14. Wargo, P.M. 1988. Judging vigor of deciduous hardwoods. USDA Agr. Info. Bull. No. 418.
15. Waring, R.H. and W.H. Schlesinger. 1985. Forest Ecosystems: Concepts and Management. Academic Press, N.Y. 340 pp.

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EUONYMUS SCALE PATTERNS OF DAMAGE TO WOODY PLANTS[1]

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Abstract. Armored scale insects include species which feed primarily on stems and those which feed on both leaves and stems. The euonymus scale is an example of the latter. Scales which feed on leaves produce a chlorotic halo that is deficient in chloroplasts. Infested leaves have impaired photosynthesis and are prone to abscission. Healthy plants may tolerate and outgrow injury from scale insects, but infested plants that experience additional environmental stress may suffer severe leaf abscission and branch dieback. Early detection of infestations and management to minimize plant stress are helpful in maintaining woody landscape plants that are susceptible to scale insect infestations.

Les cochenilles incluent des espèces qui s'alimentent principalement sur les tiges et d'autres qui s'alimentent à la fois sur les feuilles et les tiges. La cochenille du fusian est un exemple du dernier groupe. Les cochenilles qui s'alimentent sur les feuilles produisent une chlorose auréolée qui est déficiente en chloroplastes. Les feuilles infestées ont une photosynthèse réduite et sont encleintes à l'abscission. Les plantes en bon état de santé peuvent tolérer et surmonter les dommages causés par les cochenilles, mais les plantes infestées qui subissent des stress environnementaux additionnels peuvent souffrir de sévères chutes de feuilles et de dépérissement sur les branches. Une détection précoce des infestations et une gestion qui minimise les stress sur la plante sont utiles pour le maintien de plantes ligneuses ornementales qui sont susceptibles aux infestations de cochenilles.

Armored scales are tiny insects that are highly specialized to feed on the sap of woody plants. They live most of their lives under a shell of wax, snugly attached to the bark of twigs or branches, or to the leaves of their hosts. As a group, they include some of the most pernicious and difficult to control pests of woody landscape plants (1, 9).

Species of armored scale insects can be divided into two groups: those which feed on both leaf and stem tissue, and those which feed primarily on stems and rarely settle on leaves. The euonymus scale, *Unaspis euonymi,* feeds on both leaves and stems of *Euonymus* spp. and a few other landscape plants. Other armored scales with similar feeding habits include the California red

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scale and the San Jose scale. In work supported in part by a grant from the ISA Research Trust, we studied the impact of the euonymus scale on the growth and physiology of purple wintercreeper, *Euonymus fortunei.* We were especially interested in how environmental stress affects the severity of damage symptoms. This article summarizes the major findings and their implications for the management of armored scales. Details of this investigation have been reported elsewhere (3, 6).

Pest Biology. Two generations of euonymus scales occur each year in the northeastern and central U.S., while in the southern states there may be three or more. Yellow-orange eggs are produced in mid-May to June in the latitude of Kentucky. Females lay from 30 to more than 150 eggs over a period of several weeks (6, 7, 8). After a few days the newly-hatched "crawlers" emerge from under the female's wax covering, usually in early morning. Crawlers are about the size of grains of salt and may look like specks of orange dust on the plant surface. The crawlers settle on leaves or stems and insert their long, needle-like mouth-parts into the plant tissues. Soon afterward, their legs become non-functional and they begin to secrete a waxy shell or covering.

Male and female euonymus scales are so different in appearance, development, and behavior that they could easily be mistaken for separate species. Males produce a slender, white covering, and may be abundant on both stems and leaves, whereas females, which secrete a wider, gray covering, are more common on stems. Males feed for about a month, after which they molt into a tiny winged adult and emerge to search for a mate (6, 7, 8). Adult females remain eyeless and legless underneath their wax coverings where they continue to feed.

A second generation is produced in late summer in the northeast and central states. Adults of this second generation first appear in August and September. The males die after mating, and the fertilized females overwinter on the plant until new leaves appear and a new generation of eggs is laid in May or June (6, 7, 8).

Damage Symptoms. When armored scales feed on leaf tissue, a chlorotic halo develops around the feeding site. This is caused by destruction of the chloroplasts in nearby cells (5). Whether the scales feed from the upper or lower leaf surface, their mouthparts meander between cells until they reach the phloem (8). Destruction of chloroplasts is therefore an indirect effect of feeding, possibly linked to ethylene production from a few mechanically-wounded cells, or to a toxin secreted by the scale into the feeding site (2). Females are less common than males on leaves, but because they are larger and feed for a longer period, they cause up to 10 times more chlorosis (5).

Degradation of chloroplasts may enhance the nutritional quality of the scale insects' food by releasing amino acids into the phloem tissue (11). These compounds are relatively scarce in the phloem of healthy plants, and increases in their concentration are associated with improved growth, reproduction, and survival of some types of sucking insects (10).

Infested, chlorotic leaves of purple wintercreeper have a reduced rate of photosynthetic CO_2 assimilation (5). This may lead to a lower acquisition and storage of food in scale-infested plants, which compounds the loss caused by direct removal of sugars and amino acids by the insects themselves.

Infested leaves are prone to premature abscission once they have become chlorotic (3, 4, 5, 6). Increased leaf drop of scale-infested plants is common in early summer, when feeding males are abundant. It also occurs at other times of the year, especially during the natural periods of leaf abscission of purple wintercreeper (e.g., autumn and early spring) when females are present (6). As a result of increased leaf abscission and reduced CO_2 assimilation, severe infestations of scale insects reduce the amount of living leaf and stem tissue on the host plant (3, 4, 6).

Eventually, the growth of root tissue is reduced. In a field study, root weight reduction of scale-infested *Euonymus* occurred months after severe leaf abscission and branch dieback were apparent (6). Thus, lightly damaged plants usually grow back quickly, suggesting that temporary scale infestations present few chronic problems for vigorous woody plants if the insects are controlled in time.

Interaction of Environmental Stress and Scale Injury. Although scale insect infestation alone can induce significant chlorosis and leaf abscission, the impact of scales may be even greater when it occurs in combination with environmental stress. In a greenhouse experiment, we found that the combination of severe water stress and euonymus scale injury caused much greater leaf abscission than occurred with either stress alone (3). In the field, scale-infested plants suffered greater injury from winds and freezing during winter than did non-infested plants (6). Other types of environmental stress may have the same effect. Because individual plants in the landscape are exposed to varying degrees of stress, it is difficult to predict the effect of a given population level of armored scales on particular woody plants.

The heightened susceptibility of scale-infested leaves to abscission may be related to other physiological changes which occur when the chlorotic spots develop. We found that infested leaves had higher stomatal resistance, lower rates of transpiration, and a slightly higher temperature than uninfested leaves under the same environmental conditions (3).

Implications for Pest Management. These research findings have practical implications for arborists and landscape managers who deal with infestations of armored scales. Since vigorous plants are more tolerant of insect injury and recover more quickly, pest management for euonymus and other woody plants should begin with use of well-adapted cultivars, selection of a suitable planting site, and sound horticultural care. Even moderate infestations can be troublesome if they go undetected and the plants are further stressed by summer drought or severe winter cold.

Like the euonymus scale, many scale insects (e.g., pine needle scale, obscure scale, tuliptree scale) are relatively restricted in their host preferences and tend to be serious pests on only a few species of plants. Regular inspections, such as provided by an IPM scouting program (12), are advisable for susceptible plants. Because of their high fecundity and capacity for several generations per year, presence of a few scales in early summer may portend an outbreak by late autumn. Although the white, elongate males of euonymus scale are conspicuous on the leaves, females on the stems are easily overlooked, especially in the early spring when males are absent. Other scale species can be even more cryptic than euonymus scales. Landscape managers and nursery personnel should be alert for symptoms of chlorosis, leaf shed, and dieback that accompany scale insect infestations.

Literature Cited

1. Beardsley, J.W. and R.H. Gonzales. 1975. *The biology and ecology of armored scales.* Ann. Rev. Entomol. 20:47-73.
2. Carter, W. 1973. Insects in Relation to Plant Disease (2nd ed.) J. Wiley and Sons, New York. 759 pp.
3. Cockfield, S.D. and D.A. Potter. 1986. *Interaction of euonymus scale (Homoptera: Diaspididae) feeding damage and severe water stress on leaf abscission and growth of Euonymus fortunei.* Oecologia 71:41-46.
4. Cockfield, S.D. and D.A. Potter. 1987. *Distribution, development, and feeding impact of euonymus scales (Homoptera: Diaspididae) on Euonymus fortunei under greenhouse conditions.* Environ. Entomol. 16:917-921.
5. Cockfield, S.D., D.A. Potter, and R.L. Houtz. 1987. *Chlorosis and reduced CO_2 assimilation of Euonymus fortunei infested with euonymus scale (Homoptera: Diaspididae).* Environ. Entomol. 16:1314-1318.
6. Cockfield, S.D. and D.A. Potter. 1990. *Euonymus scale (Homoptera: Diaspididae) effects on plant growth and leaf abscission, and implications for differential site selection by male and female scales.* J. Econ. Entomol. *In press.*
7. Gill, S.A., D.R. Miller, and J.A. Davidson. 1982. Bionomics and taxonomy of the euonymus scale, *Unaspis euonymi* (Comstock), and detailed biological information on the scale in Maryland (Homoptera: Diaspididae). Misc. Publ. Md. Agric. Expt. Sta. no. 969.
8. Greenwood, R.A. 1969. Seasonal history and chemical control of the euonymus scale, *Unaspis euonymi* (Comstock), near Ithaca, New York. M.S. Thesis, Cornell Univ. 104 pp.
9. Kielbaso, J.J. and M.K. Kennedy. 1983. Urban forestry and entomology: a current appraisal. pp. 423-440. **In:** Urban Entomology: Interdisciplinary Perspectives. Praeger Publ., New York.
10. Mattson, W.J. 1980. *Herbivory in relation to plant nitrogen content.* Ann. Rev. Ecol. Syst. 11:119-161.
11. Sexton, R. and H.W. Woolhouse. 1984. Senescence and abscission. pp. 469-497. **In:** Advanced Plant Physiology. Pitman, London.
12. Raupp, M.J. 1985. *Monitoring: an essential factor to managing pests of landscape trees and shrubs.* J. Arboric. 11:349-355.

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