THE BIOLOGY AND CONTROL OF EUONYMUS SCALE,

UNASPIS EUONYMI (COMSTOCK),

IN OKLAHOMA

By

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CHAPTER I

INTRODUCTION

The author selected the biology and control of euonymus scale as a subject for research in hopes of obtaining experience in research with a pest which is closely related to many of the scale insects found in his country, Saudi Arabia.

Before the last decade Saudi Arabia had no restriction on the entry of plants or animals. Plant materials were introduced from different parts of the World without examination at the borders of the country. As these imported plants were brought to the country, they carried with them new pests. And as the time passed, the new pests became established in the country and often caused extensive damages to many agricultural crops. Among the most serious of these introduced pests were scale insects which attack several important plants in the country such as date trees, peaches, apricots, ornamental plants and others. Saudi Arabia spends tremendous amounts of money to reduce the amount of extensive damages which these insects do to plants, to make it possible for the farmers to stay in business.

Taxonomic Data

The euonymus scale belongs to the order Homoptera, Family Coccidae and sub-family Diaspinae or armored scale.

This insect was described in 1881 as a *Chionaspis euonymi* by Comstock. Lindinger (1921) continued the generic name but Ferris (1936) placed the euonymus scale in the genus Unaspis. Takahasi and Kanda (1939) working in Japan described U. nakayamai but this name was later shown to be a synonym of U. euonymi. Since that time the euonymus scale has been known as U. euonymi. The common name euonymus scale has been widely used because of its host and in 1948 this name was listed in the List of Common Names of Insects approved by the Entomological Society of America.

Other important members of this genus include the citrus snow scale, U. citri Comstock and the yanone scale, U. xanonensis Kuwana. Both of these insects are serious pests; the latter in China and Japan and the former throughout the warmer citrus growing areas of the world. The fourth important species U. acuminata (Greer) is common in Ceylon. U. euonymi may be separated from U. citri (Comst.) by the lack of sclerotization on the derma of the thorax and first abdominal segment and by the presence of five small groups of perivulvar pores readily seen in the American species.

The euonymus scale is one of the most serious ornamental pests throughout much of the United States and adequate control measures must be developed if these shrubs are to continue to be used as ornamentals. The research reported here was undertaken with this in mind.

CHAPTER II

REVIEW OF LITERATURE

Biology

Following the description of euonymus scale by Comstock in 1880, relatively little research was recorded for 30 years until damage by it to ornamental plantings in many areas resulted in interest in its biology and control.

Louis (1911) observed that on Long Island, N. Y., the euonymus scale overwintered as partly grown to fully grown females on the stem or, if the plant was an evergreen, on both the leaves and stems.

Horton (1918) in Ohio found that the euonymus scale overwintered in the egg stage securely protected by the rigid scale of the mother insect. He mentioned that young emerged from these overwintered eggs in late May or in June. He found that there were two generations each year.

Britton (1923) observed in Connecticut that euonymus scale overwintered as eggs about 0.2 mm long and 0.08 mm in width, dark amber in color, smooth, cylindrical and rounded on both ends. They were found under the "rigid" scale of the mother insect. In contrast he mentioned that Mr. Harold Morrison found the euonymus scale overwintered as a partially mature female, and egg laying occurred in May.

Chapman, Parker and Gould (1931) stated that in Virginia on April 4, female scale started laying eggs. The average total number of eggs was 98 per female. They noted that eggs of the euonymus scale *Chionaspis euonymi* were elongated, smooth, orange-yellow, and measured approximately .22 by .11 mm.

Sanders (1931) found that the euonymus scale, *Chionaspis euonymi* Comst., in the towns of the Eastern Shore of Maryland, overwintered as full grown or nearly full grown females. There were three generations a year, occurring from June 8th to October 30th.

Warner (1949) in Massachusetts found that each female laid approximately 12 eggs and that egg laying extended over a 4-5 week period.

Neiswander (1958) in Ohio reported that the mature female scale insects were roughly pear shaped, grayish-brown, and about one-sixteenth inch long. The mature scale form of the male was somewhat narrower than that of the female, had three longitudinal ridges and was snow white in color. He mentioned that the insect overwintered as a mature female. Two generations appeared each year.

Distribution

Houster (1918) noted that euonymus scale was found in Massachusetts, New York, New Jersey, Pennsylvania, Virginia, North Carolina, South Carolina, Georgia and California.

Britton (1921) mentioned that euonymus scale was found in the Atlantic States from Massachusetts to Georgia; Ohio, Mississippi, Texas, and California.

Bower (1943) found euonymus scale in Cherokee Co., Oklahoma, on nursery stock.

McKenzie (1947) indicated that *Unaspis euonymi* (Comst.) was found in Sacramento, California, on euonymus species and by (1956) was widely spread in the state.

Schuder (1954) indicated that Unaspis euonymi (Comst.) was found in many parts of the United States. It was found in Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, District of Columbia, Virginia, North Carolina, South Carolina, Georgia, Mississippi, Ohio, Indiana, Michigan, Missouri, Texas and California.

Apt (1959) stated that Unaspis euonymi were collected in Comanche, Garvin, Haskell, Jackson, McCurtain, McLain, Oklahoma, Payne, Tillman and Tulsa Counties in Oklahoma.

Houster (1918) and Ferris (1937) mentioned that this species had spread throughout the USA, Cuba, France and Italy following its introduction into Virginia from Japan.

Euonymus scale is an important pest in many parts of the world and has been reported by several authors: Fernold (1903) - England; Mockrzecki - Yalta; Ripper (1914) - Austria; Benlloch (1926) - Spain; Whitney (1927) - Hawaii; Balachowsky (1930) - France; Nikolskii (1936) - Russia; and De Sants (1941) - Argentina.

Whitney (1927) reported that a shipment of euonymus plants coming from Japan was infested by euonymus scale Unaspis euonymi.

Kerr (1952) mentioned that euonymus scale is the most wide-spread and serious pest of euonymus in Rhode Island.

Host Plants

Houster (1918) in Ohio mentioned that euonymus scale Chionaspis euonymi Comst. attacked:

Euonymus europaeus
Euonymus latifolia
Euonymus japonica
Euonymus redicans
Euonymus atropureus

He mentioned that it was reported from bittersweet Celastrus sandens, Althea sp. and orange.

Ferris (1937) mentioned that Unaspis euonymi (Comst.) was found on Euonymus latifolia at Norfolk, Virginia, and on Euonymus japonicus in various parts of the world.

Warner (1949) mentioned that there were 120 species of Euonymus in North America, Central America, Europe, Asia and Australia. He found that 29 out of 36 species in the Arnold Arboretum were infested. The following list includes these 29 species and varieties of Euonymus upon which the euonymus scale was found.

Euonymus americana (L.)
Euonymus bulgarica (Velen. Bots.)
Euonymus bungeana (Maxim.)
Euonymus europaea (L.)
Euonymus europaea aldenhamensis (Gibbs)
Euonymus europaea atrorubens (Rehd.)
Euonymus europaea chrysophylla (Chen)
Euonymus europaea coceinea (Hill.)
Euonymus europaea intermedia (Gaud.)
Euonymus europaea nana (Lodd.)
Euonymus fimbriata (Wall.)
Euonymus fortunei (Turez.)
Euonymus fortunei colorata (Rehd.)
Euonymus fortunei gracilis (Reg.)
Euonymus fortunei minima (Simon-Louis)
Euonymus fortunei radicans (Sieb.)
Euonymus fortunei reticulata (Reg.)
Euonymus fortunei vegeta (Rehd.)
Euonymus hians (Koehne)
Euonymus latifolia (Scop.)
Euonymus Maachii (Rupr.)
Euonymus macroptera (Rupr.)
Euonymus niroensis (Nahai)
Euonymus obovata (Nutt)
Euonymus phellomana (Loes.)
Euonymus semi-exserta (Koehne)
Euonymus verrucosa (Scop.)
Euonymus yedoensis (Koehne)

No infestation by the euonymus scale was observed in the following species and varieties of Euonymus.

Euonymus sp. no. 74-33-B
Euonymus alata aperta (Loes.)
Euonymus alata compacta (Adams)
Euonymus kiautschovica (Loes.)
Euonymus sacchalinensis (Maxim.)
Euonymus sanguinea (Loes.)

Armitage (1951) mentioned that euonymus scale Unaspis euonymi (Comst.) was collected on Rachysandra terminalis. He also mentioned that quarantine specimens in the State collection show Celastrus ordiculatus, Celastrus spp. and Lignstrum sp. were attacked by euonymus scale.

Schuder (1954) mentioned that euonymus scale insects attack several euonymus species such as Euonymus americanus, E. atropurpurens, E. europeus, E. japonicus and varieties, and E. fortunci.

Apt (1959) mentioned that Unaspis euonymi (Comst.) was collected from foliage and twigs of Euonymus sp. and Ilex spp. (holly) in Oklahoma nurseries, fields and greenhouses.

Control

Metcalf (1909) used a mixture containing kerosene and oil for controlling the euonymus scale on euonymus clumps. He found that 78 per cent of the scale were killed when the clumps were sprayed three times: once with a 20% solution and twice with a 30% solution. When it was sprayed three times with 30% kerosene emulsion, he found 100% mortality without any injury to the plant.

Mokrzecki (1913) in Taurida, U.S.S.R., mentioned that smearing the infested stems with carbolium during the winter and spraying them in the spring with an emulsion of crude linseed oil gave excellent control of Chionaspis euonymi.

Houster (1918) in Ohio mentioned that miscible oil gave almost perfect control of euonymus scale, if it was applied in early April at the strength of 1 part of oil to 15 parts of water. He found that kerosene emulsion or whole-oil soap gave good control as a summer spray.

Sanders (1928) found that a late dormant spray of 1 gallon Sunoco oil to 20 gallons water gave good control when the plants were thoroughly sprayed. He mentioned, too, that 2 per cent white oil emulsion gave great promise as a summer control for euonymus scale.

Chapman, Parker, and Gould (1931) observed that applying a 1 to 10 strength of dormant oil (Scalecide) to Euonymus japonicus, which was badly infested with euonymus scale, gave rather good control.

Chapman, Parker, and Gould (1931) reported that several heavily infested E. japonicus shrubs were treated with hydrocyanic acid gas generated from calcium cyanide. One-half ounce and one ounce per 100 cubic feet were the dosages used, while the exposure period was one hour. The data showed that scale control was excellent and no injury occurred to the plant when the dosage was one ounce per 100 cubic feet but poor control occurred at the rate of one-half ounce.

Bongini (1935) in Italy found that spraying the foliage of Euonymus japonicus infested by Chionaspis euonymi in the wintertime (41°F) with a 4 per cent mineral oil gave good control without injuring the plant.

Louis (1941) reported that a 1 per cent solution of dinitro spray was very good for controlling the euonymus scale. By spraying this material during the dormant season for two years, complete eradication of the euonymus scale on the infested plants was possible.

Hanna, Judenko, and Heatherington (1955) used paraoxon, parathion, schradan and dimefox in order to control the pseudococcids that were transmitting swollen-shoot virus disease of Cacao in Gold Coast. They found that the effects of all the insecticides were unsatisfactory or inconsistent when sprayed at concentrations of up to 1-10%. Schradan, paraoxon and parathion gave poor control when applied to the soil at 0.5, 1.0 and 1.0 gram per 100 cc, respectively. Dimefox gave excellent control when used as little as 0.1 gram of 0.1% granules was applied to each cacao plant.

Dimefox was the most effective of the four insecticides tested when applied at the rate of 40 grams in four liters of water to average sized cacao trees.

Ernest and Henry (1957) mentioned that in Maryland heavily infested bushes were sprayed with 1.0% malathion emulsion. This insecticide was applied on April 22, 1953, to determine whether or not it would penetrate the scales and kill the overwintering females. The data showed that not many insects died in this test. However, they found that 1.5% malathion sprayed on June 11 killed most of the crawlers.

They also found that the use of 2.5 pounds of 50% DDT W.P. plus 1 quart malathion per 100 gallons of water applied on August 16 gave 100% mortality of both crawlers and mature scales. Another excellent control which they discovered was one quart of malathion plus one quart of summer oil per 100 gallons of water.

Neiswander (1958) in Ohio mentioned that 50 per cent malathion emulsion concentrate at the rate of one pint in 50 gallons of water did an excellent job of controlling the young crawlers of the new brood.

Schread (1960) used systemic insecticides for control of scales, leaf miners and lace bugs. He found that soil drenches of Phorate and Phosdrin gave better control than Di-syston and schradan in controlling scale on holly. Phorate granules gave good results for the control of pine needle scale.

Koehler (1964) in northern California mentioned that when he sprayed oak trees, Quercus lobata Nee, with carbaryl, dimethoate, diazinon or malathion, in oil, all gave good control following early May applications. He found that applications made from late April until early June were effective in scale control. He observed that Bidrin reduced scale numbers 69% when it was applied as a trunk injectant.

Biological Control

Parasites and predators have been observed on the euonymus scale Unaspis euonymi since 1913.

Mokrzecki (1913) in Taurida mentioned that the specimens of Chionaspis euonymi Comst., produced a parasite of the genus Aspidrotiphagus.

Poutiers (1928) in France observed that the hymenopterous parasites, Allapus excisus, West W., was a parasite on Chionaspis euonymi Comst.

Balachowsky (1930) stated that in France a chalcidoid parasite Aenasioidea hispanica, Mercet, was collected from Chionaspis euonymi Comst.

Baker and Wharton (1951) mentioned that the mites Thyrophagus entomophagus Laboulbene were found with dried insect collections and with scale insects in the field. Although this mite may be predaceous on the scale insects, it can live on the cast skins and dead scales, which are slightly moist.

CHAPTER III

MATERIALS AND METHODS

Life History

The purpose of these experiments was to determine the life cycle of the euonymus scale in Oklahoma and test the efficiency of recently developed chemicals as controls. Initial infestations of euonymus scale studied were located on the north side of the Classroom Building of the University where approximately 10% of the shrubs were heavily infested. Plants on the other sides of the building and on nearby buildings were not infested at the start, but by midsummer 60% of the plants on the north side of the first building were infested and a small per cent of the plants on the north side of nearby buildings were infested. Similar plantings on private property were also used in the test. These plants were *Euonymus japonicus*.

Through the courtesy of the Horticulture Dept. and Prof. Raymond Kays 160 uninfested one-year-old *Euonymus japonicus* plants in gallon containers (Figure 1) were made available for study. These were maintained in a greenhouse or immediately outside for more detailed experiments where mobility was important. They were kept in good growing condition with monthly applications of a 10-20-10 soluble commercial fertilizer applied in the irrigation water.

These plants were infested with euonymus scale by removing a small heavily infested twig and placing it in close approximation to a

Figure 1. Euonymus japonicus Plant Heavily Infested With Unaspis euonymi

plant. Unless the small branches were carefully grouped and retained around the twig, transfer of infestation was reduced. Maintenance of turgidity by keeping the heavily infested twigs in small vials of water increased the number of crawlers which transferred from the infested twig to the plant to be infested.

Oviposition Studies

To determine the number of eggs laid and the periods of egg laying under field conditions, the number of eggs visible under 100 adult female scales were counted twice each week (Figure 2). Because the eggs present could not be determined without severe injury to the females, no scale insects were used a second time and the total number of eggs laid could not be determined. The egg shells were usually so deteriorated by crawler activity that accurate counting of egg shells was not possible.

Although attempts were made to select females of the same age group it was not possible to accurately determine the age of a female and in some cases eggs from females of the first and second generation may have been counted.

Collection of Winged Males

The unusual facet of the life history of scale insects whereby the female scale remained sedentary under the scale covering, but the male became a free-living two-winged insect which flew freely made it necessary to develop means of collecting the free flying forms. The small size necessitated the use of fine mesh materials which would prevent the escape of the active males.

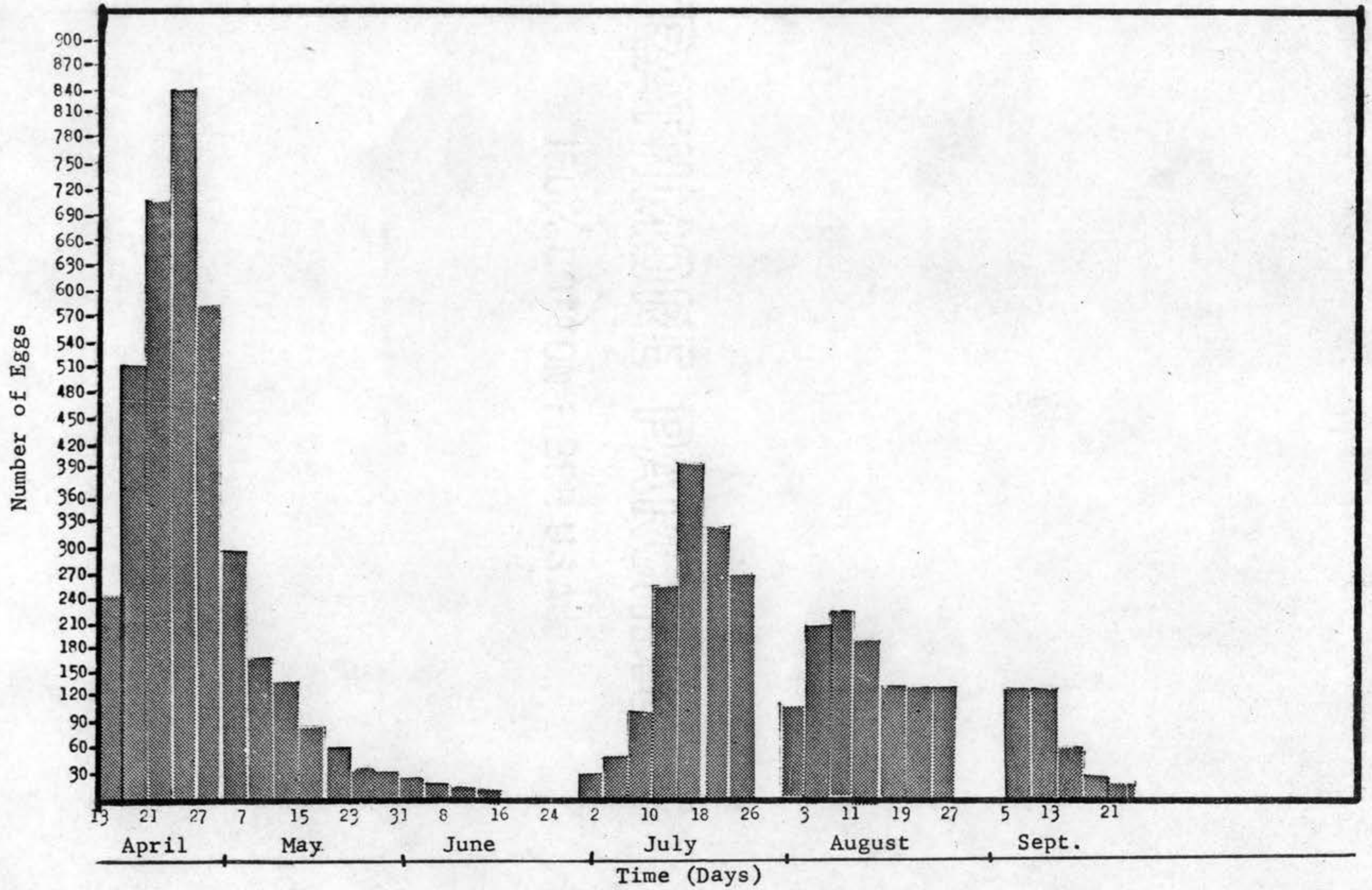


Figure 2. The Number of Eggs Found Under 100 Female Euonymus Scale at 4 Day Intervals During 1966.

To collect these males a cage composed of a glass shell vial and fine nylon was attached to the shrub (Figure 3). The males were hard to see in the cage and did not collect in the shell vials as hoped.

The second procedure was much simpler, more successful and required little preparation. Plastic bags used for preserving food were slipped over infested terminals and secured with rubber bands (Figure 4).

Male scale were readily visible through the plastic and could be easily counted or removed for storage. The cages could be reused. Cages were usually left in place for 24 hours and replaced. This provided an excellent record of male scale emergence.

Evaluation of Mortality

Separation of live and dead scales was difficult but necessary and several procedures were utilized. Each individual was lifted from the leaf surface by a probe. In living insects the mouthparts were deeply inserted and were removed with difficulty. The mouthparts were not easily broken and frequently the scale insect was suspended by the mouthparts alone. In contrast, scale insects dead more than a few hours could be removed much more easily. The mouthparts were brittle and the insect seldom remained suspended from the surface by the mouthparts.

Color of living scale was brighter, fluid was more apparent and minor movements within the body could be seen with adequate magnification before death. These movements were no longer seen, body fluids dried up and the color, particularly of inner structures, became duller after death (Figure 5).

Biological Control

Close attention was paid to the possibility of parasites and pred-

Figure 3. Nylon Mesh Cage Attached to Twig of Euonymus japonicus to Collect Male Scale

Figure 4. Plastic Bag Attached to Twig of Euonymus japonicus to Collect Male Scale

ators which _might_ alter the euonymus scale populations. The activity of a mite and a hymenopterous parasite was studied and identifications of the species made.

Chemical Control

Controls were evaluated in three different environments: laboratory, greenhouse and field, using potted plants, plant terminals kept fresh in soil or water or euonymus plantings on the campus or private homes, respectively.

Nineteen chemicals which had shown some promise for the control of similar insects were evaluated as sprays, dips, granular or systemic formulations. Factors used in their selection included safety to man and domestic animals, phytotoxicity, economy and availability. Choice of granular, sprays or systemics formulations was dependent on availability, safety, and ease of application.

Laboratory Tests

Heavily infested _Euonymus_ terminals 6-9 inches long having 6-8 leaves were removed from the plant and their cut ends were placed in four oz. plastic dose cups of moist soil. Such terminals remained relatively fresh for 2-3 weeks.

These twigs were treated by dipping the foilage briefly and then keeping the plants in small containers of soil until the conclusion of the test. All tests were replicated six times. Readings to determine scale mortality were made at four-day intervals. The small size of the terminals and the container in which the twig was kept made it relatively easy to carefully observe the scale under a dissecting

Figure 5. Crawler Males and Second Instar Unaspis euonymus on Euonymus japonicus Leaf

microscope.

A similar procedure was followed with systemic insecticides in the granular form except the granules were incorporated in the top 1/2 inch of soil in the 4 oz dose cups.

The following insecticides were tested by application to foilage: Ruelene, diazinon, Ciodrin, dichorvos, naled, phosphamidon, ethion, endosulfan, malathion, summer oil, demeton-S-methyl sulfoxide and trichlorfon; Temik, Bayer 25141 and phorate were incorporated in the soil.

Greenhouse Tests

Those insecticides which resulted in appreciable control in the laboratory tests were further tested in the greenhouse. Plants growing in 1 gallon cans were treated by adding granular formulations of disulfoton, Bayer 25141, Temik or phorate to the soil at the following rates: 10, 5 or 1 pounds per acres (Figure 6). These plants were observed at 4-day intervals to determine scale mortality.

Similar plants were sprayed thoroughly with a compressed air sprayer using a Chicago Spraying System cone nozzle delivering 0.5 gallons per minute. Other plants were dipped. Malathion, phosphamidon, Bidrin, naled, summer oil (Volk voluble oil). Plants were treated outside of the greenhouse and returned after they were thoroughly dry.

Field Tests

Shrubs growing on the campus and around private dwellings were sprayed with a power sprayer (John Bean 5 gpm) using a 4 gpm Bean

Figure 6. Phytotoxic Effects of Three Concentrations of Systemic Insecticides on Euonymus japonicus Plants

nozzle at 125 pounds pressure. Application was thorough and exceeded the point of run-off in each case.

Evaluation of effectiveness was by removing leaves from several parts of the shrubs and counting the living and dead scales with the aid of a dissecting scope.

CHAPTER IV

RESULTS AND DISCUSSION

Life History

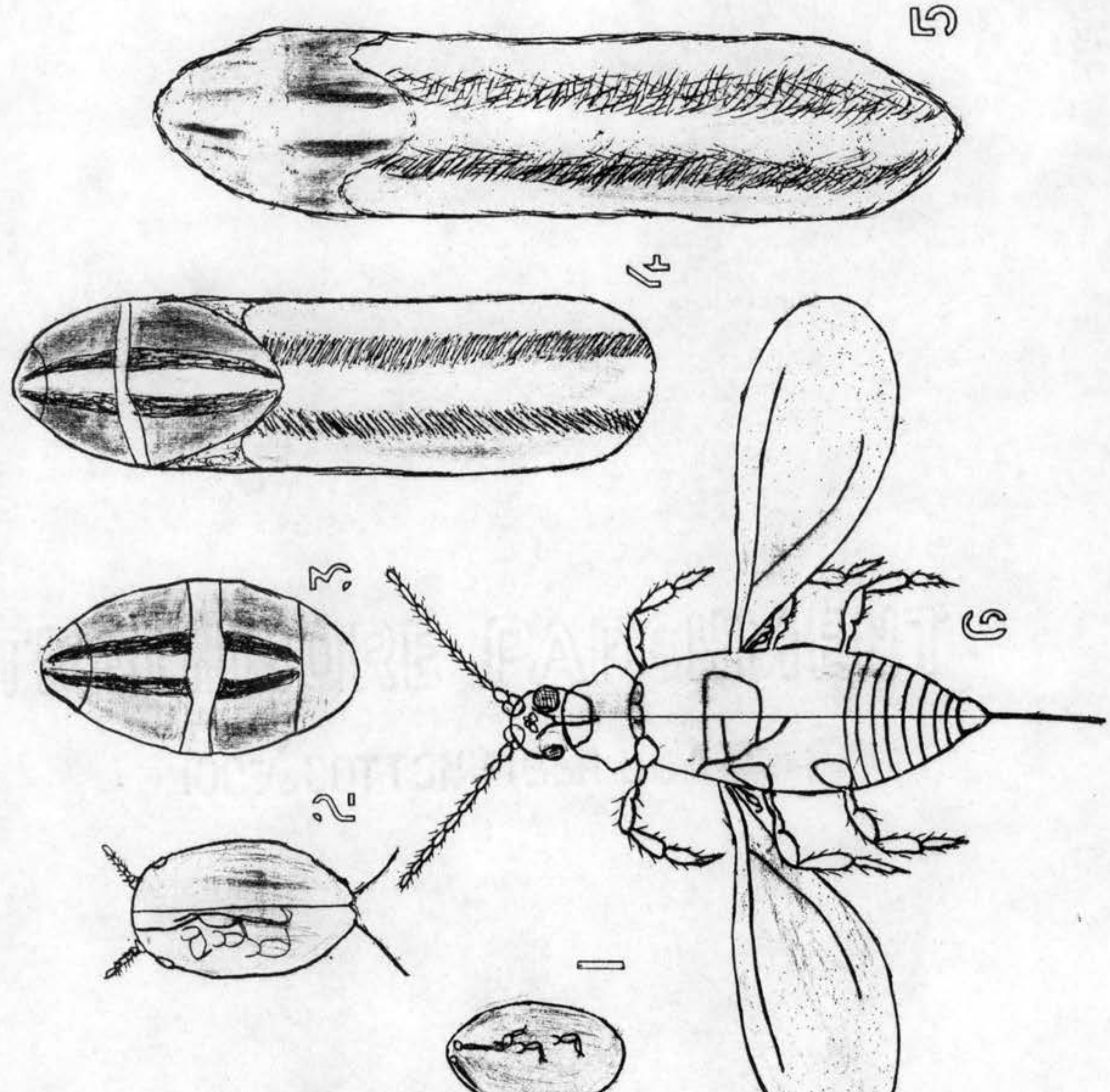
The eggs of euonymus scale were cylindrical, with rounded, smooth ends and measured approximately 220 microns in length and 80 microns in width. The color of the eggs varied from orange-yellow initially to white shortly before hatching when the appendages of the embryo were readily visible through the shell (Figure 7-1). Before oviposition began, the eggs appeared to fill the entire body cavity of the female. After oviposition, the eggs usually remained under the shell until they hatched but at times eggs were pushed out because of the pressure of other eggs being laid.

The crawlers (Figure 7) emerged from the eggs after a 2-3 day incubation period which may be somewhat longer in cooler periods of the year. If the scale covering of the female was removed the eggs failed to hatch.

The crawlers were orange-yellow in color with three pairs of well developed functional legs; nine segmented antennae, and well developed piercing-sucking mouthparts (Figure 7-2). After crawling about over the surface of the vegetation for 6-30 hours they found a suitable feeding place, inserted their stylets into the plant and became sessile within 3-5 days. A hardened, waxy material was secreted and molting to the next stage initiated. During molting the well developed legs,

Figure 7. Life Cycle of Male *Unaspis euonymi*

1. Egg
2. Crawler
3. Second Instar
4. Third Instar
5. Pupal Case
6. Adult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antennae, and filaments were greatly reduced in size and hidden by the hardened waxy covering (Figure 7-3). This stage (Figure 8) lasted 13-18 days. After this period the males and females could be separated easily because of their distinct morphology and biology. The male euonymus scale went through five instars before it became mature. The third and fourth instars (Figure 9) became elongate, oval, tricarinate, chalk white in color and the exuvium of the second instar was readily visible dorso-cephalically. Approximately 5-11 days were required for completion of the third instar. The fourth instar in the males resembled the pupal stage of holometabolus insects. The armor increased about 20% in length while the male scale underneath was changing from a sessile individual to a winged adult. This development required 8 to 14 days. The adult male was a fragile, orange-white two-winged adult with poorly developed sucking mouthparts, which normally emerged during the morning hours, flew actively in search of females and died within 18-24 hours (Figure 7-6).

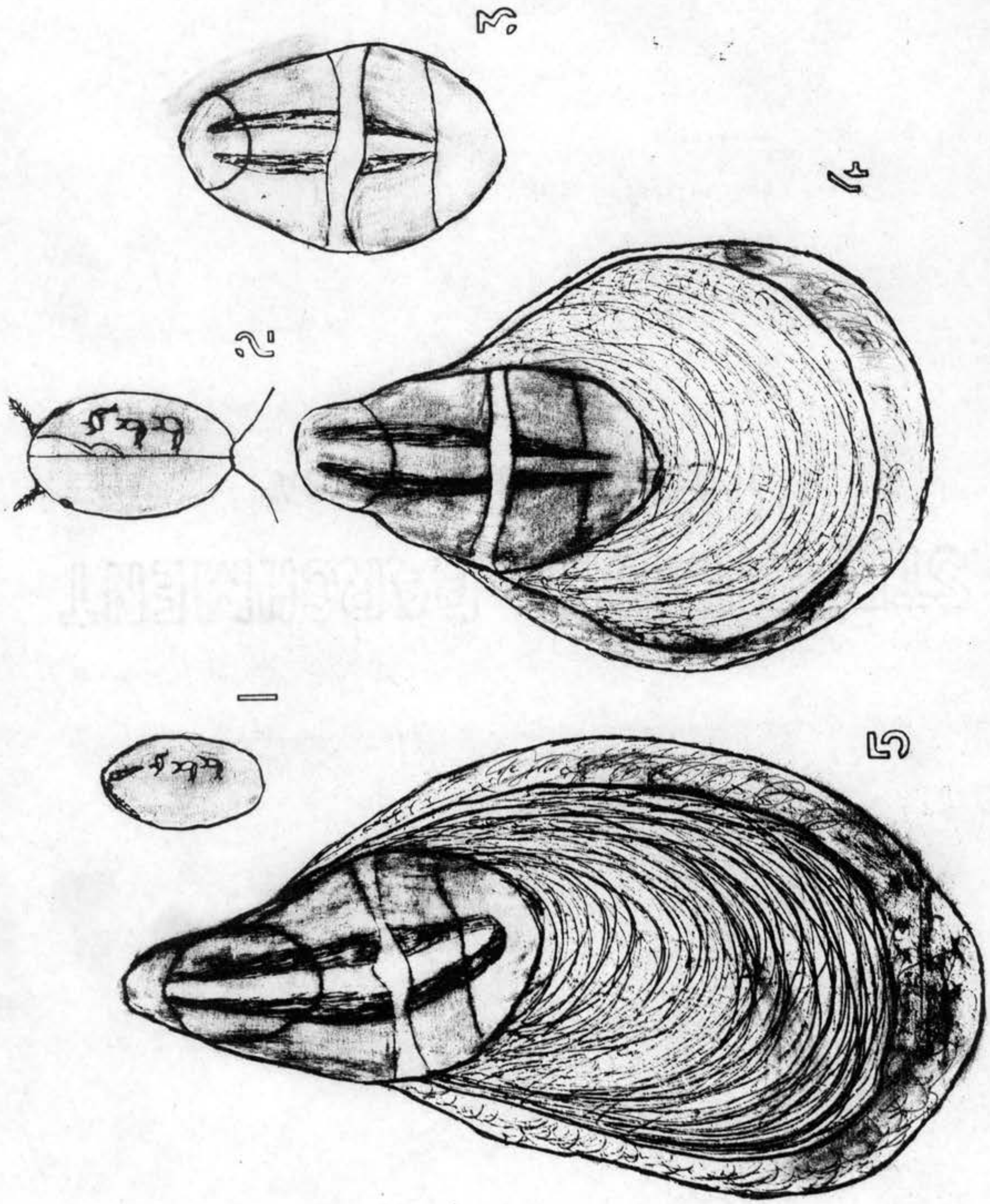
The female euonymus scale had four instars. The first two instars of the female scale were similar to those of the male except for the longer period in the second instar of the females. A secretion forming an irregular translucent, orange external covering around the caudal periphery appeared in the third instar. This armor turned grayish-brown at the completion of this instar in 2-3 weeks except for a hyaline layer on the margin (Figure 10-4). The fourth instar lasted about 10 days and in this instar an additional covering grew around the sides and end of the earlier covering. The armor covering was reddish-brown, irregularly oval and had a hyaline layer on the margins (Figure 10-1, 2, 3, 4).

Figure 8. Second Instar Unaspis euonymi on Euonymus japonicus Leaf

Figure 9. Male, Female and Second Instar Unaspis euonymi Scale on Euonymus japonicus Leaf

Figure 10. Life Cycle of Female *Unaspis euonymi*

1. Egg
2. Crawler
3. Second Instar
4. Third Instar
5. Adult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The fully developed females produced 30-50 eggs which essentially filled the area under the armor. Fertilization took place by insertion of the male genitalia under the lateral margin of the armor while the eggs were being developed.

Field Characteristics

The armor of the male was parchment white in color; elongate; felted; tricarinated and with parallel sides (Figure 9).

The female armor was brown in color; elongate; had exuviae terminal; body narrow at anterior end, broader at posterior end (Figure 9).

Seasonal Distribution

Under field conditions in 1966 *Unaspis euonymi* appeared to have four generations. Egg laying was first observed April 13 and eggs were found until June 16.

The average number of eggs laid per female during the first generation was 22.17. The maximum oviposition rate occurred during the last week of April when on April 27, 870 eggs were found under 100 females. In contrast at the end of the oviposition period on June 16, only 10 eggs were present.

Oviposition to initiate the second generation started June 28 and extended to July 30. The average number of eggs laid was 17.5 per female.

In the third generation the oviposition rate decreased to an average of 10.5 per female. The fourth generation began September 6 and egg laying was noted until September 22. In the fourth generation the insect was less harmful, because the average number of eggs laid by the female was 3.6. Egg laying was completed in a shorter period during September than with earlier generations. Only three weeks were required at this time compared with four weeks during July and August and nine weeks during the apparent first generation.

The extended period of egg laying during April, May and June which may represent the first generation, may in fact include the first and second generations with extensive overlapping. The very long period of egg laying is two times as long as with the other three generations. While eggs were found at all times from April 13, to June 16, no overlap of generations is suggested. Males were found by June 12 but adequate sampling for them was not started until June and they may have been present much longer. The experimental technique of counting the eggs present under the armor of 100 adult female scales did not indicate whether the eggs found were from first or second generation females. A detailed study of the distribution of the short-lived males is being made this year and will, it is hoped, indicate clearly how many generations are actually found. The writer believes under 1966 conditions there were five generations at Stillwater, Oklahoma, on plants outside and approximately twelve on plants held in the greenhouse.

Under greenhouse conditions, 75-85°F, a genration required 21-30 days except during the winter months when 4-5 weeks were needed. Life cycles in the laboratory required 3-4 days more than in the greenhouse.

Adult Males

The use of fine mesh nylon cloth (Figure 3), as described did not give a satisfactory collection of the males. It was started June 12, 1966 and was continued until September 11, 1966. The collection data clearly show that the method was slow and only an average of two males could be collected in 24 hours.

The plastic bag method (Figure 4) was more practical and useful. The collection of males by this method was started on September 12, 1966. The maximum average number of males per cage was 24. These average numbers gradually declined until November 10 when the last male winged scale was collected outdoors (Figure 11). It should be noted that the number of males collected from September to November was much larger than the number collected during earlier generations due to more successful trapping, not larger numbers present. This is particularly evident since the number of immature males present on the terminals was much greater during earlier generations.

Although the shell vial used in the first collection cages had the theoretical advantage of easy collection by driving the males into the vial and exchanging vials, the collections by this method were not satisfactory as the males were not attracted into the vials in large numbers. In addition, the nylon mesh was large enough to allow some loss of winged males. The plastic bags, on the other hand, were easily attached and secured and males could be seen and collected without difficulty.

Biological Control

Clearcut records of parasitization or predation of euonymus scale have not been found in the literature.

Baker and Wharton (1951) mentioned a predaceous mite *Thyreophagus entomophagus*, which was associated with a scale insect collection. But

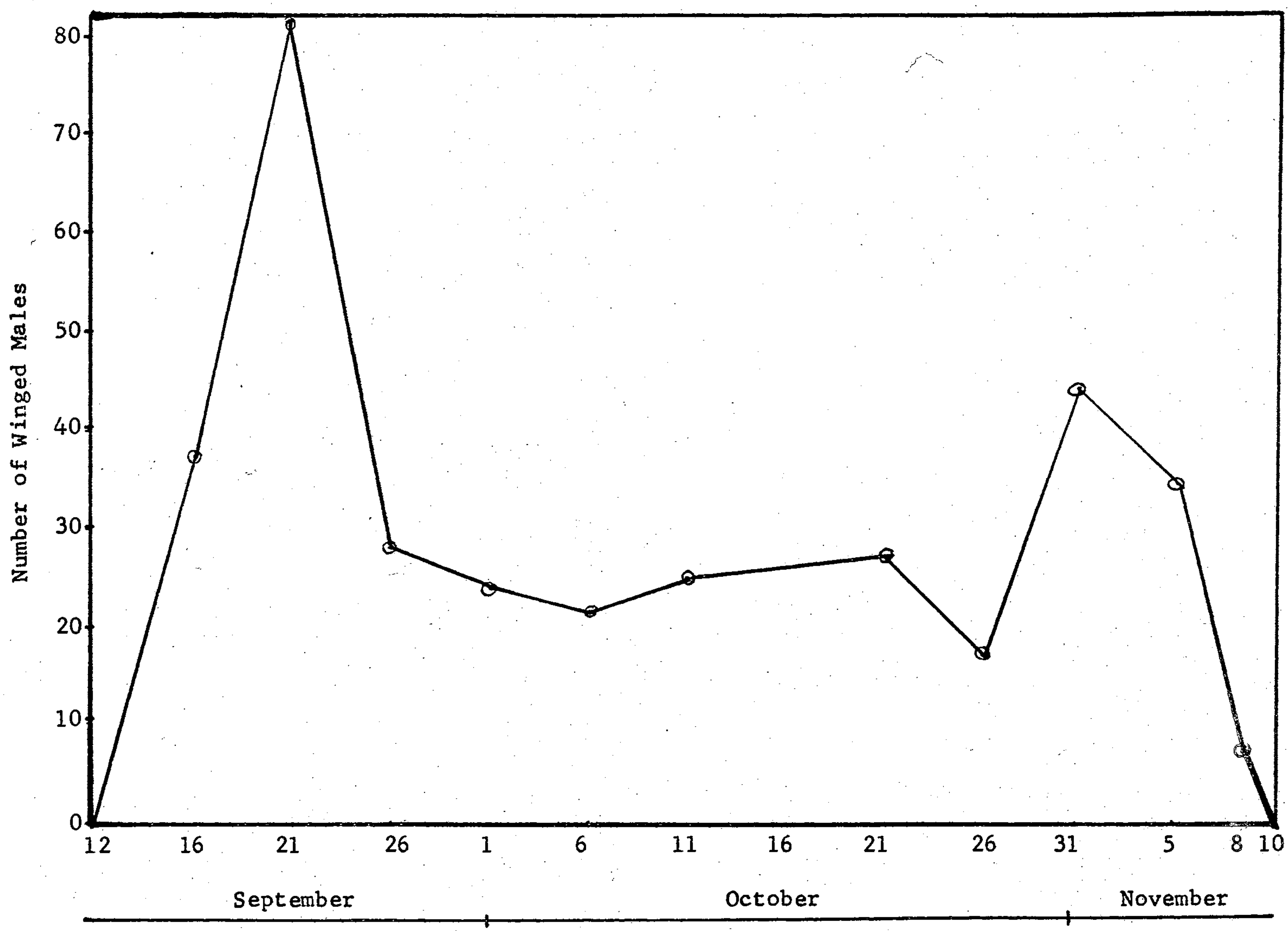

Figure 11. Emergence of Males of Euonymus Scale During the Fall of 1966

to date this predaceous mite has not been recorded on euonymus scales. During these studies all stages of a mite were found in close association with euonymus scale. Adults were first seen in May and eggs were first found July 12 among eggs of Unaspis euonymi. During June and July up to 90% of the scale examined were dead, possibly as a result of activity by these mites commonly found under the armor of the females where they apparently preyed upon eggs, crawlers and the adult females.

Edward Baker of the United States National Museum identified the mites as Thyreophagus entomophagus Laboulbene, Family Acaridae which had been described from dried insect collections and scale insects in the field. Baker and Wharton (1952) suggested that this mite normally fed on cast skins and dead animal material but it might have been predaceous on living scale. Observations during the research indicated the predaceous role was important during the months of May, June and July.

Observations were made on the effects of control applications for the scale, on mite populations. Summer oil, malathion and phosphamidon gave excellent control of the scale yet cuased little mortality of T. entomophagus. Plots treated with the insecticides not toxic to mites were reinfested with scale at a much slower rate than those treated with pesticides which also killed the mites.

Chemical Control

Laboratory Tests

The mortality caused by foliar application of insecticides to euonymus scale on plantterminals kept in the laboratory is shown in Figures 12 and 13. At least 50% mortality was noted within 4 days but

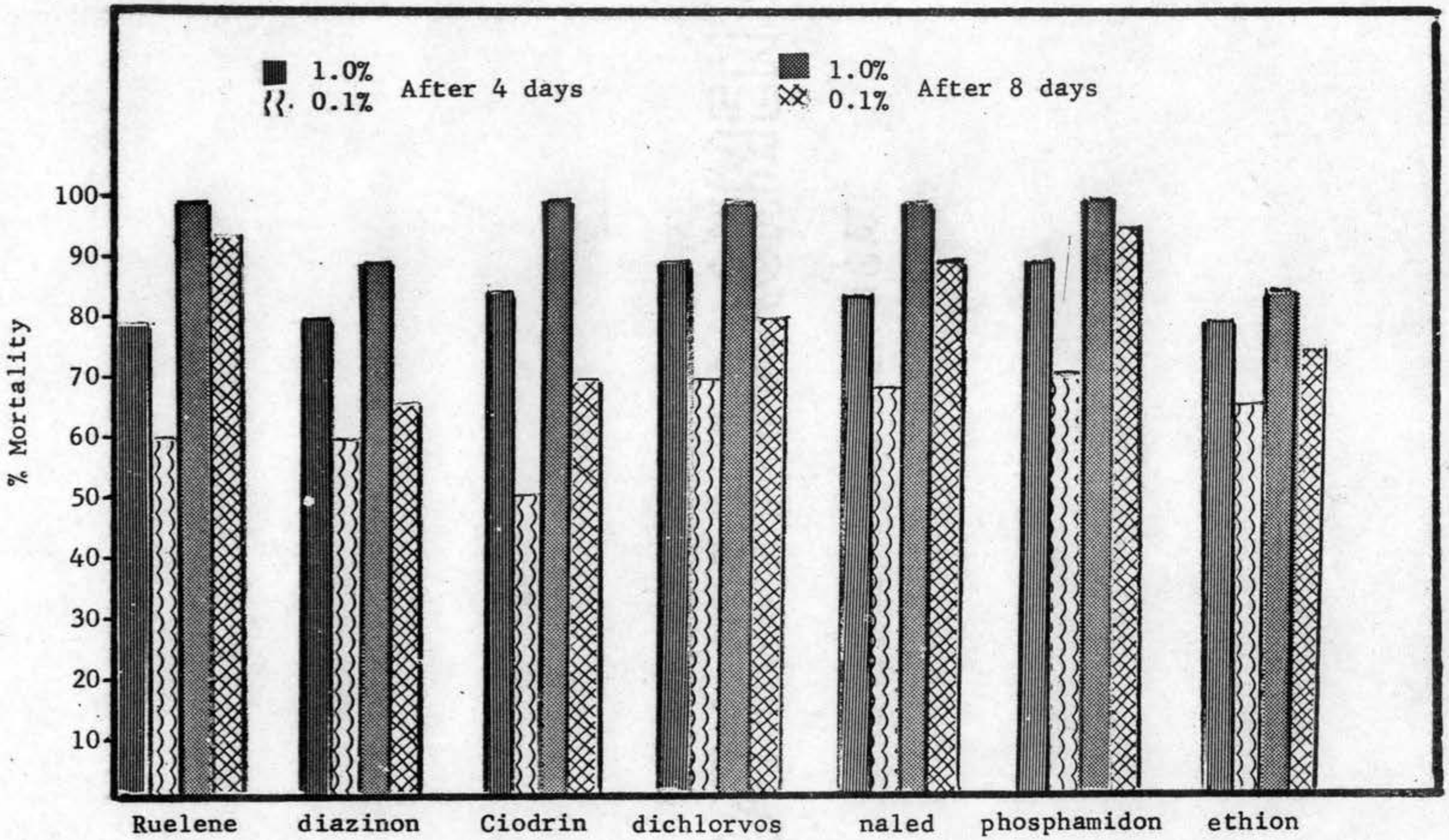

Figure 12. Mortality of <u>Unaspis euonymi</u> 4 and 8 Days After Spraying With 0.1% or 1.0% Insecticides

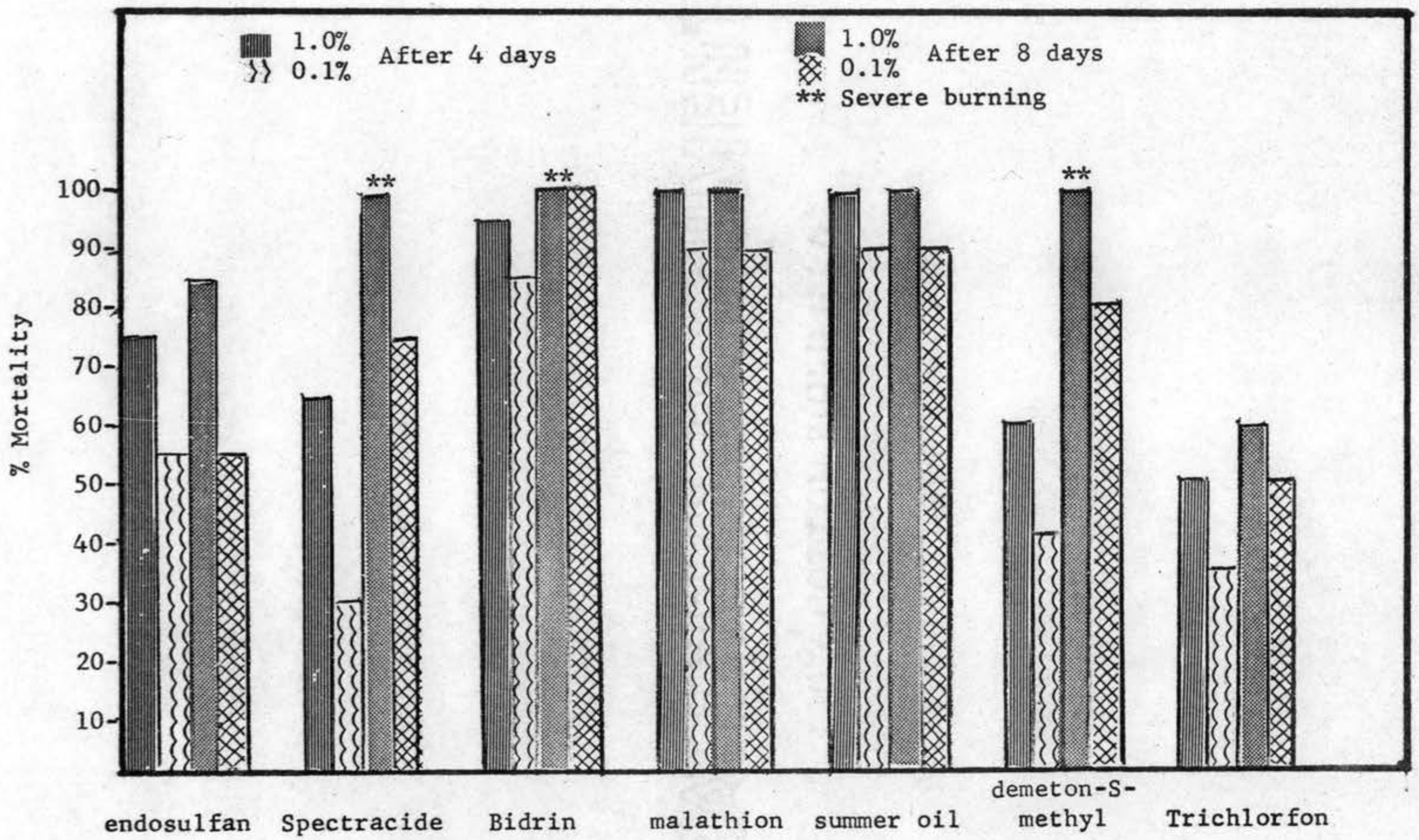

Figure 13. Mortality of Unaspis euonymi 4 and 8 Days After Spraying With 0.1% and 1.0% Insecticide

between 4 and 8 days mortality increased substantially.

Treatment with 1.0% Ruelene, Ciodrin, naled, dichorvos, Spectricide, Bidrin, malathion, summer oil, demeton-S-trichlorfon and phosphamidon resulted in 100% mortality of the euonymus scale present. However, Ruelene, Ciodrin, dichorvos and phosphamidon cause severe burning and leaf drop at this concentration. Malathion, Bidrin and summer oil gave complete control within 4 days when used at 1.0% but only Bidrin provided complete kill when used as a 0.1% foliar application. Malathion or summer oil were quite effective at 0.1%.

Systemics applied in granular form at rates of 10 pounds, 5 pounds or 1 pound per acre were not as effective as foliar sprays. Figure 7 indicates that only Temik at the 10 pound per acre level provided 100% control and 8 days were required to attain this level. However, even at the high rates no phytotoxicity was noted in any of the systemic insecticides.

Greenhouse

Results with systemic insecticides applied as granules to euonymus plants in gallon cans in late September were much less effective than when applied when the plants were growing more rapidly in August. Only Temik used at the 10 pound per acre level provided 50% control or better within 4 days. After 8 days the mortality reached 60%. These data are shown in Figure 8. Some phytotoxicity was noted in all test plants, regardless of systemic used or concentration (Figure 4).

Foliar applications in September and October were much more effective than were the systemics applied to the soil in the fall. Summer oils were most effective but required 8-16 days for complete control of the feeding stages.

Bidrin and naled gave at least 90% control. No injury to foilage was noted following the September application (Figure 16). Sprays applied October 28, 1966 were somewhat less effective. Only 1.0% naled provided 100% control but the plants were severely burned and lost most of their leaves (Figure 2). New growth appeared within a month and the plants did not appear to be seriously harmed. Malathion and summer oil were quite effective and did not cause foilage injury (Figure 18).

Field Tests

Extensive spraying with 0.1% summer oil applied with power equipment provided excellent control of the feeding forms but the eggs were not killed and within a month many of the plants were heavily infested. Extensive sampling did not reveal live feeding forms but the shrubs were growing close to buildings and complete coverage was difficult. Scales not contacted by the spray may have been responsible for some of the scales wich appeared within a month, not just the eggs present at spraying time.

Sprays applied in the field in late September were not as effective as the same concentration of the sprays applied earlier. Summer oil used at 0.1% was the only insecticide that provided 100% control and this was noted only after 16 days. Phosphamidon (0.1%), naled (1.0%) and malathion (1.0%) gave acceptable control (Figures 16 and 18).

Sprays applied October 28 were approximately equal in effect to those applied in September. Summer oil was less effective while naled was more effective (Figure 18).

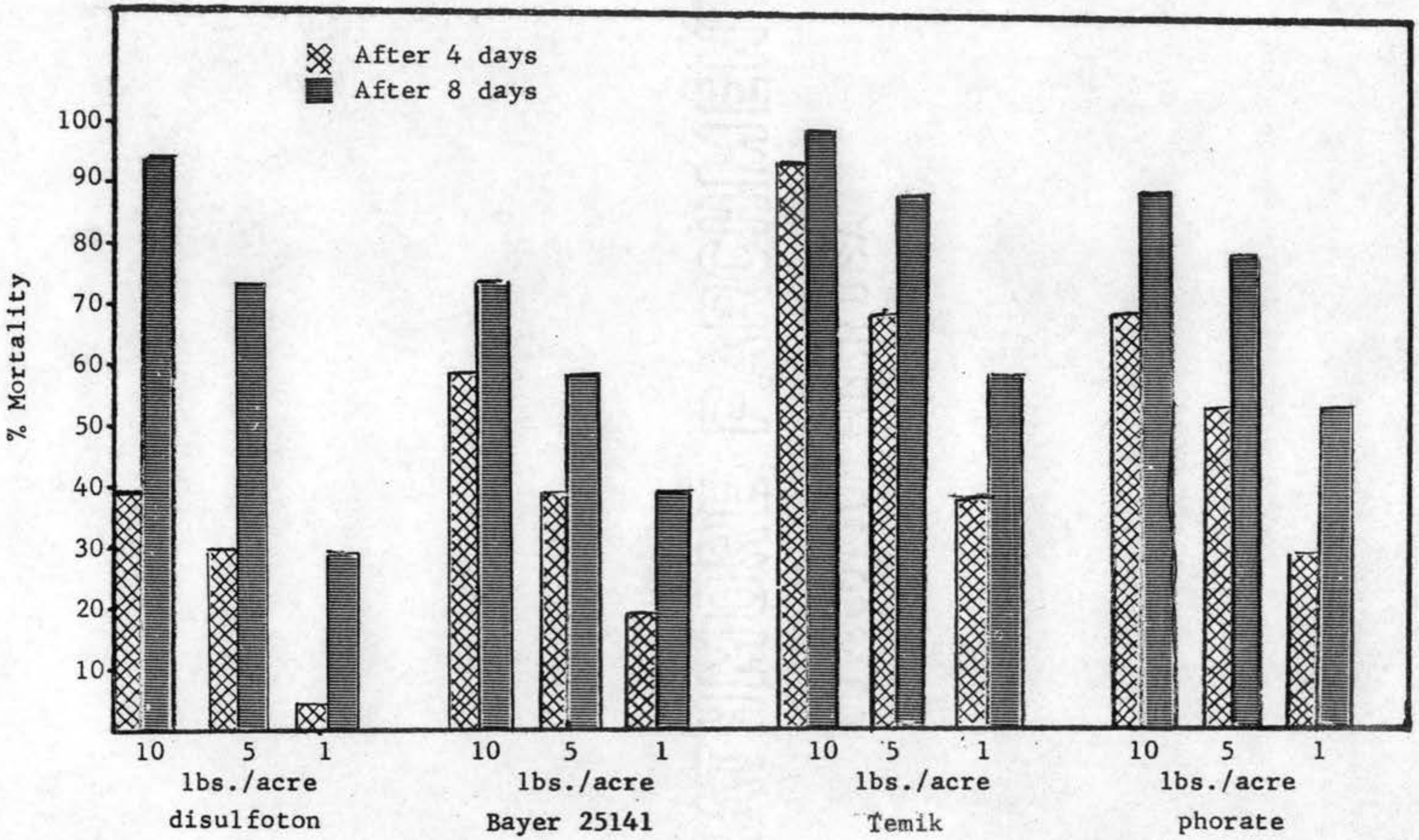

Figure 14. Mortality of <u>Unaspis euonymi</u> 4 and 8 Days After Application of Granular Systemic Insecticides to the Soil

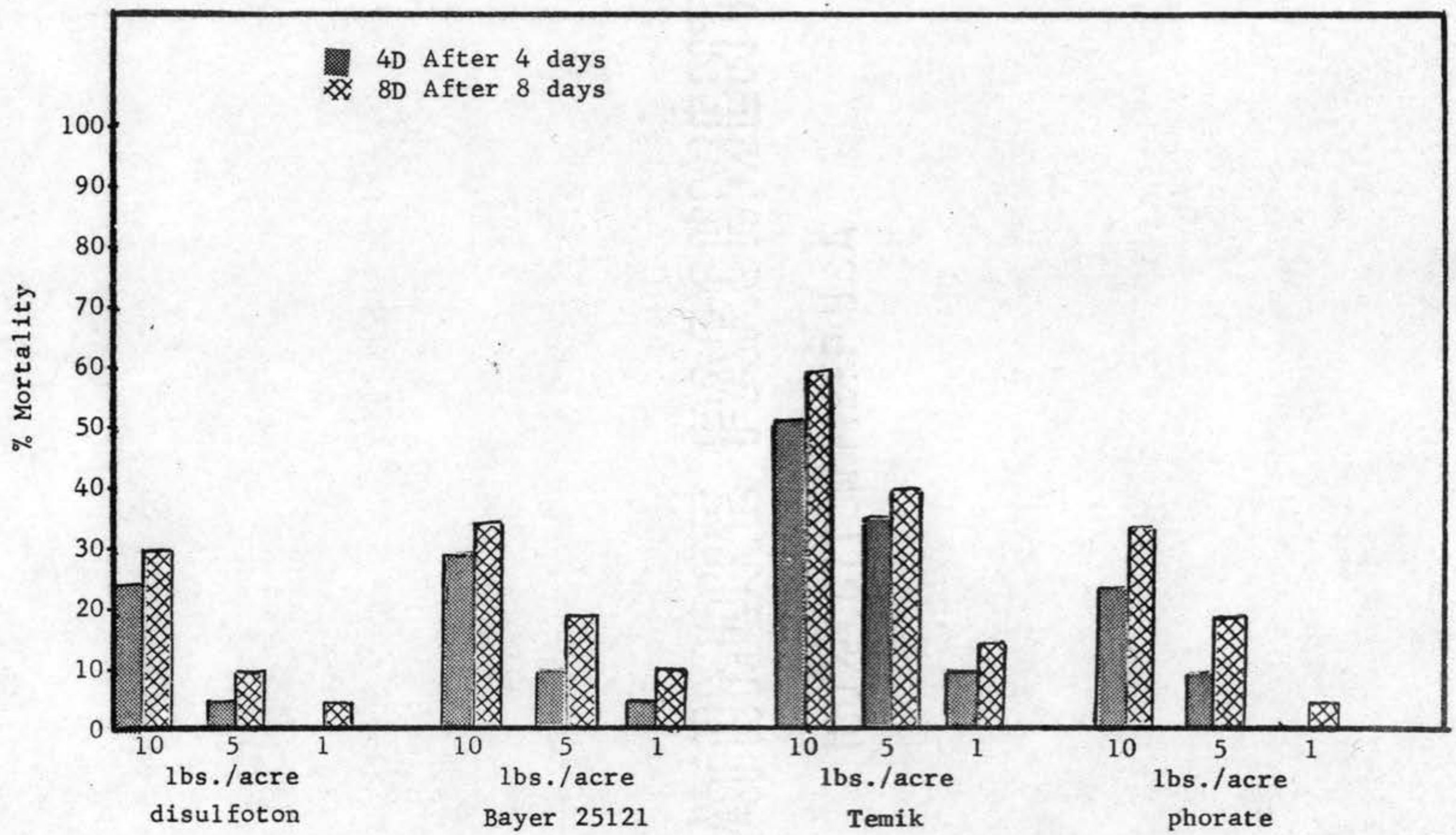

Figure 15. Mortality of Unaspis euonymi 4 and 8 Days After Application of Granular Systemic Insecticides to the Soil

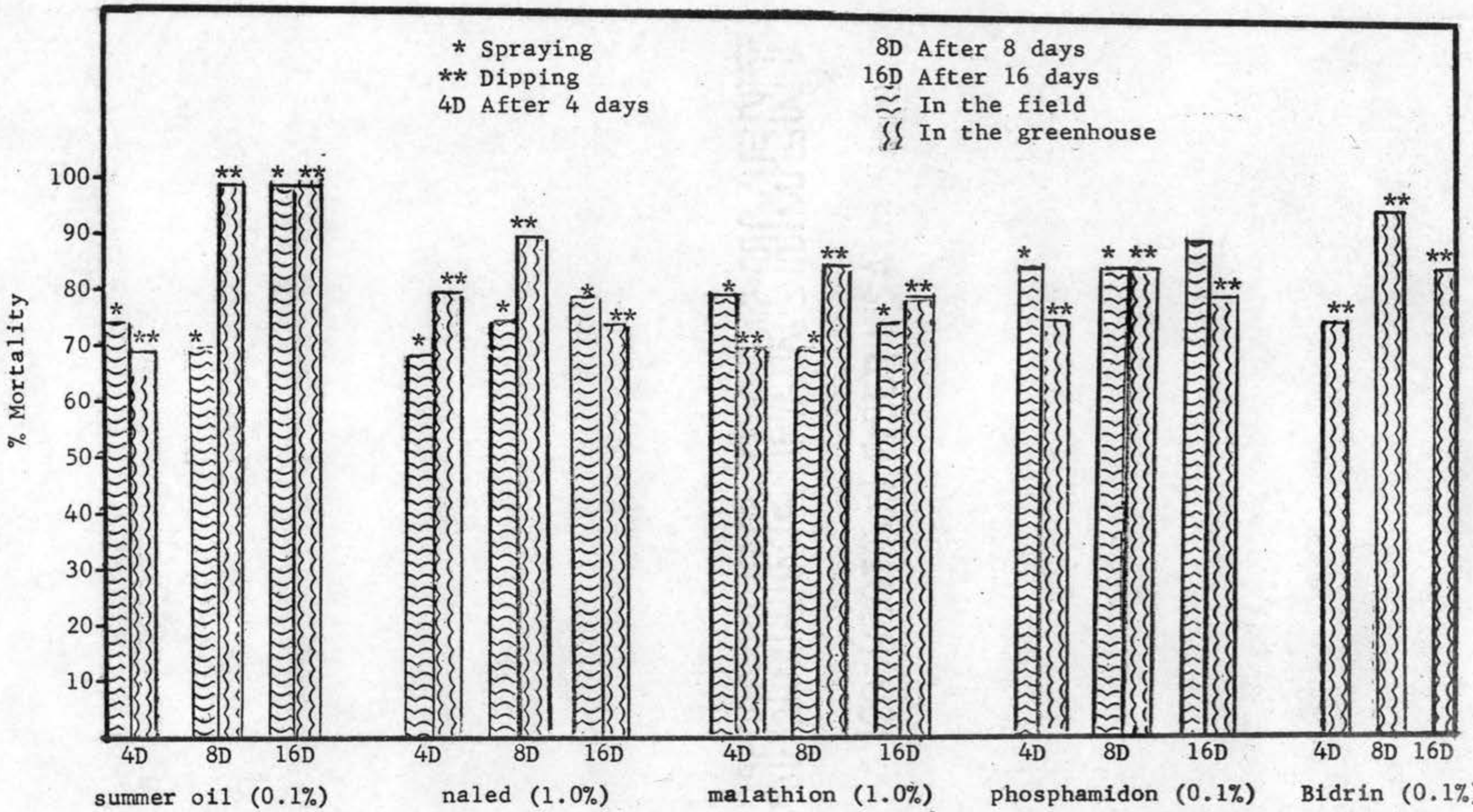

Figure 16. Mortality of Unaspis euonymi From Foliar Applications in the Greenhouse and in the Field, September 28, 1966

Figure 17. Phytotoxic Effects of naled on
Euonymus japonicus Plants

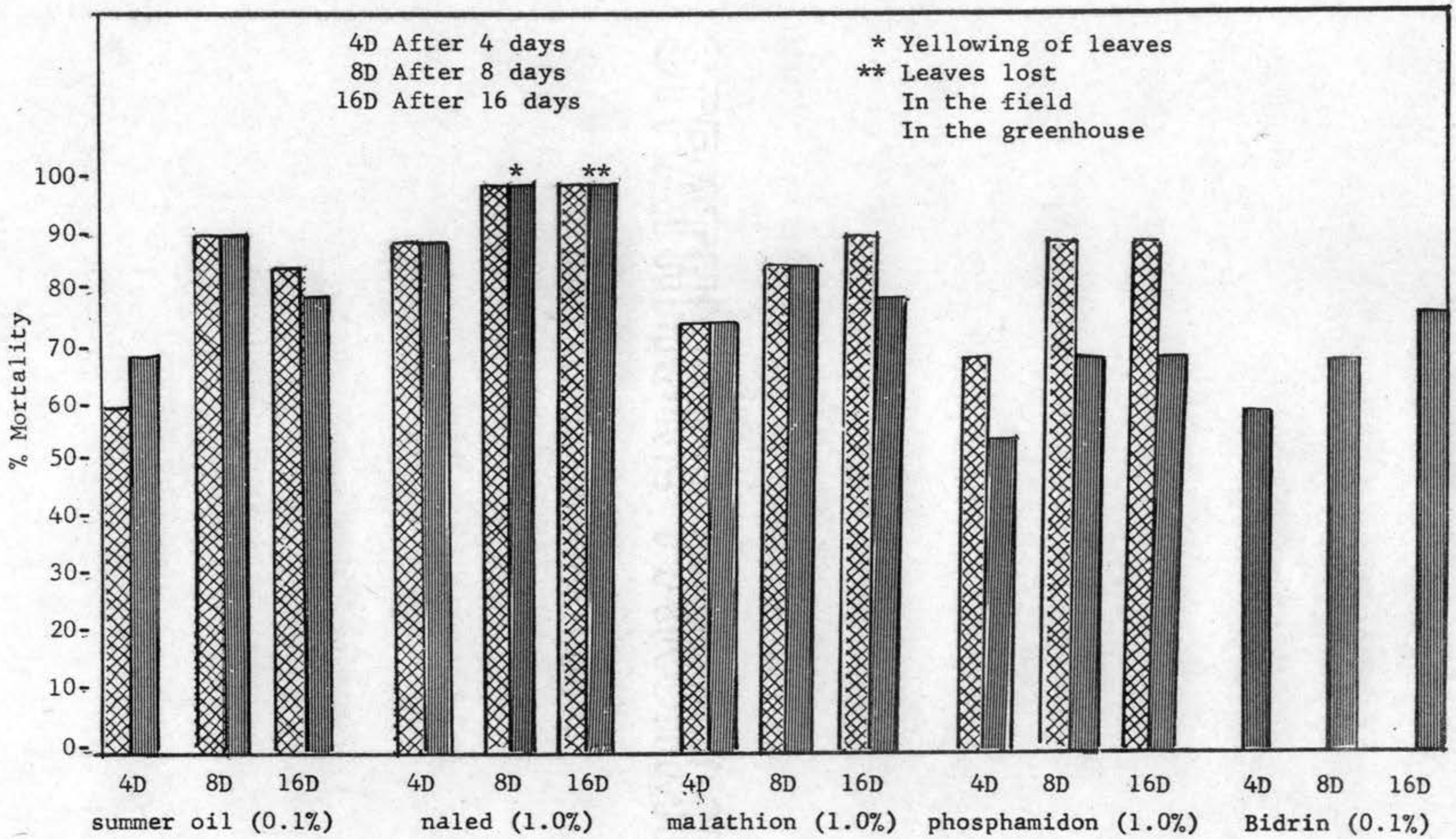

Figure 18. Mortality of <u>Unaspis euonymi</u> From Foliar Applications in the Greenhouse and in the Field, October 28, 1966

Appearance and Injury

The appearance of shrubs infested with euonymus scale is quite characteristic. The plants tend to be unhealthy, lack vigor and the dirty brown, or paper white scale coverings of the females and males respectively are quite apparent and may be readily seen from a distance (Figure 3). When heavily infested the plants turn yellow drop their leaves and dead branches are frequently present (Figure 1). As a rule of thumb, the older growth is more heavily infested than new growth, and during winter months the female reddish-brown scales are more evident than the white males. In summer the situation is reversed. In addition, females are more frequently seen on the leaves (Figure 1).

Insecticides Selection

The experiment was started with the objective of determining a thorough and effective means of control for the scale insects. The insecticides were selected as to their toxicity, safety to the wild life and human beings, and their economic availability. Granular systemics, systemic sprays, and dipping of the twigs in insecticides were used only in the laboratory and greenhouse, even though it was insecticidally effective because it was considered to toxic for outside use where rigid controls were not available. Temik was considered safe to use because of the plastic coating of each granule which reduced the possibility of toxic dusts and made handling relatively easy. Sprays containing summer oil, malathion, naled or phosphamidon were used in field tests because they were safe to handle under field conditions. It was noted that systemic insecticides were more effective in the laboratory than in the greenhouse. The reason for this variation

Figure 19. Euonymus japonicus Twig Killed by a Heavy Infestation of Unaspis euonymi

may have been that in the greenhouse the pots used had drainage holes which allowed the insecticides to be leached out during watering before being fully absorbed by the plant. In the laboratory on the other hand, glass vials were used which did not allow systemic loss and, thus, made possible more complete absorption of insecticide by the plant. Among all the systemics, Temik gave best results both in laboratory and in the greenhouse.

CHAPTER V.

SUMMARY AND CONCLUSIONS

Euonymus scale, *Unaspis euonymi* was studied over a two year period in Stillwater, Oklahoma. Experimental data on the biology, life cycles and the effects of insecticides on all stages of euonymus scale were collected in the laboratory using twigs of *Euonymus* spp. kept in small containers of soil; in the greenhouse using potted plants; or under natural conditions on the campus and around private dwellings. The life cycles of the scale were determined in these environments.

Eighteen chemicals which had shown promise for the control of related pests were tested in sprays, dips or by soil applications to determine the effect on both scale and plants. The most effective materials were tested extensively in the greenhouse and outdoor plantings.

Under greenhouse conditions (75-85°F.) a generation was completed in 21-30 days. Under outdoor conditions five generations were found. The most rapid increase occurred during April and May. Adult males were collected in large numbers during the summer months.

Biological control by mites and small parasitic wasps reduced populations when environmental conditions were favorable.

Insecticides most effective for the control of euonymus scale when used as sprays or dips were malathion, summer oil (Volk soluble oil 97%), Bidrin and naled. The last two caused phytotoxicity at effective levels. Only Temik, of the systemics tested, provided satisfactory scale control without phytotoxicity.

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