# EFFECTS OF COVER SPRAYS AND RESIDUAL PESTICIDES ON SCALE INSECTS AND NATURAL ENEMIES IN URBAN FORESTS

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**Abstract.** Cover sprays and residual insecticides are tactics used by landscapers and arborists to control arthropod pests on trees and shrubs in urban settings. Trees in residential landscapes that received three cover sprays annually for at least 4 years harbored a greater diversity of scale insect pests and were much more likely to be infested with scales than trees in landscapes treated with cover sprays for shorter periods of time. Oak (*Quercus palustris*) trees in an institutional landscape treated with residual insecticides harbored significantly lower numbers of beneficial arthropods than trees treated with a pesticide that lacked residual activity. The suppressive effect of the residual insecticides on natural enemies was pronounced on the community of parasitic wasps that attack the obscure scale *(Melanaspis obscura)*, a common scale insect pest of oak. The effect of residual insecticides on individual wasp species persisted 4 weeks after the pesticides were applied. By reducing the use of cover sprays and residual insecticides, arborists may be able to conserve communities of natural enemies in managed landscapes. This will enhance the biological diversity of beneficial insects found in urban forests and thereby aid in increasing their sustainability.

**Key Words.** Biological control; Integrated Pest Management; Plant Health Care; horticultural oil; chlorpyrifos; diazinon.

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We are just beginning to understand the types and levels of control provided by naturally occurring predators, parasites, and pathogens of insect and mite pests in urban forests. In general, the natural enemy community in managed landscapes and urban forests is poorly understood in terms of taxonomic richness. The few comprehensive studies to date reveal large and complex communities of natural enemies in urban settings (Owen 1978; Taylor et al. 1978; Owen 1983; Hanks and Denno 1995; Shrewsbury 1996; Lozzia 1999; Rigamonti and Lozzia 1999; Balder et al. 2000).

The central role beneficial insects play in reducing pest populations in urban forests is exemplified by several studies in which natural enemies have been imported and released to control populations of introduced pests. Recently, successes have been seen in the biological control of the eucalyptus longhorned borer (*Phoracantha semipunctata*) (Paine et al. 1993), the obscure scale (*Melanaspis obscura*) (Ehler 1995), and the ash whitefly (*Siphoninus phillyreae*) (Pickett et al. 1996). It is clear that natural enemies are an enormous asset in reducing damage caused by insects and mites in urban forests.

One practice still used in the landscape maintenance industry is the scheduled application of pesticides to many or all trees and shrubs found in a landscape. A survey of 350 of lawn and landscape maintenance professionals in the Atlanta, Georgia, U.S., area revealed that 32% of such professionals applied pesticides on a predetermined schedule whether pests were known to be present or not (Braman et al. 1998). As recently as 1991, blanket sprays of insecticides and other chemicals were practiced by 31% of arborists, property owners, and managers who participated in a large national study conducted by ISA and NAA (Gerstenberger 1991).

Some indication of the types of problems associated with the widespread application of pesticides to urban forests can be seen in pest outbreaks observed in resort settings where attempts were made to reduce nuisance pests. In a resort community in California, mosquito-fogging programs greatly reduced the numbers of parasitoids attacking the pine needle scale (*Chionaspis pinifoliae*). This allowed populations of the scale to increase dramatically and severely damage the lodgepole pines (*Pinus contorta*) and Jeffrey pines (*P. jeffreyi*) that populated the landscape around the community. When the mosquito control program was modified and the fogging reduced, scale populations declined as mortality by predators and parasitoids increased (Roberts et al. 1973; Luck and Dahlsten 1975).

A similar case was documented in a resort community in Michigan where the European fruit lecanium (*Parthenolecanium corni*) reached outbreak levels on street trees following weekly applications of dimethoate to control filth-flies (Merritt et al. 1983). Following the implementation of an IPM program to control the flies in their breeding sites and the cessation of weekly sprays, scale populations rapidly declined to innocuous levels. This was apparently due to increased activities of natural enemies that helped to hold the scale populations in check (Merritt et al. 1983).

Wide-scale applications of pesticides to eradicate introduced pests have had similar unfavorable consequences on natural enemies in urban forests. In southern California, attempts to eradicate a localized infestation of the Japanese beetle (*Popillia japonica*) resulted in serious outbreaks of citrus red mite (*Panonychus citri*), woolly whitefly (*Aleurothrixus floccosus*), purple scale (*Lepidosaphis beckii*), and citrus mealybug, (*Planococcus citri*) in landscapes (DeBach and Rose 1977). Pesticides used in the initial eradication program and in subsequent attempts to control secondary pest outbreaks were far more toxic to beneficial insects and mites than to the primary pests and contributed to the outbreak of secondary pests (DeBach and Rose 1977). Also in California, attempts to eradicate the Mediterranean fruit fly (*Ceratitis capitata*) with insecticidal baits resulted in outbreaks of several species of Homoptera and mites in urban areas. As with the case of Japanese beetles, disruption of the natural enemy community was implicated as the mechanism associated with pest outbreaks (Dreistadt and Dahlsten 1986).

Similar detrimental effects were seen in Georgia and Oklahoma pine seed orchards where pyrethroids applied over 2 years resulted in serious outbreaks of five scale species. These outbreaks were attributed to suppression of the parasitoid community attacking the scale species (Clarke et al. 1992).

The previous examples dealt with widespread applications of pesticides on an area-wide basis. What evidence indicates that applications to individual trees can have similar negative impacts on natural enemies? McClure (1977) investigated the impact of single pesticide applications of dimethoate to eastern hemlocks (*Tsuga canadensis*) infested with elongate hemlock scale (*Fiorinia externa*). An application of pesticide to only a portion of a tree's canopy, a likely event in a managed landscape, resulted in a dramatic resurgence in armored scale populations. McClure (1977) noted that the primary parasitoid of the scale and three species of common predators were virtually eliminated from the lower crowns of partially treated trees. Apparently, highly mobile natural enemies encountered pesticides in portions of trees that had been treated with residual insecticides and were killed. McClure (1977) concluded that a reduction in predators and parasitoids played an important part in allowing scale populations to resurge on partially treated trees.

A second practice widely used by commercial arborists and landscape managers is the application of residual insecticides (Holmes and Davidson 1984; Neely et al. 1984; Raupp and Noland 1984; Coffelt and Shultz 1990; Gerstenberger 1991; Neely and Smith 1991; Latimer et al. 1996). Pests of woody landscape plants differ dramatically in their life cycles, feeding behaviors, and vulnerability to management tactics. The selection of chemical controls must be tailored to the idiosyncrasies of the biology of the particular pest in question. Insecticides with long periods of residual activity can be remarkably effective in controlling serious pests such as wood borers, and are widely recommended (Davidson and Raupp 1999; Shetlar and Herms 1999). Furthermore, many of these residual materials are very toxic to pests such as aphids, scale insects, and lace bugs, and are regularly recommended for control of these pests (Davidson and Raupp 1999; Shetlar and Herms 1999; Sadof and Sclar 2000). However, many key pests that consume leaves or suck sap are relatively easy to control with thorough applications of contact insecticides such as horticulture oils or soaps (Grossman 1990; Neilsen 1990; Sadof and Sclar 2000). Not only are residual insecticides toxic to a wide variety of arthropod pests, but also they may be extremely toxic to natural enemies, particularly parasitic wasps, that help reduce pest populations (Michelbacher and Hitchcock 1958; DeBach 1969, 1974; Campbell 1975; Davies and McLaren 1977; Morse et al. 1987; Pratt and Croft 2000).

In this article, we report findings of studies that examined the effects of cover sprays and the use of residual pesticides on scale insects and natural enemies found in the canopies of trees and shrubs in urban forests in Maryland, U.S. The first study investigated the effect of long-term application of insecticides on populations of armored scale insects associated with woody landscape plants in residential settings. The second study examined the effect of residual insecticides on the community of natural enemies that populate tree canopies in an institutional landscape. In particular, we wanted to compare the effects of three commonly used insecticides, chlorpyrifos, diazinon, and horticultural oil, on nontarget insects found in the canopies of pin oak (*Quercus palustris*) trees.

## MATERIALS AND METHODS

During spring, summer, and fall 1982, we sampled pest populations in 26 residential landscapes in the suburbs of central Maryland. At each landscape, a complete inventory of all woody plants was developed, and all woody plants were monitored for problems caused by pests and abiotic factors for a period of about 6 months (Holmes and Davidson 1984).

During the course of that sampling, we noticed that some landscapes housed large and often damaging populations of armored and soft scales on several types of plants, while other landscapes had few, if any, scale problems. In assessing possible causes for these pest outbreaks, it did not appear that factors such as the age of the landscape planting or type of material planted explained the patterns of scale abundance. However, historical records of pesticide use on the landscapes were available and revealed an interesting scenario. All landscapes under study had received general cover sprays as part of their pest control program.

Cover sprays consisted of three contact insecticide and miticide sprays applied to all plants at each site in late April, late May–early June, and late June–early July. Records indicated that the range of participation in this cover spray program varied between 1 and 17 years. To evaluate the effect of cover sprays on scale abundance in these landscapes, we separated the landscapes into two groups, those that had received cover sprays for 4 or more years (4 to 17 years) and those that received cover sprays for less than 4 years. A period of 4 years was chosen to create pesticide treatment categories with sufficient numbers of individuals to permit statistical analysis (Zar 1999). We then compared the proportion of plants infested by scale insects under the different management regimes using a chi-square goodness of fit analysis (Zar 1999). We compared the frequency with which plants were infested with euonymus scale, white peach scale, and pine needle scale at sites under long (>4 years) and short (<4 years) cover spray regimes.

In 1986, we undertook a study to evaluate the impact of three commonly used insecticides, chlorpyrifos, diazinon, and horticultural oil, on nontarget insects found in the canopies of pin oaks (*Quercus palustrus*). Twenty-five mature pin oaks on the campus of the University of Maryland, infested with obscure scale (*Melanaspis obscura*), were each randomly assigned to one of five treatments. Five trees were treated with horticultural oil (Sunspray 6E®) at the rate of 7.57 L oil per 378.5 L water (2 gal oil/100 gal water), five were treated with chlorpyrifos (Dursban 50% WP®) at the rate of 0.908 kg chlorpyrifos per 378.5 L water (2 lb chlorpyrifos/100 gal water), five were treated with Diazinon 50% WP® at the rate of 0.454 kg per 378.5 L water (1 lb diazinon/100 gal water), five were treated with chlorpyrifos (Dursban 4EC®) at the rate of 0.95 L chlorpyrifos per 378.5 L water (1 qt chlorpyrifos/100 gal water) mixed with 2% Sunspray 6E® at the rate of 7.57 L oil per 378.5 L water (2 gal oil/100 gal water), and five were not sprayed and served as controls. All materials were applied at the rate specified on the label, and the applications were made with an FMC® sprayer operated at 200 psi. Trees were treated in the second week in July to correspond with the emergence of crawlers of the obscure scale. The timing of sprays and use of materials conformed to common recommendations for control of scale insects.

One week after the trees were treated, four adhesive-coated cards [80 mm wide × 165 mm long (3.15 in. wide × 6.49 in. long)] were stapled to the bole of each tree at a height of approximately 2.5 m (8.2 ft.). At weekly intervals for a period of 6 weeks, exposed cards were replaced with fresh ones. Following a week of exposure, traps were taken to the laboratory and all insects captured on the trap were identified and counted. Known parasitoids of the obscure scale in the family Aphelinidae were identified to species following the verification of voucher specimens by staff of the United States National Museum. Other beneficial insects were identified to family. Noninsect arthropods were identified to order and counted.

The effect of the insecticide treatments on the community of nontarget arthropods sampled in the sticky traps was evaluated by summing counts from all dates and subjecting the data to a one-way analysis of variance. Prior to the analysis of variance, data were transformed using a $\log_{10}(x + 1)$ transformation where $x$ = natural enemy counts to achieve homogeneity of variance (Zar 1999). Separation of treatment means following the analysis of variance was accomplished using a Duncan's multiple-range test at the $P = 0.05$ level (Zar 1999). The effect of insecticide treatments on the three most common parasitoids of obscure scale was evaluated by comparing trap catches among treatments for the two sampling dates on which parasitoids were most abundant. A one-way analysis of variance followed by a Duncan's multiple-range test was used to test for treatment effects and separate treatment means, respectively (Zar 1999).

## RESULTS AND DISCUSSION

Landscapes subjected to cover sprays for prolonged periods were more frequently infested with scale insects than those receiving cover sprays for shorter periods of time. Seventy-five percent of the sites sprayed 4 years or more had scale problems, whereas only 40% of sites sprayed less than 4 years had scale outbreaks. Moreover, a total of 12 species of scales, nine armored scales and three soft scales, were detected in home sites treated with cover sprays for many years. Only four species of armored scales were detected at sites treated less than 4 years. Plant species utilized by the three most common species of scales were much more frequently infested at sites receiving cover sprays for prolonged periods of time (Figure 1). Chi-square test values were $\chi^2 = 661.17$, $\chi^2 = 71.62$, and $\chi^2 = 141.65$ for euomymus, white prunicola, and pine needle scales, respectively. *Euonymus* spp. were about 25 times more likely to be infested, *Prunus* spp. were about 10 times more likely to be infested, and *Pinus* spp. were roughly five times more likely to be infested by euonymus, white prunicola, and pine needle scale, respectively, where long-term cover sprays were applied.

The mechanisms underlying these differences are unknown and could include many factors operating alone or in concert. In some cases, a pest may re-

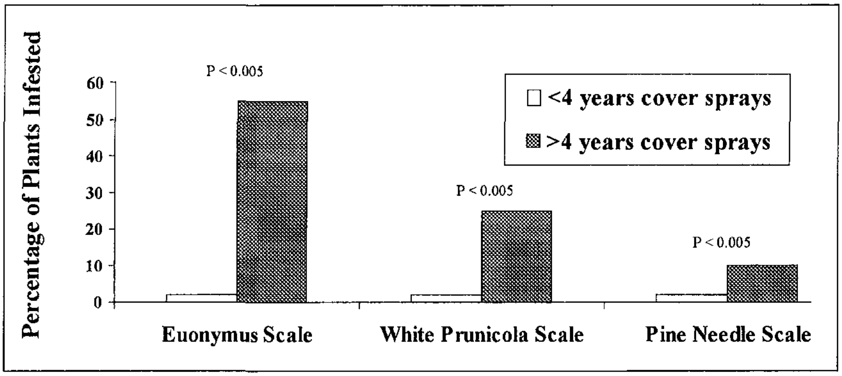


**Figure 1. Effects of short and prolonged periods of cover sprays on the frequency of scale infestations in residential landscapes. Bars represent percentage of plants infested. Probability statements above bars indicate the results of a Chi-square goodness of fit test.**

ceive a sublethal level of a pesticide. This exposure may stimulate the pest to develop faster or produce more eggs. This phenomenon, known as hormoligosis, has been demonstrated in spider mites treated with DDT and carbaryl (Dittrich et al. 1974). In other cases pesticides may alter the nutritional quality of the treated plant and thereby benefit the pest. Cases of pesticide-related host improvement acting alone or in conjunction with hormoligosis have been reported for spider mites (Dittrich et al. 1974; Jones and Parella 1984) and plant hoppers (Chelliah et al. 1980). To our knowledge, no such cases have been demonstrated for scale insects.

A more plausible explanation for the greater diversity and frequency of scale insects in landscapes with a prolonged history of cover sprays is the detrimental effect of cover sprays on populations and communities of predators and parasites that normally suppress scale populations. Similar scale outbreaks were observed in landscapes where pesticides were applied to control biting flies in resorts (Roberts et al. 1973; Luck and Dahlsten 1975; Merritt et al. 1983), to eradicate introduced pests on area wide bases (DeBach and Rose 1977), and to control scales on individual trees (McClure 1977).

The effects of diazinon, chlorpyrifos, and horticultural oil on natural enemies in oak canopies were as follows. Seventeen taxa of natural enemies were collected frequently and were analyzed individually. They were minute pirate bugs (Anthocoridae), spiders (Araneae), brachonid wasps (Braconidae), ground beetles (Carabidae), chalcid wasps (Chalcidoidea), lacewings (Chrysopidae and Hemerobiidae), lady beetles (Coccinellidae), long-legged flies (Dolicopodidae), ants (Formicidae), ichneumonid wasps (Ichneumonidae), stink bugs (Pentatomidae), harvestmen (Opiliones), predatory thrips (Phleothripidae), scelionid wasps (Scelionidae), sphecid wasps (Sphecidae), rove beetles (Staphylinidae), and yellowjackets (Vespidae).

The effects of the residual insecticides on the community of natural enemies were dramatic. Natural enemies in the canopies of pin oaks treated with chlorpyrifos and diazinon were only about one-quarter to one-third as abundant as in trees left untreated (Figure 2). However, the abundance of natural enemies in the canopies of trees treated with horticultural oil did not differ from untreated trees (Figure 2).

Of the 17 orders and families of natural enemies collected, three groups were affected significantly by the application of insecticides. Parasitic wasps in the superfamily Chalicidoidae, ants, and lacewings were less abundant in the canopies of oaks treated with insecticides. Moreover, the application of chlorpyrifos and diazinon generally reduced populations of these natural enemies more than horticultural oil (Figures 3 and 4). Although there were trends for several other families of insects to be reduced on one or more dates on trees treated with residual insecticides, these differences were not significant.

Several small parasitic wasps in the family Aphelinidae are known to be integral in reduc-

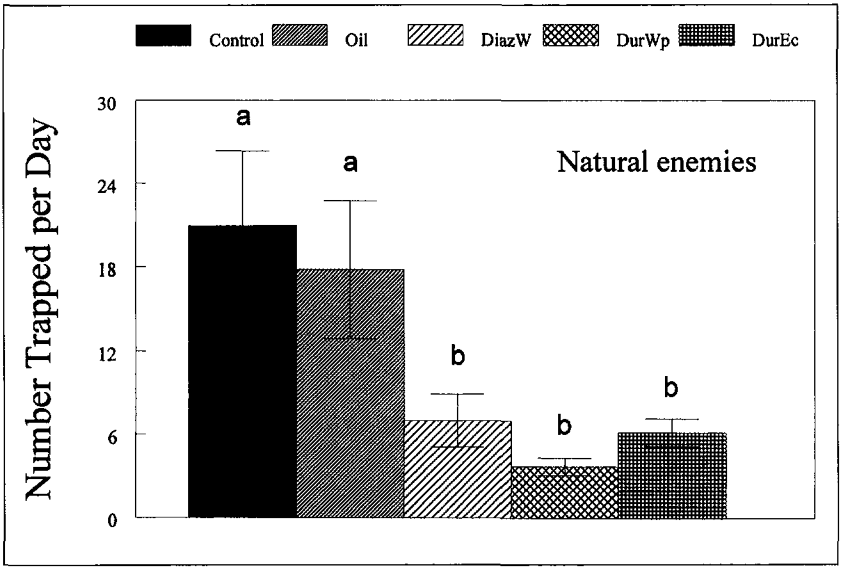


**Figure 2.** Effects of horticultural oil (Oil), diazinon wettable powder (DiazW), Dursban wettable powder (DurWp), and Dursban emulsifiable concentrate and horticultural oil (DurEc) on the natural enemies trapped in the canopies of pin oaks over a 6-week period following the application of insecticides. Bars represent mean numbers of natural enemies trapped per tree, and vertical lines represent standard errors. Treatment means that share a common letter did not differ significantly by a Duncan's multiple-range test ($P = 0.05$).

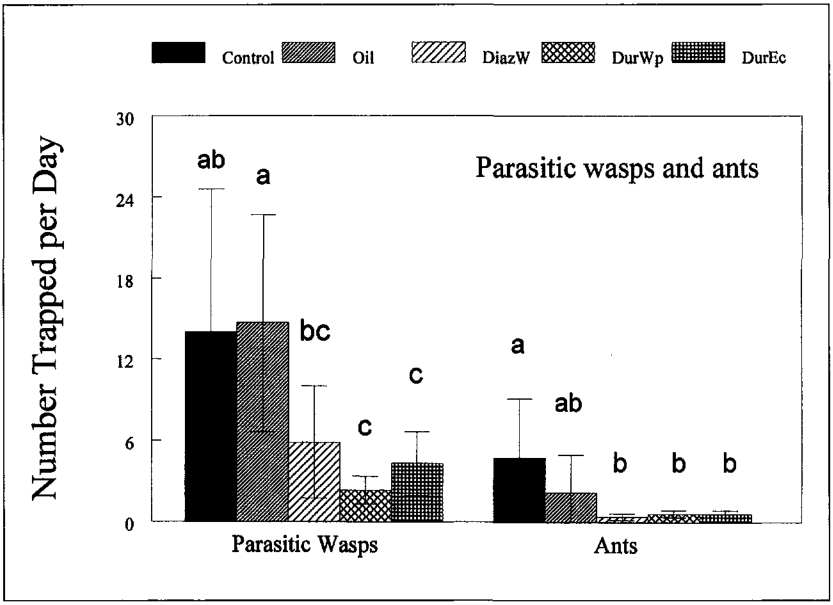


**Figure 3.** Effects of horticultural oil (Oil), diazinon wettable powder (DiazW), Dursban wettable powder (DurWp), and Dursban emulsifiable concentrate and horticultural oil (DurEc) on the parasitic wasps and ants trapped in the canopies of pin oaks over a 6-week period following the application of insecticides. Bars represent mean numbers of wasps and ants trapped per tree, and vertical lines represent standard errors. Treatment means that share a common letter did not differ significantly by a Duncan's multiple-range test ($P = 0.05$).

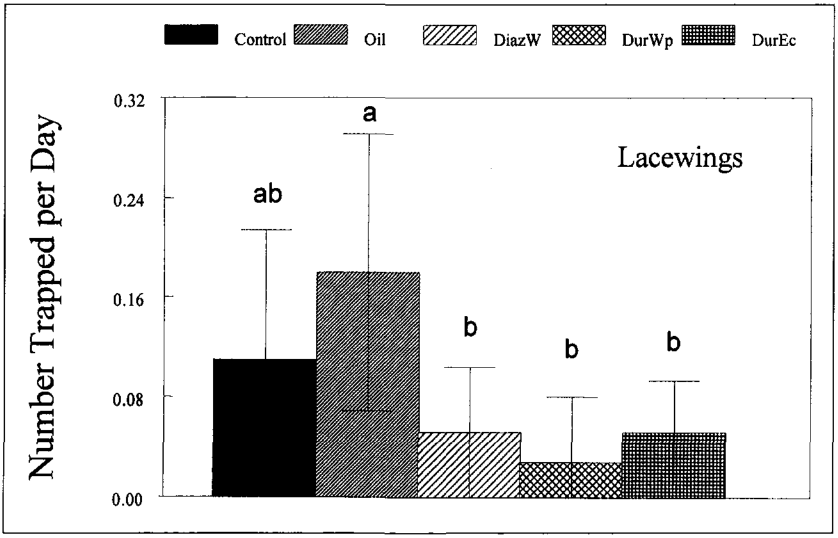


**Figure 4. Effects of horticultural oil (Oil), diazinon wettable powder (DiazW), Dursban wettable powder (DurWp), and Dursban emulsifiable concentrate and horticultural oil (DurEc) on lacewings trapped in the canopies of pin oaks over a 6-week period following the application of insecticides. Bars represent mean numbers of lacewings trapped per tree, and vertical lines represent standard errors. Treatment means that share a common letter did not differ significantly by a Duncan's multiple-range test (*P* = 0.05).**

ing populations of obscure scale on pin oaks (Stoetzel and Davidson 1971; Pinto 1980; Potter et al. 1989; Ehler 1995). We found three of these wasps, *Physcus varicornus, Ablerus clisiocampae,* and *Coccophagus fuscipennis,* to be common in our traps on two of the sample dates. As with the other groups of natural enemies, these parasitoids were adversly affected by the insecticide sprays containing chlorpyrifos and diazinon. Furthermore, chlorpyrifos and diazinon generally had a much greater adverse effect on scale parasites than oil. One exception was observed on the third sampling date for the parasitoid *P. varicornus.* On this date, *P. varicornus* populations were reduced on trees treated with horticultural oil (Figures 5 and 6).

Residual insecticides such as diazinon and chlorpyrifos can cause a significant reduction in the abundance of natural enemies found in the canopies of trees. Moreover, this effect can be relatively long lasting for important groups of natural enemies such as the tiny parasitoids that attack scale insects. Populations of the three most common species of obscure scale parasitoids were suppressed 1 month after the application of insecticides. These results also support those of previous researchers who have noted that horticultural spray oil appears to have little lasting impact on communities of natural enemies (Morse et al. 1987), while residual insecticides can have major and lasting repercussions for beneficial insect communities. Outbreaks of scale insects have been documented in orchards where residual pesticides have reduced or eliminated populations of scale predators and parasites (Michelbacher and Hitchcock 1958; DeBach 1969, 1974; Clarke et al. 1992).

## CONCLUSIONS

Applications of cover sprays to residential landscapes over prolonged periods of time have the potential to exacerbate problems with many species of scale insects. Although the mechanism underlying this result was not elucidated, our ex-

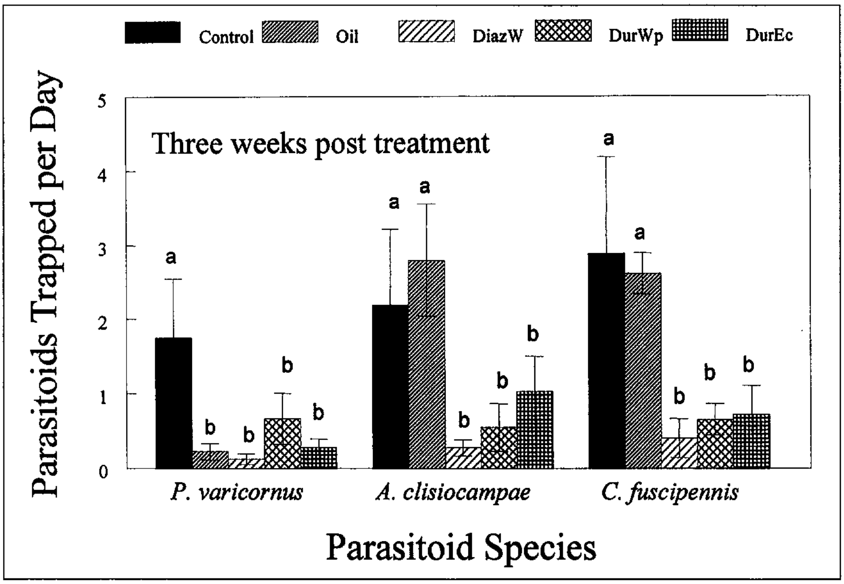


**Figure 5. Effects of horticultural oil (Oil), diazinon wettable powder (DiazW), Dursban wettable powder (DurWp), and Dursban emulsifiable concentrate and horticultural oil (DurEc) on three species of obscure scale parasitoids trapped in the canopies of pin oaks 3 weeks following the application of insecticides. Bars represent mean numbers of parasitoids trapped per tree, and vertical lines represent standard errors. Treatment means that share a common letter did not differ significantly by a Duncan's multiple-range test ($P$ = 0.05).**

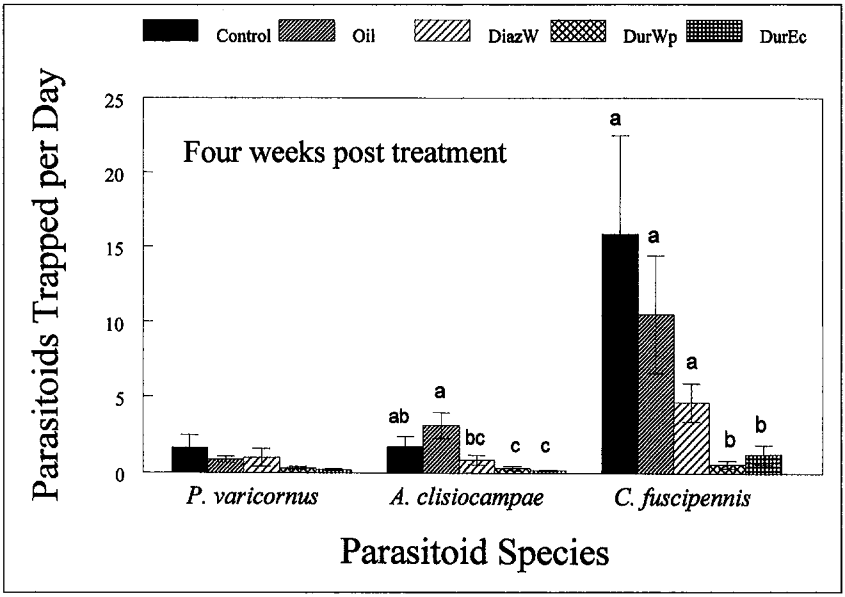


**Figure 6. Effects of horticultural oil (Oil), diazinon wettable powder (DiazW), Dursban wettable powder (DurWp), and Dursban emulsifiable concentrate and horticultural oil (DurEc) on three species of obscure scale parasitoids trapped in the canopies of pin oaks 4 weeks following the application of insecticides. Bars represent mean numbers of parasitoids trapped per tree, and vertical lines represent standard errors. Treatment means that share a common letter did not differ significantly by a Duncan's multiple-range test ($P$ = 0.05).**

perimental data suggest that repetitive cover sprays could selectively remove natural enemies from landscapes. This may have allowed scale populations to increase. The application of residual pesticides to the canopies of oak trees significantly reduced the abundance of several taxa of natural enemies. Populations of three species of parasitoids of obscure scale were reduced 4 weeks after diazinon and chlorpyrifos were applied. Horticultural oil had little effect on the natural enemy community in oak canopies. Practices such as well-timed spot treatments or targeted insecticide applications based on biological observations should be substituted for cover sprays whenever possible. Likewise, insecticides with short periods of residual activity should be substituted for residual materials that kill natural enemies. By increasing the adoption of these two practices, arborists and landscape managers can help conserve natural enemies found in urban forests and thereby play an active role in enhancing the sustainability of these vital members of urban forest communities.

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**Acknowledgments.** We are grateful to the many homeowners in the suburban Maryland communities who allowed the use of their landscapes as study sites. We also thank the Department of Physical Plant of the University of Maryland at College Park for assisting in the study. Two anonymous reviewers provided helpful editorial comments to the manuscript. Although this work was funded in part by the United States Environmental Protection Agency, it does not necessarily reflect the position or opinion of the EPA.

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**Résumé.** L'emploi de vaporisations généralisées et d'insecticides persistants sont des tactiques utilisés par les jardiniers et les arboriculteurs pour contrôler les arthropodes parasites sur les arbres et les arbustes dans les zones urbaines. Les arbres dans les aménagements résidentiels qui ont reçu trois vaporisations généralisées annuellement et pendant au moins quatre années consécutives abritaient une plus grande diversité de cochenilles parasites et étaient plus sujets à en être infestés que les arbres traités avec des vaporisations généralisés sur de plus courtes périodes de temps. Les chênes d'une institution qui étaient traités avec des insecticides persistants abritaient des quantités significativement moindre d'arthropodes bénéfiques que les arbres traités avec un produit antiparasitaire non persistant. L'effet d'élimination des insecticides persistants sur les ennemis naturels était prononcé au sein de la communauté de guêpes parasites qui attaquent le *Melanaspis obscura*, une cochenille parasite commune chez le chêne. L'effet des insecticides persistants sur les espèces de guêpes parasites durait quatre semaines après que les pesticides étaient appliqués. En diminuant l'emploi de vaporisations généralisées ainsi que celle des insecticides persistants, les arboriculteurs pourraient être capable de conserver des communautés d'ennemis naturels au sein des aménagements paysagers. Ceci va permettre d'augmenter la diversité biologique d'insectes bénéfiques dans les forêts urbaines et ainsi assurer leur maintien accru.

**Zusammenfassung.** Deckende Sprays und rückstandsbildende Insektizide werden von Landschaftsgärtnern und Arboristen gerne eingesetzt, um Gliederfüßer auf Bäumen und Büschen in Gärten zu kontrollieren. Bäume in besiedelten Landschaften, die jährlich drei Spritzungen für mindestens vier Jahre erhalten haben, beherbergen eine größere Anzahl an Schildläusen und sind viel anfälliger, von Insekten besiedelt zu werden, als Bäume in der Landschaft, die über einen kürzeren Zeitraum Spritzungen erhielten. Eichenbäume in einer institutionalisierten Landschaft, die mit rückstandsbildenden Insektiziden behandelt wurden, beherbergten deutlich geringere Anzahlen von Nützlingen als die Bäume, die eine Pestizidbehandlung ohne die rückstandsbildende Wirkung erhalten hatten. Der unterdrückende Effekt von diesen Insektiziden auf natürliche Feinde war in der Gemeinde angekündigt als Attacke von parasitisierenden Wespen auf die gemeine Schildlaus *Melanaspis obscura*, die ziemlich häufig auf eiche vorkommt. Der Effekt dieser Insektizide auf individuelle Wespenarten hielt für ca. 4 Wochen nach der Aufbringung. Durch das Reduzieren und den eingeschränkten Gebrauch des Insektizids, können Arboristen in die Lage versetzt werden, Nützlingspopulationen in bewirtschafteten Landschaften zu erhalten. Das kann die biologische Diversität von Nützlingen in Stadtforstanlagen vebesseren und ihre Nachhaltigkeit zu erhöhen.

**Resumen.** Los spray de cobertura y los insecticidas residuales son tácticas usadas por los paisajistas y arboristas para controlar plagas de artrópodos en árboles y arbustos en localidades urbanas. Los árboles en áreas residenciales que reciben spray de cobertura anualmente por al menos cuatro años, mantuvieron una mayor diversidad de plagas de insectos de escamas y fueron mucho más susceptibles a plagarse con escamas, que los árboles tratados con spray de cobertura por cortos períodos de tiempo. Árboles de encino en áreas institucionales tratados con insecticidas residuales mantuvieron significativamente un menor número de artrópodo benéficos que los árboles tratados con un pesticida de menor actividad residual. El sorprendente efecto de los insecticidas residuales sobre los enemigos naturales fue más pronunciado en las comunidades de avispas parásitas que atacan la escama oscura (*Melanaspis obscura*), una plaga de escama común en el encino. El efecto de los insecticidas residuales sobre especies individuales de avispas persistió cuatro semanas después que los pesticidas fueron aplicados. Reduciendo el uso de insecticidas de spray e insecticidas residuales, los arboristas pueden ser capaces de conservar las comunidades de enemigos naturales en áreas manejadas. Esto realzará la diversidad biológica de insectos benéficos, encontrados en los bosques urbanos, y por tanto, se incrementará su sustentabilidad.