Differential Susceptibility of Six *Euonymus* Species and Cultivars to Euonymus Scale, *Unaspis euonymi* (Comstock)[1]

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Abstract

The susceptibility of *Euonymus* species and cultivars to infestation by euonymus scale was studied in both field-grown and container plants. Significantly lower levels of euonymus scale were observed on *Euonymus kiautschovicus* 'Manhattan', *E. japonicus*, and *E. fortunei* in the field studies. In contrast, *E. japonicus* 'Albo-marginatus' and *E. japonicus* 'Microphyllus' had the highest infestation levels, indicating greater susceptibility to euonymus scale. In container studies, *E. japonicus* 'Albo-marginatus' was the most susceptible of the species and cultivars; however, none of the remaining 5 differed significantly from one another.

Index words: euonymus scale infestation, cultivar susceptibility.

Species used in this study: Euonymus scale (*Unaspis euonymi* (Comstock); 'Manhattan' (*E. kiautschovicus* Loes.); Evergreen Euonymus (*E. japonicus* Thunb.); Wintercreeper (*E. fortunei* (Turcz.) Hand.-Mazz.); *E. japonicus* 'Albo-marginatus'; *E. japonicus* 'Microphyllus'.

Significance to the Nursery Industry

This study identifies the susceptibility of 6 *Euonymus* species and cultivars to infestation of euonymus scale. The significantly lower levels of euonymus scale infesting *E. kiautschovicus* 'Manhattan', *E. japonicus* and *E. fortunei* in field studies indicate that these are desirable selections for landscape production. In contrast, *E. japonicus* 'Albo-marginatus' and *E. japonicus* 'Microphyllus' in landscape plantings would likely be more susceptible to euonymus scale infestation. These susceptible cultivars can still be successful in the landscape, as euonymus scale can be suppressed using integrated pest management practices including the release of *Chilocorus kuwanae* (Silvestri), an introduced ladybird beetle, and applications of horticultural oils or insecticidal soaps.

Introduction

Euonymus scale, *Unaspis euonymi* (Comstock) (Homoptera: Diaspididae), is a serious pest of landscape shrubs in the United States. It attacks a number of hosts including species in the genera *Euonymus*, *Pachysandra*, and *Celastrus* with *Euonymus* being its primary host. Symptoms of initial infestation are yellow or white spotting on the foliage. Heavier infestation results in encrustation of stems by females and foliar discoloration by male feeding that results in defoliation and subsequent plant death.

Euonymus ranked 12 in a survey of the 20 most commonly used landscape plants (4). It exhibits a wide variety of growth forms including ground covers, climbing vines, and both evergreen and deciduous shrubs. Selections of *Euonymus japonicus* (Thunb.) and *Euonymus fortunei* (Turcz.) have resulted in variegated cultivars that are popular in urban landscapes.

Euonymus scale was apparently introduced from Asia (3). Mature, inseminated females overwinter on the stem and leaf veins of the host plant. Eggs are deposited in early spring (June in Ohio and New York) beneath the female test. In Virginia, eggs hatch in May, with a second generation hatching in August. Dennis (1) obtained control with several insecticides, but observed that no effective method of nonchemical control had been found. Cultural control, by selection of cultivars showing resistance, is a long-term, nonchemical option. The objective of this study was to evaluate several *Euonymus* species and cultivars for susceptibility to euonymus scale infestation.

Materials and Methods

Field study. In September 1990, 24 plants of each of 6 *Euonymus* species and cultivars of different growth habits, foliage colors and variegation patterns were planted at Hampton Roads Agricultural Research and Extension Center, Virginia Beach, VA. The field planting was in a completely randomized design. The following species and cultivars were included: *Euonymus japonicus* (Thunb.), *E. japonicus* 'Microphyllus', *E. japonicus* 'Aureus', *E. japonicus* 'Albo-marginatus', *E. fortunei* (Turcz.), and *E. kiautschovicus* (Loes.) 'Manhattan' (2).

On May 10 1992, in conjunction with the first crawler emergence period, scale-infested twigs were removed from a hedge of *E. japonicus* located near the AREC. The twigs were cut to a length of 10 cm (4 in) and the ends of the twigs were dipped in paraffin wax to retard desiccation. Two 10 cm (4 in) twigs were then tied to current season's growth on each plant in the field plots for one week, and then removed. In November 1993, after four generations, the scale population densities on each plant in the study were rated and assigned the following scores: 0 = none (no scale observed after 1 minute examination), 1 = low infestation (1-2 scattered areas of scale tests on foliage, 2 = medium infestation (leaves and stems covered with white specks [male scales]), 3 = heavy, non-continuous infestation (leaves and stems covered with a brown crust of female scales, large numbers of male scales on leaves), and 4 = continuous infestation (leaves

[1]Received for publication March 28,1995; in revised form June 26, 1995. **This project was supported in part by the Horticultural Research Institute, Inc. 1250 I Street, N.W., Suite 500, Washington, DC 20005**, by the Virginia Nurserymen's Association, and by the Virginia Agricultural Experiment Station.

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Table 1. Mean euonymus scale density rating in field plots.

Euonymus species and cultivars	Mean score (SE)[z] 1993	1994
E. japonicus 'Albo-marginatus'	1.80 (.41)a	0.67(.33)b
E. japonicus 'Microphyllus'	1.74 (.29)a	1.40(.27)a
E. japonicus 'Aureus'	0.87 (.27)bc	0.35(.15)bc
E. fortunei	0.53 (.19)c	0.12(.12)c
E. kiatschovicus 'Manhattan'	0.00c	0.00c
E. japonicus	0.04 (.04)c	0.04(.04)c

[z]Means within columns followed by the same letter are not significantly different ($P > 0.05$; Tukey's test); mean scores: 0 = none, 1 = low infestation, 2 = medium infestation, 3 = heavy, non-continuous infestation, 4 = heavy, continuous infestation. Values in parentheses are standard errors of the mean (SE).

and stems of entire plant covered with female and male scales) . An analysis of variance (ANOVA) was performed to determine if there were any significant differences among species and cultivars and the degree of infestation (P = 0.05). Tukey's honestly significant difference (HSD) test was used to compare means (5).

Container study. On July 1, 1992, stem cuttings were taken from each of the six *Euonymus* species and cultivars for propagation (Table 1). Each cutting was inserted in a 15 cm (6 in) pot containing a mixture of peat moss and pine bark (1:2 by vol). The containerized cuttings were then placed in a ventilated high humidity propagator (Humidifan, Jaybird Manufacturing, Centre Hall, PA) to promote rooting. After rooting, plants were placed for one month under shade-cloth that permitted 45% light penetration to facilitate acclimation to ambient conditions. The containerized *Euonymus* were then transferred to a growing area where they received daily overhead irrigation. Plants were overwintered in an unheated greenhouse. On May 5, 1993, plants were removed from the greenhouse and placed beneath the shade fabric to protect plants and insects from rainfall and desiccation.

Beginning May 1, 1993, scale-infested landscape plants were examined daily to determine the onset of crawler emergence. On May 11, 1993, crawler emergence was observed, and branches of previous year's growth from a heavily infested *E. japonicus* landscape plant were used to inoculate the plants. Two freshly cut 10 cm (4 in) twig sections were tied to each plant in 12 blocks containing one plant of each of six species and cultivars of the year-old, container-grown euonymus plants and replaced at 2-day intervals for six days. During the inoculation process, the plants were placed in darkness at 27C (80F) and 70% RH to minimize mortality. On May 18, 1993, following crawler transfer, the newly infested plants were placed under shade fabric with 45% light penetration, and settled first instar nymphs were counted. Subsequent counts of surviving scales were made June 1 and 15. The density of scale insects (scales/cm of stem length) was recorded at each counting date. A two-way analysis of variance (ANOVA) for a randomized complete block design was carried out using block and cultivar as class variables. Where statistically significant differences were found (P = 0.05), Tukey's HSD mean comparison procedure was used to compare means.

Table 2. Mean scale density on each of six container-grown *Euonymus* species and cultivars.

Euonymus species and cultivars	Mean scale density (SE)[z] May 18	June 1	June 15
E. japonicus 'Albo-marginatus'	5.90 (.31)a	4.90 (.32)a	3.32 (.20)a
E. japonicus 'Microphyllus'	4.34 (.31)ab	3.30 (.26)ab	1.78 (.15)ab
E. japonicus 'Aureus'	1.40 (.13)b	1.51 (.14)b	1.10 (.11)b
E. fortunei	2.78 (.27)ab	2.74 (.19)ab	0.92 (.12)b
E. kiatschovicus 'Manhattan'	5.65 (.38)a	4.80 (.32)a	1.66 (.13)ab
E. japonicus	2.71 (.30)ab	2.16 (.13)ab	1.16 (.09)b

[z]Means within columns followed by the same letter are not significantly different ($P > 0.05$; Tukey's test); mean scores: 0 = none, 1 = low infestation, 2 = medium infestation, 3 = heavy, non-continuous infestation, 4 = heavy, continuous infestation. Values in parentheses are standard errors of the mean (SE).

Results and Discussion

Field study. Initial, observable crawler transfer on the field-grown *Euonymus* in 1992 was successful on only a few plants; thus, no counts were taken. Each plant was re-examined in fall 1993, after euonymus scale had completed 4 generations, and assigned a scale density rating. These ratings showed significant differences in infestation levels among the six different *Euonymus* species and cultivars (F = 11.19, df = 121, P < 0.001). Lowest density ratings were on the species and cultivars *E. japonicus*, *E. kiautschovicus* 'Manhattan', and *E. fortunei*; significantly lower than *E. japonicus* 'Albo-marginatus' and *E. japonicus* 'Microphyllus', but not significantly different from *E. japonicus* 'Aureus' (Table 1). In 1994, *E. japonicus* 'Microphyllus' had significantly greater scale density than the other species and cultivars. In both years, *E. kiautschovicus* 'Manhattan', *E. japonicus, and E. fortunei* had signficantly lower densities than *E. japonicus* 'Albo-marginatus' and *E. japonicus* 'Microphyllus'.

Container study. Analysis of scale survival data on container-grown *Euonymus* showed trends similar to field-grown plants. *Euonymus japonicus* 'Albo-marginatus' and *E. japonicus* 'Microphyllus' had the two highest average scale densities, the former being significantly greater than three of the remaining five species and cultivars at the conclusion of the study (Table 2). Scale survival was non-uniform between species and cultivars over the six weeks subsequent to crawler emergence. Initially (May 18), *E. japonicus* 'Albo-marginatus' and *E. kiautschovicus* 'Manhattan' showed highest settled crawler densities. However, by the final count (June 15), *E. kiautschovicus* 'Manhattan' had dropped in rank and *E. japonicus* 'Albo-marginatus' and *E. japonicus* 'Microphyllus' had the two highest average scale densities (Table 2). Although *E. kiautschovicus* 'Manhattan' had the second highest initial scale density, the scale on this cultivar sustained 80% mortality, the highest level of mortality between the initial and final counts of all six species and cultivars. *Euonymus japonicus* 'Aureus' showed the lowest initial settled crawler density of the six species and cultivars, and subsequently the least mortality. The lack of separation in the container study could be attributed to the termination of the study after six weeks, compared to the two year time period for the field study.

The results of this study, which uses *E. japonicus* as the source plant, identify the susceptibility of *Euonymus* species and cultivars to infestation of euonymus scale. The significantly lower levels of euonymus scale on *E. kiautschovicus* 'Manhattan' in the field study make this a desirable selection for landscape production. In contrast, the use of *E. japonicus* 'Albo-marginatus' and *E. japonicus* 'Microphyllus' in landscape plantings would likely be more susceptible to euonymus scale infestation. These susceptible cultivars can still be successful in the landscape, as euonymus scale can be suppressed using integrated pest management practices including the release of *Chilocorus kuwanae* (Silvestri), an introduced ladybird beetle, and applications of horticultural oils, insecticidal soap, or conventional insecticide.

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Seed Source Affects Seedling Development and Nitrogen Fixation of *Maackia amurensis*[1]

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Abstract

Seeds of *Maackia amurensis* Rupr. & Maxim. were obtained from 38 sources, and 2,393 seedlings were examined for variation in plant growth and development. Mean stem length and number of leaves per plant after 21 months ranged from 10 to 40 cm (4 to 16 in) and from 6 to 13, respectively, among seedlings from different sources. The mean product of length and width of a representative leaflet was 362 to 1510 mm^2 (0.6 to 2.3 in^2) among sources. A subset of seven seed sources was used to determine how seedling growth, root nodulation, and N content of shoots are influenced by applied N and inoculation with *Bradyrhizobium*. Plants from the seven sources varied in nodule dry mass and shoot N. Mean stem length, laminar area, and dry mass of plants provided N and grown in uninoculated medium were higher than those of plants not provided N regardless of inoculation. When N was not provided, inoculation increased N in shoots but did not affect growth. Nodule dry mass of plants in inoculated medium was correlated positively with surface area of lamina. Variation among seedlings provides a basis for selecting genotypes that produce high nodule mass and grow rapidly.

Index words: Amur maackia, *Bradyrhizobium*, sustainable production.

Significance to the Nursery Industry

Maackia amurensis has potential for increased use in small and urban landscapes, but little attention has been given to selecting superior forms. This project focused on variation among plants we grew from seeds collected from 38 sources at 17 locations in the United States. Variation in growth among seedlings from all sources was determined in the first experiment because slow growth of plants in nurseries may be discouraging production of this species. In a second experiment, variation in root nodulation, N content of shoots, and plant growth were assessed among seedlings from seven sources. Both experiments demonstrated potential to select genotypes that grow quickly and nodulate well with rhizobial bacteria. This project provides the basis for long-term research we are conducting to identify genotypes of *M. amurensis* that are particularly well-adapted for low-input nursery production and survival in landscapes with infertile soils.

Introduction

Maackia amurensis is a tree species in the Fabaceae with traits desirable for landscaping (3, 7), and this species forms root nodules in which nitrogen gas (N_2) is fixed by rhizobial bacteria (2). Management of N_2 fixation by growers of *M. amurensis* might facilitate nursery production with low inputs of N fertilizer and improve the performance of trees at landscape sites with infertile soils.

Commercial production and use of *M. amurensis* are limited, perhaps because plants of this species grow slowly. Dirr (4) noted that shoot height of trees has been reported by others to increase by only 3.7 m (12 ft) over 20 years. Seedlings also grow slowly. Seedling mass of two other legumes, *Gleditsia triacanthos* L. var. *inermis* Willd. (thornless honey locust) and *Sophora japonica* L. (Japanese pagoda tree), was

[1]Received for publication March 28, 1995; in revised form June 6, 1995. Journal paper no. J-16282 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa. Project no. 3229. **This research was funded by a grant from the Horticultural Research Institute, Inc., 1250 I Street, N.W., Suite 500, Washington, DC 20005.**

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