Considering the male first, this sex takes four to six days to complete the first instar, i.e., four to six days after the crawlers were placed on potted plants. When the removable translucent cover is formed the first instar is considered completed. In fourteen to seventeen days the male scale develops three white lobes at the hind end of the body which grow and fuse together for six days. The appearance of the three lobes marks the end of the second instar, and the stoppage of growth of these lobes marks the end of the third. After a short resting period, a purple area shaped like a figure eight develops on each side of the cephalic end. These

two purple areas may also be seen on the adult male. At this time the new white exuvium is three times as long as the previous covering which has been pushed forward to the head of the scale. Growth continues for five to eleven days until the new covering is three and one-half to four times as long as the exuvium of the second instar. A pseudopupal stage is now formed. In eight to fourteen days the tiny male emerges. It is evident that the male must back out from under its nymphal covering, as an opening is found at the tail end of the exuvium and the exuvium seems to fit too tightly to permit the male to turn around. As it lives for less than twenty-four hours, it must immediately start searching for a mature female to fertilize.

The life history of the male scale was determined from the second generation studies where the most accurate and detailed observations were made. The writer believes these instar periods can be applied to the first generation because first generation males were found to have emerged forty-nine days after the crawlers were put on the plants. They may have emerged a few days earlier, i.e., since the previous examination - a period of

five days, and so reduced the length of their cycle to nearer that of the second generation (forty-six days).

As no females were produced from the crawlers used for the second generation studies, the less accurate data of the first generation must be used. The first two instars of the female are indistinguishable from those of the male scale except that the second instar is a few days longer. At the beginning of the third instar a grayish-brown covering starts and continues to grow for three weeks followed for ten days by the growth of another similar exuvium around the sides and end of the earlier one to form the fourth instar scale. When this scale secretion ceases the female is considered mature. As in the males, the second instar scale is found in a tilted position on the head end of the scale with the third instar scale under it. The speed of growth of the scale was not affected by the plant used for life history studies. Pachysandra, Euonymus vegetus, and E. radicans, on which the scales were reared. all gave equal results.

The female scale oviposits for well over a month and in some specimens likely the oviposition period lasts for two months.

It is rather remarkable that all the adult males emerge at nearly the same time (see table 3). This was clearly demonstrated with scales that were kept on a potted plant enclosed by a kerosene lamp chimney having a fine cloth top. All the scales were put on this plant on the same day, and all the males were noted to have emerged within three days of each other, with the greatest abundance occurring on the second or middle day. It appears that where one instar is longer than average it is equalized by having a later instar shorter than average or vice-versa.

A count was made from several twigs to determine the ratio of the two sexes on the different parts of the plant. If the main stem had been included, the ration may have increased of females to males, and females on the stem to females on the leaves.

TABLE 2. DISTRIBUTION OF EUONYMUS SCALE
ON HEAVILY INFESTED PLANTS

Number of males 3560	Number of females 702	Ratio 5.07:1
Number of males on stem 373	Number of females on stem 311	1.20:1
Number of males on leaf 3187	Number of females on leaf 391	8.15:1
Number of males on leaf 3187	Number of males on stem 373	8.54:1
Number of females on leaf 391	Number of females on stem 311	1.26:1
Total scales on leaf 3578	Total scales on stem 684	5.23:1
Number of females on top of leaf 292	Number of females on bottom of leaf 99	2.95 :1
Number of males on bottom of leaf 2228	Number of males on top of leaf 959	2.32:1
Total scales on botton of leaf 2327	Total scales on top of leaf 1251	1.86:1

TABLE 3. COMPARATIVE INSTAR LENGTHS FOR MALE SCALES (IN DAYS).

Second generation in nature (1949)	Instar 1	2	3	4	5	Total
	6	15	6	11	8	46
	4	17	6	5	14	46
	4	17	6	5		
	4	17	6	5		
	4	- 23 -		5		
	4	14	9	11	12	50 (likely died)
	5	16	6			
	4	15				
	4	15	6	19		46
	4	17	6	7	12	46
	4	17	6	9	10	46
	4	17	6			
Average	4.25	14.75	6	7.6	10.8	46
Constant Temperature of 60° F.						
	8	23				
	8	23				
	8	23	15			
	8	20	14	25		67
	8	23	11	26		68
Average	8	22.4	13.3	25.5		67.5

TABLE 3. (Cont.)

Constant Temperature of 70° F.

4				
5				
6				
6	12	11	15	44

Constant Temperature of 80° F.

5	6	27	?
5			
5			
4			
5			

SEASONAL HISTORY

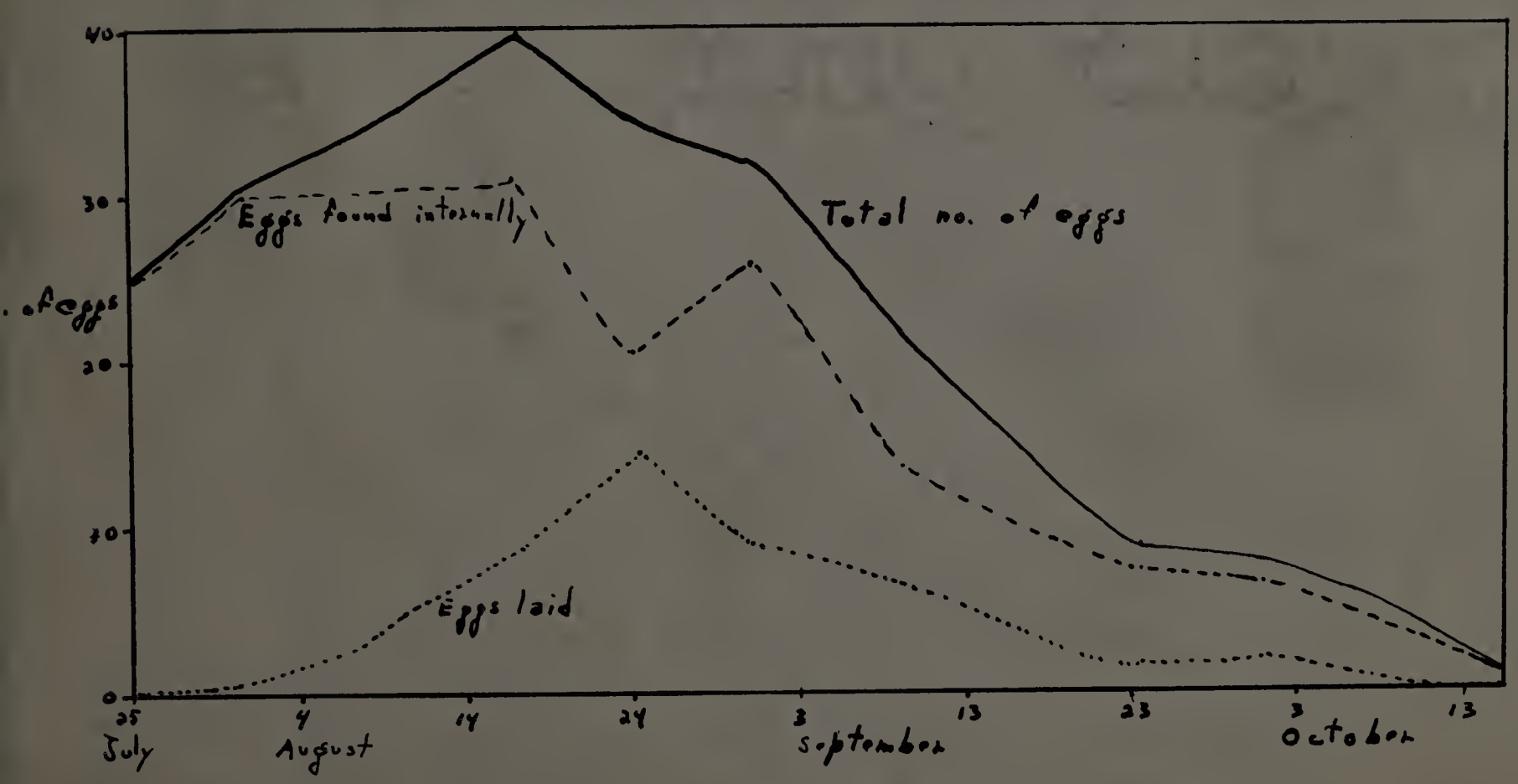
There are two generations annually with the mature female or occasionally the immature female overwintering. In this latter case there may be a partial third generation. Presumably, the overwintering female is fertilized in the fall as no live male nymphs are found in the winter which would effect fertilization when they matured in the spring. A live adult male was observed on June the twenty-fourth and another on July the fifteenth, which suggests the possibility of male overwintering as the scale had not time to reach maturity if it had been reproduced at the same time as were the first eggs observed. Premature ovipositing or nymphal overwintering are possible explanations of this rarity. These premature males may be responsible for the fertilization of the immature (early third instar) females observed during the winter. Likely these females could live long enough to be fertilized by the first generation males, if need be.

An attempt was made to determine the effect of fall weather on the scales by placing thirty crawlers on planted euonymus weekly, for the month of September. Neither did the scales

develop nor were there any settled crawlers observed. This may have been due to the handling technique, the weather, parasites or predators, or to the inability of the crawler to settle on plants that are approaching dormancy.

To ascertain the number of eggs oviposited per female and the length of the oviposition period, females were examined weekly. The exuvium was first opened and the eggs that had been laid were counted, then the female was carefully opened and the immature eggs were counted. Twenty females were observed each week. The most eggs found in any one female was forty-eight on August the first, and the most found laid was forty-three on August twenty-four, but some of the latter were undoubtedly dead and so cannot be used to determine oviposition rate or incubation period. For results see Figure 2.

FIG. 2. AVERAGE NUMBER OF EGGS PER FEMALE.



As observed by Cantelo and Whitcomb (in press), the seasonal history of the scale depends on the temperature and general trend of the weather. In 1948, a cool late season, Warner (1949) noted the first crawlers June the fifteenth, while in 1949, an early warm summer, they were observed June the first. Likewise the first generation completed development in forty-nine days in 1949, but it required sixty-three days in 1948.

The seasonal history in 1949 is shown approximately in the following table.

TABLE 4. SEASONAL HISTORY OF U. EUONYMI, WALTHAM, MASSACHUSETTS, 1949

	First Generation			Second Generation		
Development	Eggs	Crawler	Adult	Eggs	Crawler	Adult
First	May 30	June 1	July 20	Aug. 1	Aug. 3	Sept. 20
Maximum	June 25	June 27	June 27	Aug.24	Aug. 26	_____
Last	July 25	July 27	Sept. 12	Oct. 1	Oct. 4	_____

To determine the effect of a constant temperature on the speed of the insects' development, crawlers were put on potted plants in three constant temperature cabinets, set at 60° F., 70° F., and 80° F., containing two plants

each. Because of lack of sunlight, no change or circulation of air and in the two warmer cabinets, excessive evaporation, it was very difficult to keep the plants healthy. There was abundant dropping of leaves in the 70° and 80° cabinets, and by the time the experiment was completed, one leaf was left on the two plants in the 70° cabinet and no leaves on the plants in the 80° cabinet. The results are given in table 3 along with the results of the normal second generation for comparison. No females were produced on the plants in the cabinets. Although only one scale survived in the 70° cabinet, the writer believes that the timing should be considered accurate for that temperature because the scale has shown little variation of emergence time among the different individual males.

DORMANT CONTROL

~~As noted by Cantelo and Whitcomb (in press),~~ A logical control of this scale is by means of an effective dormant spray. Warner (1949) in 1948 obtained almost perfect control on parts of infested plants by using Elgetol at one percent and one-and-a-half percent and good control from lubricating oil emulsion at four percent actual oil. In 1949, oil emulsions were applied to heavily infested plants growing in a thick mat over the ground. A hand sprayer was used carefully, but it was impossible to give thorough coverage by such means. A count was taken from random samples of live and dead females before and after spraying, and also of the females alive per inch of twig before and after spraying. The results are given in table 5. The percentage of control was determined by using Abbott's formula, $\frac{X-Y}{X} \cdot 100$ = percent control. X refers to the percent alive before treatment and Y to the percent dead after treatment.

TABLE 5. DORMANT CONTROL OF U. EUONYMI
BELMONT, MASSACHUSETTS, MAY 18, 1949.

INSECTICIDE	DILUTION	Percent scales dead Before	After	Percent Control
Spra-Cream	4% actual	74.7	86.6	47.0
Spra-Cream	3% actual oil	48.05	64.25	31.1
Superior Oil Emulsion	1½% actual oil	52.95	78.7	54.7
Superior Oil Emulsion	2% actual oil	65.5	83.6	52.5

INSECTICIDE	Females alive per inch Before	After	Percent Reduction
Spra-Cream 4%	14.9	2.4	83.9
Spra-Cream 3%	15.0	21.4	-29.9
Superior Oil Emulsion 1½%	8.5	5.1	40.0
Superior Oil Emulsion 2%	15.6	4.2	73.1

The low percentages of control obtained by counting the dead and live females is likely due to the rubbing off of the dead scales while they were being transported to a place where a count could be made, after spraying. Although they were handled gently and the twigs from the different plots were put in separate paper bags, many scales were found to have been rubbed off. As only the dead scales came off, the count of scales alive per inch of twig seems to be soundest in this instance, because it does not depend on dead scales which are loosely attached to the twig, for determining the final results. By using this method with Spra-Cream four percent, an 83.9% reduction of scale was obtained, which compares favorably with Warner's (1949) 87% reduction using the same concentration of Spra-Cream.

As control with Spra-Cream and Superior Oil Emulsion does not compare with the excellent control of Elgetol obtained by Warner, the latter is recommended at a one and one-half percent concentration except near woodwork, which it stains. Plants growing on or near woodwork may be sprayed with Spra-Cream four percent.

The sprayed shrubs were examined about a month later and most of the twigs that had been defoliated the previous summer were found to appear healthy with very little infection. Although the plants appeared relatively uninfected, it is likely that the scale population would build up its previous level in two or three generations.

SUMMER CONTROL

Since DDT has been found of value for the control of the crawlers, laboratory studies were made with DDT and three of its analogues, DFDT, TDE, and Methoxychlor. An analogue is a material very similar to the original but having a minor change in the composition or arrangement of its chemical structure. DDT is an abbreviation of dichlorodiphenyltrichloroethane. The structural formula generally accepted is:

```
        Cl                      Cl
   OHC        COH          OHC        COH
                                                - Aromatic rings
   OHC        COH          OHC        COH

        C                       C

                   H
                   C
             Cl    C    Cl        - Aliphatic ring
                   Cl
```

DFDT is an abbreviation of difluorodiphenyltrichloroethane. The chlorine atoms in the aromatic rings are replaced by fluorine atoms.

TDE (formerly known as DDD) has the aromatic ring identical with that of DDT but the aliphatic ring is:

```
                   H
                   C
                   C
             Cl         Cl
```

In Methoxychlor, OCH_3 replaces the two chlorine atoms in the aromatic ring. Potted plants were used which were infested with thirty crawlers each.

A residual test was made in the first experiment using the four insecticides. The insecticide was sprayed on the plant in the form of fifty percent wettable powder at the rate of three pounds per hundred gallons of water, and then the crawlers were put on at different intervals. As shown in table 6, control with DDT, DFDT and Methoxychlor is excellent for a day after spraying and good with DDT one week after spraying and fair two weeks after. DDT obviously has the greatest residual toxicity with Methoxychlor next best.

TABLE 6. EFFECT OF RESIDUE OF DDT AND ANALOGUES ON U. EUONYMI WHEN PLACED ON SPRAYED PLANTS.

Number of days after spraying when crawlers liberated	Percent crawlers dead			
	DDT	DFDT	TDE	Methoxychlor
1	100.00	95.46	85.72	100.00
7	95.24	45.00	81.48	86.37
14	68.18	33.33	45.46	50.00
21	33.33	10.53	20.00	29.17

To determine the toxicity of the different sprays to the different stages of the insect, the

crawlers were liberated on plants and then sprayed with different concentrations of the insecticide, at different intervals. The insecticide was in the form of fifty percent wettable powder. See table 7 for results. As one pound per hundred gallons of water gave complete control on one-day old crawlers and ineffective control (except for DFDT) one week after crawler application, this concentration was not used in later tests. DFDT, in the stronger concentrations, gave the best control and was the only one to do this for scales two weeks old. DDT was next best, giving fair control for two week old scales. TDE gave erratic results and Methoxychlor effected poor control. It was noted that the female nymphs were more difficult to kill than the scale and this was particularly true when TDE was used.

The crawler and first instar nymph are quite susceptible to the insecticides but as the scale gets into the later part of the second instar, it becomes more resistant until, by the time it reaches the last of the third instar only one-fifth to one-third of the scales are killed. This resistance is likely due to the exuvium of the scale becoming thicker and more impermeable, and also to the increase in body volume which permits more insecticide to be absorbed without fatal effects.

TABLE 7. EFFECT OF DDT AND ANALOGUES ON CRAWLERS OF U. EUONYMI FOR 1 TO 28 DAYS AFTER SETTLING.

Amount per hundred gallons	Age and Instar of Crawlers	Percent of Crawlers Dead			
		DDT	TDE	DFDT	Methoxychlor
1 lb.	1 day - first instar	100.00	100.00	100.00	100.00
	1 week - second instar	80.00	75.00	95.00	70.00
	1 week - second instar	100.00	89.48	100.00	*
	2 weeks - second instar	*	52.63	94.12	77.28
2 lbs.	3 weeks - third instar	33.33	86.67	50.00	23.09
	4 weeks - third instar	10.72	20.00	*	21.74
	1 week - second instar	100.00	90.00	100.00	76.19
	2 weeks - second instar	82.61	71.31	90.48	47.62
3 lbs.	3 weeks - third instar	50.00	55.18	71.46	23.81
	4 weeks - third instar	16.00	30.77	19.05	43.49

* Plant died.

In another experiment the effect of rain on the residue of the insecticides was determined by placing plants sprayed the previous day under the sprinkling system and, as soon as they had died, put crawlers on each plant. It must be understood that the results obtained apply only to the type of sprinkling the plants received, for rain can vary tremendously in volume and force. The plants were placed between the water outlets and to where the main force of the water was carried, so the droplets would be approximately equal in size and velocity. The insecticides were used at the rate of one and a half pounds of actual insecticide per hundred gallons of water. As shown in table 8, one half inch of water reduces the effectiveness of DDT and Methoxychlor spray residue to about that of unwashed spray residue about two weeks old.

TABLE 8. EFFECT OF WASHING ON RESIDUES OF DDT AND ANALOGUES ON CRAWLERS LIBERATED ONE DAY LATER.

AMOUNT OF WATER SPRINKLED	PERCENT OF CRAWLERS DEAD			
	DDT	DFDT	TDE	Methoxychlor
1/2 inch	69.57	78.95	66.67	50.00
1 inch	11.77	60.87	85.72	*

* Plant died

Field experiments were run to determine the usefulness of possible plant protectants on the first and second generations of the scale. An infected Euonymus vegetus hedge about thirty-five feet long was divided into five parts and sprayed with DDT wettable powder, Resitox (a DDT oil emulsion), Volck-nicotine, and Parathion using an electric wheelbarrow sprayer furnishing about two hundred pounds pressure. All the foliage was thoroughly covered. A count was made of the adult scales before spraying and a count of all scales was made two weeks after spraying.

Ten random samples of twigs with leaves were taken from each lot. Over fifty thousand scales were counted so there could have been no error in the sampling. In counting after spraying, differentiation was made between the nymphs over two weeks old (those that hatched before the spray application) and nymphs under two weeks old (those that hatched since spraying). Because later observation showed that Parathion gave inadequate control except for the adult females and fifty percent DDT wettable powder, two pounds per hundred gallons, showed spots of infection, only Volck-nicotine, Resitox and DDT wettable powder three pounds per hundred gallons were used against the second generation of the scale. The latter three produced clean

uninfected-looking shrubbery. There is a contrasting difference between infected and uninfected foliage, with the bright yellowing of the infected area and the dark green of the healthy plant. The yellowed leaf will return to its natural color if the scales on it are killed unless it has been too seriously injured and then it will drop.

See table 9 for results obtained. It should be noted that the oil sprays give a better control of the adult females than the wettable powders, except for Parathion. This may be due to the ability of the oil to "creep" through the small openings in the female exuvium and then come in contact with her.

TABLE 9. CONTROL OF U. EUONYMI FROM SUMMER SPRAYS AGAINST THE FIRST AND SECOND GENERATIONS. WALTHAM, MASSACHUSETTS

INSECTICIDE	Dilution in 100 Gal. (Actual Concentration)	Percent scales dead: Before Spraying: Adult Females Only	After Spraying: Adult Females	After Spraying: Nymphs Over 2 weeks old	After Spraying: Nymphs Less than 2 weeks old
First Generation					
15% Parathion	1 lb. (0.018%)	27.4	87.7	61.3	87.0
Volck emulsion + 40% nicotine sulfate	1 gal. (1.0%) 1 pint (0.05%)	10.4	84.3	72.6	96.6
50% DDT wettable	2 lb. (0.119%)	24.3	71.4	47.0	91.8
50% DDT wettable	3 lb. (0.179%)	8.5	82.1	71.8	95.1
Resitox 25%	2 qts. (125%)	8.5	91.7	73.5	95.3
Second Generation					
Volck Emulsion + 40% nicotine sulfate	1 gal. 1 pint	11.7	62.6	63.8	90.2
Resitox 25%	2 qts.	14.5	34.4	47.6	86.4
50% DDT wettable	3 lbs.	19.3	23.2	41.0	84.2

BIOLOGICAL CONTROL

On occasions many dead adult females and male and female nymphs were found having a parasite's emergence hole in the center of their dorsal exuvium. Up to twenty-five percent parasitism was observed. On July the eighteenth, two female parasites were noted examining the scales and ovipositing into them. These were caught and identified as Aspidiotophagus citrinus (Craw.), by A. B. Gahan of the Federal Bureau of Entomology and Plant Quarantine. This species belongs to the family Aphelinidae of the superfamily Chalcidoidea.

Later in the year the same parasites were occasionally found on the twigs. Several of these were collected and put on a scale-infested plant enclosed by a kerosene lamp chimney, but no parasitism occurred. On September the ninth, and October the fifteenth, fusiform parasitic larvae were observed inside female scales from specimens collected in the field. A parasitized female scale was observed producing eggs although in a smaller quantity than average, so this parasite is not soon fatal, but the scale likely dies before emergence of this wasp. Because of their slow effect on the scale and their comparatively rare appearance,

A. citrinus cannot be considered of any practical value in controlling this pest.

A. citrinus has also been reported from France, by Pontiers (1928); from Spain in 1939; From Argentina, by DesSantis (1941); as a parasite of the euonymus scale. Balachowsky (1930) bred Aenasioidea hispanica from the scale.

Mites were observed in the early spring in and around dead female scales. It is possible that these are predacious mites that feed on the dormant scales, but this is conjecture only as no information could be found in the literature about mites that are predacious on scales.

Aphis-lions (larvae of the family Chrysopidae, order, Neuroptera) are perhaps the most important of the biological forms attacking the euonymus scale. These larvae and the stalked eggs, from which they emerged, were frequently noticed in the field on the plants. On one occasion, two days after crawlers had been put on potted plants, two active aphis-lions were found on the plant and no scales were observed. On other plants on which crawlers were put at the same time, the normal amount of scales were noticed. Thus, it appears that one aphis-lion can destroy many scale

insects, since thirty crawlers had been put on each plant, and thus be more effective than a parasite which feeds on only one. The aphis-lion may not be able to attack the older scales with their tough exuvium, as can the parasite.

Because of the various forms which attack the euonymus scale, all the plants used for laboratory experimentation were kept in a screened insectary while the test was being made.

CULTURAL CONTROL

It is claimed by a landscape designer that euonymus is less likely to be infected by the scale if the shrubs are planted in the shade, but the writer has noted several instances of heavy infestation in shaded areas. If shrubs on the south side of a building and those on the north side are equally infested, it is very likely that due to the higher temperature of the former, that development would take place faster and over a longer period. This may be the reason for the designer's belief.

SUMMARY

The euonymus scale, Unaspis euonymi, is yearly increasing its destruction of ornamental shrubbery, especially Euonymus sp. It has been found in Europe, Asia, North and South America. It is found throughout the United States, although it is likely more destructive in the northeast. The most commonly observed form is the white, immature male scale which, if abundant, will give a white appearance to the leaves. The female has a greyish-brown scale shaped somewhat like an oyster shell.

When the orange-yellow eggs hatch, a similarly colored crawler emerges. These crawlers are positively phototropic or thermophilic and negatively geotropic. They may crawl between one-eighth of an inch and sixteen inches, depending upon their location on the plant upon hatching. About forty-six days are required for the male scale to pass through five instars and the same length of time for the females to pass through four.

There are two generations a year and possibly a partial third in warmer years. The scale overwinters as an immature or mature fertilized female. In constant temperature cabinets, the

length of the life cycle was found to be sixty-eight days at 60° F. and forty-four at 70° F.

As a dormant control, Elgetol seemed far superior to Spra-Cream or Superior Oil. DDT, DFDT, TDE, and Methoxychlor were used in summer laboratory experiments. DDT had the most residual toxicity to the crawlers being effective for over a week. One-half inch of rain reduced the toxicity of one day old residue to that of two-week-old unwashed residue. All four of the insecticides would kill one day old scale at one pound per hundred gallons but only DFDT and DDT could effectively kill two week old crawlers.

Volck-nicotine, Parathion, Resitox, and DDT wettable powder were used in field experiments. Volck-nicotine, Resitox and DDT wettable powder three pounds per hundred gallons gave the best control with the oil containing sprays giving a higher kill to the adults.

<u>Aspidiotophagus citrinus</u> was found parasitizing the scales and up to twenty-five percent parasitism was noted. Probably aphis-lions give more effective control of the scale than any other biological factor but the control is still not likely adequate.

Based on these studies and observations ~~as noted by Cantelo and Whitcomb (in press)~~, it appears that five applications annually are necessary to control a heavy infestation and that these must be repeated each year until the scale is eliminated. As the crawlers are the most susceptible forms, it is essential that the sprays be applied when this form is active; and as the biotic potential of this scale is high, it is necessary to get a thorough coverage as well as have good timing. These two factors are more important than the insecticide applied.

The recommended treatments are:

1. DORMANT - From about April 1, to the swelling of the buds.

   Dinitro-ortho-cresylate (Elgetol) 1 to 1½

2. WHEN CRAWLERS OF FIRST GENERATION HATCH - June 1 to 15 - in order of preference.

   Summer Oil Emulsion (Volck) 1 gal. + 40% Nicotine Sulfate 1 pint.

   <u>or</u> Resitox 25, 2 qts. to 100 gals. of water.

   <u>or</u> 50% DDT wettable powder, 3 lbs. to 100 gals. of water.

3. REPEAT NO. 2 - 10 to 14 days later.

4. WHEN CRAWLERS OF SECOND GENERATION HATCH - August 5 to 20.

   Same materials as No. 2

5. REPEAT NO. 4 - 10 to 14 days later.

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