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Host Plant Suitability of the Orangestriped Oakworm (*Lepidoptera: Saturniidae*)[1]

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Abstract

Orangestriped oakworm, *Anisota senatoria* (J. E. Smith), suitability for oak (*Quercus* sp.) was determined by tree defoliation, percentage survival, developmental rate, pupal weight and oviposition. Suitable hosts, from the greatest to the least, were determined for the following oak species grown in southeastern Virginia: pin oak (*Quercus palustris*), scarlet oak (*Q. coccinea*), willow oak (*Q. phellos*), northern red oak (*Q. rubra borealis*), and sawtooth oak (*Q. acutissima*); intermediate in swamp white oak (*Q. bicolor*), chestnut oak (*Q. prinus*), southern red oak (*Q. falcata*), bur oak (*Q. macrocarpa*), and water oak (*Q. nigra*); and least in white oak (*Q. alba*). Planting less suitable species in the urban landscape, like white oak (*Q. alba*), may contribute to lower *A. senatoria* populations.

Index words: Orangestriped oakworm, *Anisota senatoria*, oak suitability.

Species used in this study: White oak (*Quercus alba* L.); sawtooth oak (*Q. acutissima* Carruth.), swamp white oak (*Q. bicolor* Willd.); scarlet oak (*Q. coccinea* Michx.); southern red oak (*Q. falcata* Michx.); bur oak (*Q. macrocarpa* Michx.); water oak (*Q. nigra* L.); pin oak (*Q. palustris* Muench.); willow oak (*Q. phellos* L.); chestnut oak (*Q. prinus* L.); northern red oak (*Q. rubra borealis* Michx. f.).

Significance to the Nursery Industry

Orangestriped oakworm, *Anisota senatoria* (J. E. Smith), has become a serious pest of oak trees in nurseries and landscapes in some areas of North America. Identification of less suitable oak species will be an important component of an integrated pest management (IPM) strategy for this pest. This research evaluated 11 oak species for suitability by *A. senatoria* and found that pin oak (*Q. palustris*) was one of the most suitable species while white oak (*Q. alba*) was less suitable. We recommend that growers who have *A. senatoria* populations select less suitable oak species, like white oak, as components of an IPM program.

Introduction

Host plant suitability by insects can be defined as a behavioral response where plants within an insect's host plant range are more acceptable to the insect, while host plant preference is similar, but insects are provided a choice and plants are selected instead of others (3). Host plant suitability, host plant preference, and insect-resistant trees and shrubs are important IPM strategies (22). Host plant suitability and host plant preference has been documented for several shade tree pests including the Asiatic oak weevil (15), gypsy moth (1, 23), and carpenterworm (27). Cultivar suitability and preference for trees and shrubs by mimosa webworm (2) and hawthorn lace bug (26) has been identified. Factors evaluated in suitability and preference studies are larval survival, development rate, consumption, longevity, pupal weight, oviposition, fecundity, and defoliation.

Orangestriped oakworm is native to the United States and has caused widespread defoliation of oaks in southeastern Virginia (5, 7). IPM strategies using aesthetic injury levels (6) and biological control (8) have been implemented. Adults emerge from overwintering pupae in late June to late July and mate on grass blades or tree trunks. Yellow eggs are oviposited during July on leaf undersides on terminal twigs in masses of 200–700. Early instars are gregarious and skeletonize leaves, whereas fourth and fifth instars consume entire leaves except the main vein. During September, larvae migrate from defoliated trees and burrow 7-10 cm (2.5-4.0 in) in the soil and pupate. There are one and possibly two generations per year, depending on location. A second generation occurred from September to December in Virginia Beach, VA (9).

Only observational information has been collected on *A. senatoria* host suitability. The literature suggests that oaks are more suitable (18), but birch (*Betula*) (10, 16), maple (*Acer*), hazelnut (*Corylus*) and hickory (*Carya*) species are susceptible (19, 4). Observations indicated that oak suitability by *A. senatoria* varied between the southern and northern regions of the United States, and with the prevalence of certain species grown in these regions (20, 21, 13, 14, 17, 24).

The objectives of this study were to identify *A. senatoria* suitability among oak species by determining tree defoliation, percentage *A. senatoria* survival, developmental rate, pupal weight and oviposition.

Materials and Methods

1989 field experiments. All of the oak species evaluated for *A. senatoria* suitability in this study are found in southeastern Virginia (11) and planted in nurseries and urban landscapes. Eleven oak species were planted in November 1985, in a completely randomized design (CRD) at the Hampton Roads Agricultural Experiment Station (HRAES), Virginia Beach, VA. There were 12 trees of each species, and trees were received bare root from the same nursery.

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Trees were approximately 1 m (3.3 ft) in height when planted. Oak species included in these evaluations were: sawtooth oak, white oak, swamp white oak, scarlet oak, southern red oak, bur oak, water oak, pin oak, willow oak, chestnut oak, and northern red oak.

On July 11, 1989, one egg mass (mean = 505 ± 18.2 eggs) per tree was pinned on leaf undersides of 10 oak species mentioned above, excluding water oak. These egg masses were initially collected from pin oak and willow oak. Water oak was the only species that had grown poorly and did not have sufficient foliage to support one egg mass. The other oak species were approximately equal in foliage and growth. The number of tree replicates ranged from three to ten (Table 1). Observations in 1988 indicated that one egg mass placed on individual trees was capable of causing 90-100% defoliation of trees in the CRD plot. Natural populations of *A. senatoria* were prevented from infesting experimental trees by wrapping the trunks with tape coated with petroleum jelly (5). Upon egg eclosion (over 1-3 days), the number of live larvae were recorded. Live larvae were recorded every 5-7 days (4-5 recorded counts) until the fifth instar. All trees were counted for live larvae at the same time by the same individual. Percentage survival was based on counting the number of live larvae per tree that survived to the fifth instar. Defoliation was visually estimated (7) on August 10 after larvae completed feeding. Estimates were made by visually dividing trees into four quadrants (25% of total leaf area) and estimating the percentage leaf area missing.

1990 laboratory experiments. Ten cm (4 in) twig cuttings were taken from the 11 oak species located in the CRD plot. The number of leaves (5-10) varied with species, but the amount of foliage was approximately equal. Five replications per species were maintained, except chestnut oak and bur oak had four. There were a sufficient number of *A. senatoria* eggs (8) pinned on leaf undersides of oak species cuttings to ensure that at least five live larvae were available. Upon egg eclosion, five larvae were established per cutting. Each individual cutting was placed in 100 ml (3.4 oz) water-filled cups placed in separate 19 x 11 cm (7.5 x 4.3 in) plastic boxes. Cuttings were replaced as needed (usually every 3-4 days). Boxes were placed in an environmental chamber maintained at 26.4°C (80°F) (L) and 21°C (70°F) (D) and a photoperiod of 16:8 (L:D). Larvae were examined at the same time each morning. For each instar, the date of 60% larval molting to the next instar from the number of live larvae were recorded. Larvae were reared from first instar to prepupae. Prepupae were placed in laboratory boxes filled with 3 cm (1.1 in) of soil and allowed to pupate. Development time and percent survival in each stage was determined. Percentage survival was based on the number of live larvae entering each stage. The sex of male and female pupae was determined (12) and each pupa was weighed to the nearest 0.01 g (0.28 oz) with a Mettler AE50 balance.

1990 and 1991 ovipositional preference. Trees that were planted in 1985 in the CRD plot were used in 1990 and 1991 field experiments. Trees were planted 6 m (19.6 ft) apart in mulched rows separated by 2 m (6.5 ft) of mowed grass. There were 12 rows of trees and each row had 11 different tree species. In 1990, six trees were dead and a total of 126 trees were available for *A. senatoria* oviposition. Native populations of *A. senatoria* were not established at the HRAES in 1989 or 1990.

In 1990, unmated female and male moths were collected each morning during the last week of June and the first week of July as they emerged from overwintering pupae. Moths were collected in Norfolk, VA, from lawns that had either willow oaks or pin oaks. Moths were placed in screened cages and transported to the CRD plot. Moths were released every 6 m (19.6 ft) in the grass area between rows (12 females, 8 males) and most of the females were observed mating. Gravid females are poor fliers (19) and crawled up tree trunks and oviposited on leaves attached to lower limbs. Moths were released in each of 11 grass areas between rows (total released: 220, 132 female, 88 male) and therefore were provided a choice of trees for oviposition. The number of egg masses and the number of eggs per mass per tree were counted during the last week of July.

In 1991, native HRAES populations of *A. senatoria* that had overwintered from 1990 were used to determine ovipositional preference. Moths were observed ovipositing on trees in the CRD plot during early July. The number of egg masses per tree was counted during the last week of July. Moth counts were not made in 1991 because moth emergence occurred throughout July and it was difficult to obtain accurate counts.

To determine ovipositional preference, the total number of egg masses oviposited in 1990 and 1991 was divided by the total number of trees for each species to obtain the mean number of egg masses per species.

Data were subjected to analysis of variance (ANOVA) and differences between means were tested for significance ($P < 0.05$) with the Waller-Duncan *k* ratio procedure (*k* ratio = 100) (25). Arcsin transformation was performed on percent survival data to maintain homogeneity of variance (28).

Results and Discussion

1989 field experiments. Mean defoliation was significantly ($P < 0.05$) higher on scarlet oak, northern red oak, and pin oak compared with chestnut oak, sawtooth oak and bur oak (Table 1). Mean defoliation was significantly ($P < 0.05$) higher on willow oak compared with sawtooth oak and bur oak. These data may indicate *A. senatoria* suitability for scarlet oak, northern red oak, pin oak and willow oak. Pin oak and willow oak are widely planted and commonly attacked species in southeastern Virginia (5). Defoliation levels in this study can be used as one indicator of host plant suitability by *A. senatoria*. Defoliation levels have been used to determine host plant susceptibility to gypsy moth (23). Leaf consumption by asiatic oak weevil determined preference for several hardwoods (15).

Survival of *A. senatoria* was not significantly ($P > 0.05$) different between oak species (Table 1). Species that had high defoliation (scarlet oak, northern red oak, pin oak, and willow oak) varied in percentage *A. senatoria* survival (from 59.9-81.7%). These data indicate that the amount of leaf consumption was not the only factor that influenced caterpillar survival. Additional factors such as parasitism, leaf microclimate, leaf chemistry, and environmental conditions may have affected survival. The high variability in the survival data showed that these factors should be measured in future research. Furthermore, oaks that had low defoliation but high *A. senatoria* survival, like sawtooth oak and bur oak, may suggest tolerance. Tolerance is the ability of *A.*

Table 1. **Mean defoliation and survival of *A. senatoria* on oaks, 1989 field experiments.**

Host plant	Mean ± percentage[z] Defoliation	N[y]	Survival[x]	N
Scarlet oak	89.5 ± 5.2a[w]	10	81.7 ± 12.1[v]	4
N. red oak	88.0 ± 8.3a	10	59.9 ± 11.9	5
Pin oak	84.4 ± 9.7a	9	71.4 ± 15.3	4
Willow oak	81.2 ± 11.9ab	4	74.6 ± 5.6	3
White oak	68.7 ± 12.8abc	8	68.5 ± 13.0	6
S. red oak	65.0 ± 13.8abc	5	67.4 ± 18.0	5
Swamp white oak	54.0 ± 12.5abc	10	67.6 ± 10.3	7
Chestnut oak	43.7 ± 11.9bc	10	59.3 ± 8.6	8
Sawtooth oak	35.5 ± 9.1c	9	82.5 ± 4.7	9
Bur oak	35.5 ± 11.0c	9	65.6 ± 8.9	8

[z]Arcsin transformation performed on percentage survival data.

[y]Number of tree replicates.

[x]Percentage of larvae that survived to the fifth instar.

[w]Means followed by the same letter are not significantly different (P > 0.05) Waller-Duncan *k* ratio procedure (25).

[v]Means were not significantly different (P > 0.05).

senatoria to withstand the host plant's defensive mechanisms and larvae successfully develop and survive.

1990 laboratory experiments. Development was significantly (P < 0.05) accelerated for larvae reared on pin oak in three of the five instars and for willow oak and scarlet oak in two of the five instars (Table 2). Significantly (P < 0.05) slower development occurred for larvae reared on water oak and white oak in four of the five instars. These data indicate that pin oak, willow oak, and scarlet oak are more suitable because of accelerated development, and water oak and white oak are less suitable. White oak also had low defoliation levels (Table 1). Larval development has been shown to be an accurate indicator of host plant suitability in some species (2, 27).

Under laboratory conditions, larvae reared on scarlet oak had significantly (P < 0.05) higher survival than larvae reared on water oak, southern red oak, and bur oak (Table 3). Significantly (P < 0.05) higher survival occurred for larvae reared on sawtooth oak, white oak, northern red oak, pin oak, and willow oak compared with bur oak. Factors that influenced field survival (Table 1) were eliminated in laboratory experiments (Table 3). Laboratory data indicated high survival on 6 of the 11 species.

Table 2. **Laboratory development of *A. senatoria* reared on oaks, 1990.**

Host plant	Mean ± SEM days in each instar: First	N[z]	Second	Third	Fourth	Fifth	Prepupae
Water oak	9.1 ± 0.2a[y]	5	9.5 ± 0.5a	7.9 ± 0.3a	7.2 ± 0.3ab	7.4 ± 0.5a	3.2 ± 0.1a
Chestnut oak	9.0 ± 0.3a	4	8.5 ± 0.2abc	6.6 ± 0.1cd	6.7 ± 0.4ab	6.8 ± 0.4ab	3.3 ± 0.1a
White oak	8.9 ± 0.1a	5	9.0 ± 0.3ab	7.3 ± 0.2abc	7.5 ± 0.2ab	7.4 ± 0.2a	3.3 ± 0.1a
N. red oak	8.7 ± 0.1ab	5	8.3 ± 0.3abc	7.0 ± 0.2abc	6.8 ± 0.3ab	7.0 ± 0.5ab	3.6 ± 0.2a
S. red oak	8.7 ± 0.2ab	5	8.0 ± 0.3bcd	6.3 ± 0.1cd	6.5 ± 0.2ab	5.3 ± 0.4bc	3.6 ± 0.1a
Swamp white oak	8.6 ± 0.2ab	5	8.6 ± 0.5abc	6.8 ± 0.3a-d	6.5 ± 0.2ab	6.2 ± 0.4abc	3.5 ± 0.2a
Bur oak	8.6 ± 0.3ab	4	7.3 ± 0.2cd	6.3 ± 0.1cd	8.0 ± 2.0a	5.0 ± 0.0c	3.5 ± 0.4a
Scarlet oak	8.6 ± 0.1ab	5	7.5 ± 0.0cd	7.0 ± 0.2abc	6.3 ± 0.2b	6.5 ± 0.1ab	3.4 ± 0.2a
Pin oak	8.3 ± 0.1ab	5	6.8 ± 0.1d	5.9 ± 0.3d	6.2 ± 0.1b	6.6 ± 0.1ab	3.7 ± 0.1a
Sawtooth oak	8.3 ± 0.2ab	5	8.3 ± 0.2abc	7.3 ± 0.2abc	6.8 ± 0.2ab	6.8 ± 0.2ab	4.1 ± 0.4a
Willow oak	7.7 ± 0.3b	5	7.7 ± 0.2bcd	7.5 ± 0.1ab	7.6 ± 0.1ab	6.8 ± 0.2ab	3.6 ± 0.2a

[z]Number of replications were the same for each instar.

[y]Means followed by the same letter are not significantly different (P > 0.05) Waller-Duncan *k* ratio procedure (25).

Table 3. **Survival and pupal weight of *A. senatoria* reared on oaks, 1990.**

Host plant	Mean ± SEM Percentage Survival[z]	N[y]	Mean ± SEM Pupal weight (g) Female	N	Male	N
Water oak	48.0 ± 8.0cd[x]	5	0.8 ± 0.05ab	5	0.5 ± 0.01[w]	3
Chestnut oak	64.0 ± 18.3a-d	4	0.8 ± 0.03ab	2	0.5 ± 0.06	2
White oak	88.0 ± 8.0ab	5	0.9 ± 0.10ab	3	0.5 ± 0.01	4
N. red oak	88.0 ± 8.0ab	5	1.0 ± 0.05a	5	0.5 ± 0.04	4
S. red oak	44.0 ± 19.4cd	5	0.6 ± 0.02b	2	0.4 ± 0.03	3
Swamp white oak	70.0 ± 13.0a-d	5	0.9 ± 0.04ab	3	0.5 ± 0.03	3
Bur oak	32.0 ± 20.6d	4	no pupae		0.6 ± 0.09	2
Scarlet oak	96.0 ± 4.0a	5	1.0 ± 0.08a	5	0.5 ± 0.02	5
Pin oak	84.0 ± 7.4abc	5	1.0 ± 0.04a	5	0.4 ± 0.01	5
Sawtooth oak	92.0 ± 4.8ab	5	1.0 ± 0.03a	2	0.5 ± 0.08	3
Willow oak	84.0 ± 16.0abc	5	0.8 ± 0.03ab	3	0.4 ± 0.03	5

[z]Arcsin transformation performed on percent survival data.

[y]N = number of replications.

[x]Means followed by the same letter are not significantly different (P > 0.05) Waller-Duncan *k* ratio procedure (25).

[w]Means are not significantly different (P > 0.05).

Table 4. Ovipositional preference of *A. senatoria* for oaks, 1990–1991 field experiments.

Host plant	Mean ± SEM 1990 No. masses per sp.	N[z]	Mean ± SEM 1991 No masses per sp.	N	Mean ± SEM 1990 No. eggs per mass	N
Pin oak	0.8 ± 0.3[y]	12	0.5 ± 0.1	12	152.0 ± 60.7	12
S. red oak	0.5 ± 0.4	7	0.4 ± 0.2	7	74.4 ± 48.0	7
Sawtooth oak	0.5 ± 0.3	10	0.1 ± 0.1	10	78.9 ± 44.5	10
Swamp white oak	0.5 ± 0.2	14	0.4 ± 0.2	14	156.2 ± 67.1	14
N. red oak	0.5 ± 0.1	16	0.2 ± 0.1	16	89.3 ± 31.4	16
Scarlet oak	0.4 ± 0.2	11	0.3 ± 0.1	11	67.3 ± 45.2	11
Willow oak	0.3 ± 0.2	9	0.2 ± 0.1	9	49.1 ± 33.4	9
Bur oak	0.2 ± 0.1	14	0.4 ± 0.1	14	69.8 ± 40.6	14
Chestnut oak	0.1 ± 0.1	12	0.3 ± 0.2	12	7.2 ± 7.2	12
White oak	0.0 ± 0.0	13	0.1 ± 0.1	13	0.0 ± 0.0	13
Water oak	0.0 ± 0.0	8	0.3 ± 0.1	8	0.0 ± 0.0	8
Grand Mean	0.3 ± 0.6	126	0.3 ± 0.04	126	71.4 ± 13.3	126

[z]Number of tree replicates 1990–1991.

[y]Means were nonsignificant (P > 0.05).

Female pupal weight was significantly (P < 0.05) higher for larvae reared on sawtooth oak, scarlet oak, pin oak, and northern red oak than larvae reared on southern red oak (Table 3). Higher female pupal weight may indicate that larvae developed faster and consumed more foliage on these four species. Although data was not taken on egg production, these adults probably produced more eggs when reared on these four species. Female pupal weight may indicate suitability by *A. senatoria* for sawtooth oak, scarlet oak, pin oak, and northern red oak. Male pupal weight was not significantly (P > 0.05) different between species.

1990 and 1991 ovipositional preference. The number of *A. senatoria* egg masses per oak species were not significantly (P > 0.05) different in 1990 and 1991 with a mean of 0.3 ± 0.06 and 0.3 ± 0.04 egg masses per species, respectively (Table 4). In both 1990 and 1991, more oviposition occurred on pin oak than any other oak species, and the least number of egg masses were oviposited on white oak. In 1990, the number of eggs per *A. senatoria* egg mass were not significantly (P > 0.05) different and highly variable between oak species with a mean of 71.4 ± 13.3 eggs per mass.

Significant differences in oviposition between oak species were not detected for several reasons. The ratio of females released in 1990 (132 females) to available oak species (126) may have been too low to detect differences in oviposition. High adult mortality may have occurred before oviposition. Moreover, adult *A. senatoria* may not be able to discriminate between oak species.

Significant differences in tree defoliation (Table 1) and percentage *A. senatoria* survival, developmental rate, and pupal weight in the laboratory (Tables 2-3) showed that five species were most suitable in southeastern VA: pin oak, scarlet oak, willow oak, northern red oak, and sawtooth oak. Pin oak and willow oak are commonly planted in southeastern Virginia and are heavily defoliated (5, 6). Intermediate levels of suitability were determined for five species: swamp white oak, chestnut oak, southern red oak, bur oak, and water oak. Significantly slower development in the laboratory occurred for larvae reared on white oak. The least number of egg masses were oviposited on white oak. Furthermore, observations from 1985-1990 have indicated that white oak is rarely defoliated when larvae are given a choice in the field (5). Complete defoliation of pin oak has been observed but adjacent white oak has not been defoliated in southeastern Virginia. These data indicated that white oak is the less suitable species.

An abundance of favored host species that produce the most fecund adults is a major cause of pest population increases (27). Abundance of suitable oak species, like pin oak and willow oak, in southeastern Virginia has contributed to high *A. senatoria* populations. Planting less suitable species in the urban landscape, like white oak, may contribute to lower *A. senatoria* populations.

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Changes in Physical and Chemical Properties of a Loamy Sand Soil When Amended With Composted Poultry Litter[1]

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Abstract

The objective of this study was to determine the effects of composted poultry litter (CPL) on the physical and chemical properties of a loamy sand soil. To accomplish this, a loamy sand soil, amended with 0, 10, 20, 30, 40 and 50% by volume with CPL, was placed in 3.8-liter (#1) container for 13 weeks. Substrate pH increased with increasing rates of CPL. For most landscape plants, pH was in the recommended range ($5.5 \leq pH \leq 6.5$) at 10% to 30% CPL incorporation. Cation exchange capacity, available P, exchangeable K, Ca, and Mg increased linearly with increasing rates of CPL. The 20% amendment rate raised the available P, exchangeable K, Ca, and Mg to levels within the recommended range for landscape plants (N.C. Dept. of Agr.). Total porosity and unavailable water increased linearly with increasing rate of CPL amendment from 42% to 55.5% and 4% to 30.2%, respectively. Bulk density decreased linearly with increasing CPL concentration. Water content and available water capacity increased with increasing CPL rates. CPL amended soil had a 100% to 116% increase in available water capacity, compared to unamended soil. Amending soil with CPL reduced air space 3% to 36% with the largest decrease occurring between 20% and 30% CPL. This data supports the use of composted poultry litter to improve the chemical and physical properties of a loamy sand soil.

Index words: soil water, soil fertility, soil amendments.

Significance to the Nursery Industry: Twenty percent CPL amendment (by vol) modified all measured chemical properties to levels within the range specified for landscape plants. In addition, available water capacity was increased about 0.5 times over unamended soil within the upper 60 cm (24 in), which contains the majority of the root systems of most landscape plants. Available water capacity was increased with only a 6 to 9% decrease in air space.

This data supports the use of composted poultry litter to improve the chemical and physical properties of a loamy sand soil. It would be possible to apply higher rates, however, the increased pH and decreased air space might become limiting for optimal plant growth.

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