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Suitability of Selected Weeds and Ground Covers as Host Plants of *Nezara viridula* (L.) (Hemiptera: Pentatomidae)

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ABSTRACT. The suitability of 4 plant species as hosts of *Nezara viridula* (Hemiptera: Pentatomidae) in macadamia orchards was investigated in the laboratory. No nymphs survived to adult when given fleshy stems of *Commelina diffusa* and no eggs were laid when adults were given *C. diffusa*. *Ricinus communis* was a good host plant for nymphs, but adult *N. viridula* fecundity was less than that of adults fed *Desmodium tortuosum* or a standard diet of green bean, *Phaseolus vulgaris*, and peanut, *Arachis hypogaea*. Survival of nymphs and adult reproduction was high when fed *D. tortuosum*, indicating it is a suitable host plant for *N. viridula* in Hawai'i. Assays of *Desmodium ovalifolium*, a legume being investigated for orchard ground cover use in Hawai'i, indicate that it is not a suitable host plant even though all life stages of *N. viridula* have been observed on this plant in the field. Results of this study suggest that ground cover management is a desirable strategy to reduce *N. viridula* damage to macadamia nuts.

INTRODUCTION

The southern green stink bug, *Nezara viridula* (Linnaeus) (Hemiptera: Pentatomidae), is one of the most important pentatomid pests in the world (Todd 1989). The host plant list of *N. viridula* is quite extensive and includes over 30 families of plants (Drake 1920, Hoffman 1940, DeWitt & Godfrey 1972). *Nezara viridula* exhibits preferences for certain plants, especially in the Fabaceae (Drake 1920, Todd & Herzog 1980). It is considered a pest of many agricultural crops including, soybean, *Glycine max* (Linnaeus) (Todd & Herzog 1980, Panizzi & Slansky 1985); cowpea, *Vigna unguiculata* (Linnaeus); beans, *Phaseolus vulgaris* Linnaeus (Drake 1920); tomato, *Lycopersicon esculentum* Miller (Lye & Story 1988);corn, *Zea mays* Linnaeus (Clower 1958); rice, *Oryza sativa* Linnaeus (Kiritani & Hokyo 1962) ; and macadamia, *Macadamia integrifolia* (Maiden & Betche) (Mitchell *et al.* 1965, Mitchell & Ironside 1982).

The host plant list of *N. viridula* also includes many plants considered to be weeds, such as the wild Brassicaceae *Rapistrum rugosum* (Linnaeus) and *Rapistrum raphanistrum* (Linnaeus) (Velasco & Walter 1992); castor bean, *Ricinus communis* Linnaeus (Panizzi & Meneguim 1989); rattlepod, *Crotalaria* spp.; pigweed, *Amaranthus* spp.; lambsquarters, *Chenopodium acuminatum* Linnaeus (Drake 1920); and beggarweed, *Desmodium* spp. (Quayle 1938). These plants may serve as reservoirs of *N. viridula* between cropping cycles (Jones & Sullivan 1982, Velasco & Walter 1992).

Many weed host plants of *N. viridula* are found in and around macadamia orchards in Hawai'i (Mitchell *et al.* 1965). Recommendations for *N. viridula* management in macadamia orchards include reducing populations of weeds (Bittenbender & Hirae 1990, Jones & Shearer 1994). However, no information exists describing the role that weeds and ground covers play in the population dynamics of this pest in macadamia. The objective of this study was to determine if some common weeds associated with macadamia orchards in Hawai'i are suitable host plants of *N. viridula*. In addition, a plant being studied as a potential ground cover in Hawai'i orchards, *Desmodium ovalifolium* (Prain) Wallich (J. DeFrank, University of Hawai'i at Mānoa, Honolulu, Hawai'i, personal observation), was investigated.

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MATERIALS AND METHODS

Test Insects

A laboratory colony of *N. viridula* was started during February 1994 by collecting adult *N. viridula* from weeds and vegetable host plants at various sites around the island of O'ahu, Hawai'i. The insects were then placed inside rearing cages and allowed to oviposit. Rearing cages were wood and metal framed boxes (25 × 25 × 25 cm) covered with nylon screen (size 32 mesh = 12.6 openings/cm). Paper towels were suspended inside the cages to serve as oviposition sites. Egg masses were collected daily, placed in petri dishes, and allowed to hatch. Both wild adult *N. viridula* and their F_1 offspring were reared on a diet of fresh green beans (*Phaseolus vulgaris*) and shelled peanuts (*Arachis hypogaea*), a standard diet used in many *N. viridula* studies (Harris & Todd 1981, Brewer & Jones 1985, Jones 1985). Only F_1 insects were used for testing. For adult *N. viridula* studies, newly emerged F_1 adults were sexed, held separately in rearing cages, and maintained on the standard diet ≈ 3 days until needed for testing. For studies involving immature *N. viridula*, only individuals recently (≈ 1 day) molted to the 2nd instar were tested. The colony was maintained in the laboratory at ≈ 21 ± 1 °C, 60–70% RH, and a 14:10 (L:D) hour photoperiod supplied by 8-watt fluorescent bulbs.

Sources of diets

The ground covers and weeds used for this study were castor bean (*R. communis*); honohono (*Commelina diffusa*), and Florida beggarweed (*D. tortuosum* and *D. ovalifolium*). All plants, except for *C. diffusa*, were collected twice weekly from the University of Hawai'i Waimānalo Experiment Station, Waimānalo, O'ahu. Green fruit of *R. communis* was collected from borders surrounding the experiment station. Stems with green seed pods of *D. tortuosum* were collected from fallow fields. Stems with green seed pods of *D. ovalifolium* were collected from a demonstration planting. Harvested plants were stored in plastic bags in the refrigerator until needed. Young shoots of *C. diffusa* were harvested from potted plants grown outdoors at the University of Hawai'i at Mānoa, O'ahu, every time diets were replaced.

The standard diet consisted of fresh green beans and peanuts. The green beans were purchased from a local supermarket twice a week, washed for 5 min. under running tap water, and then bagged and refrigerated until needed. The peanuts were purchased locally as blanched peanuts that had the shell and seed coat removed and were stored in plastic bags in a refrigerator.

Adult fecundity study

Five diets were used in this study to investigate the suitability of the four plant species as host plants for *N. viridula*, with the standard green bean and peanut diet as a control. Six *R. communis* fruit were placed on the bottom of a test cage and the standard diet (1 fresh green bean and ≈ 9 g of peanuts) was placed in another cage. Bouquets containing either *D. ovalifolium*, *D. tortuosum*, or *C. diffusa* were prepared by wrapping 3 or 4 stems (≈ 7–10 cm long) with cotton and then placing the stems in 1 dram glass vials (15 × 45 mm) containing water. Individual bouquets were then placed in separate test cages.

Fifty ≈ 3-day old adult *N. viridula* of each sex were randomly assigned to separate test cages, 1 male and 1 female to each cage. Pairs of *N. viridula* were then randomly assigned to 1 of the 5 diets. Each diet was replicated 10 times with a single mating pair in a particular diet considered as a replicate.

Test cages were constructed from clear plastic cups (296 ml) (#TP10; Solo, Urbana, IL). Each cup was ventilated by a nylon screen (size 32 mesh) covered 2 cm hole cut in the bottom of the cup. Two 0.5 cm diameter holes were cut opposite each other near the

rim of the cup to provide additional ventilation. A strip of paper towel (7 × 1.5 cm) was suspended inside each cup and served as an oviposition site. Additional water was dispensed from 1 dram glass vials filled with distilled water and plugged with cotton. Each cup was inverted over the diet, a water dispenser, and a 2/4 pair of *N. viridula*. Food and water were replaced every 2–3 days during the experiment.

Cages were examined daily for eggs during the 30-day test period. All egg masses were removed when first observed. Egg masses were placed in separate petri dishes. The total number of eggs and the number of eggs not hatched were recorded. Adult mortality was also recorded. If a female died, that replicate was removed from further testing. If a male died, it was replaced with a male of comparable age maintained on the standard diet. The environmental conditions for adults and eggs were the same as those used for maintaining the colony of test insects.

Nymph study

The same 5 diets used in the adult fecundity study were used in this study to investigate the suitability of the 4 plant species as host plants for immature *N. viridula*. Diets were prepared and presented as in the adult study.

Five 2nd instar *N. viridula* were placed in each test cage. Each diet was replicated 6 times for a total of 30 nymphs per diet. Mortality was recorded every 2–3 days until the immatures began to molt to adults and then daily from that time on. Newly emerged adults were weighed within 1 day of molting.

Test cages were made from white plastic cups (900 ml) (#DG32; Solo; Urbana, IL), 13.7 cm tall and 10.0 cm wide at the opening. An 8 cm diameter hole was cut out of the clear plastic top and replaced with nylon screen (size 32 mesh) to provide ventilation. Two 7 cm diameter filter papers (#42; Whatman Ltd., UK) were placed on the bottom of each cup to absorb *N. viridula* excrement. Additional water was dispensed from 1 dram glass vials filled with distilled water and plugged with cotton. Food, water, and filter papers were replaced every 2–3 days during the experiment. The environmental conditions were the same as those used for maintaining the colony.

Statistical analysis

Analysis of variance (ANOVA) was used with data from the adult fecundity test to analyze the number of days to first oviposition (Cruze *et al.* 1991). The average number of eggs per egg mass and average percentage egg hatch (arsine squareroot X transformation) were analyzed with ANOVA using pooled per female averages. These latter 2 analyses were weighted based upon the number of egg masses laid per female (Cruze *et al.* 1991). Data from the *C. diffusa* treatment were excluded from the analyses because no eggs were laid. The Tukey multiple comparison procedure was used for mean comparison testing using a 0.05 family error rate (Neter *et al.* 1990).

Survivorship of *N. viridula* nymphs, weights of newly molted adults and number of days from the start of the test to adulthood were analyzed separately with ANOVA using within-replicate averages. The analyses (excluding survivorship) were weighted based upon the number of survivors in a replicate. Data from the *C. diffusa* treatment were excluded from the two latter analyses because no immatures survived to the adult stage. The Tukey multiple comparison procedure was used for mean comparison testing using a 0.05 family error rate (Neter *et al.* 1990).

RESULTS

Adult fecundity study

The diets used in this study affected fecundity of *N. viridula* females (Table 1). Adult female *N. viridula* in both the standard diet and *D. tortuosum* treatments laid ≈ 4–5 times more egg masses than females given *D. ovalifolium* or *R. communis* (Table 1). No eggs were laid in the *C. diffusa* treatment (Table 3.1). Diet also affected the average number of eggs per egg mass ($F = 3.86$; df = 3, 22; $P = 0.023$) (Table 1). Female *N. viridula* given *D. tortuosum* seedpods to feed on laid as many eggs per egg mass as females given the standard diet (Table 1). Females in these 2 treatments laid more eggs per egg mass than females given *D. ovalifolium* or *R. communis* (Table 1).

Diet affected the length of time to first oviposition ($F = 3.32$; df = 3, 22; $P = 0.038$) (Table 1). Oviposition was delayed for females given *D. ovalifolium* and *R. communis* compared with those given *D. tortuosum* or the standard diet. There was no statistical difference in percentage egg hatch ($F = 0.61$; df = 3, 22; $P = 0.62$) (Table 1).

Table 1. Effect of diet on adult female *Nezara viridula* fecundity and fertility after being reared on a standard diet and switched to a different diet for a 30 day test period

Diet	% females that laid eggs	Total egg masses per treatment	Average days to first oviposition ± SE[a]	Average # eggs per egg mass ± SE	Average % hatch ± SE
Commelina diffusa	0	0	—	—	—
Desmodium tortuosum	90	19	15.1 ± 0.5 b	82.2 ± 2.2 a	72.4 ± 2.1 ns
Desmodium ovalifolium	30	3	22.7 ± 1.5 a	35.7 ± 9.0 b	80.5 ± 8.7
Ricinus communis	40	4	21.3 ± 1.1 a	50.0 ± 6.9 b	55.7 ± 6.5
Standard diet (green bean & peanut)	100	21	16.7 ± 0.4 b	80.6 ± 1.8 a	70.6 ± 70.6

[a]. Means in the same column followed by the same letter are not significantly different [ANOVA; $P > 0.05$; Tukey multiple comparison test (Neter *et al.* 1991)]; ns = not significant

Nymph study

The diets used in this study affected survival of immature *N. viridula* to adulthood ($F = 26.67$; df = 4, 19; $P < 0.0001$) (Table 2). Nymphal mortality was higher in *D. ovalifolium* and *C. diffusa* treatments compared with mortality of nymphs in the *D. tortuosum*, *R. communis*, and standard diet treatments (Table 2). No nymphs given *C. diffusa* survived to adult (Table 2).

Diet also affected the length of time it took 2nd instar *N. viridula* to reach adulthood (Table 2). It took ≈ 10 days or more for nymphs given the *D. ovalifolium* and *R. communis* treatments to reach adulthood than nymphs given either *D. tortuosum* or the standard diet ($F = 74.79$; df = 3, 18; $P < 0.0001$) (Table 2).

The average weight of young *N. viridula* adults was also affected by the diet they were fed as nymphs ($F = 20.15$; df = 3,18; $P < 0.0001$) (Table 2). The average weight of adult *N. viridula* given the standard diet as nymphs was higher than those given other treatments. Adult weights from *D. tortuosum* and *R. communis* treatments were similar, but adults from these treatments weighed more than adults from the *D. ovalifolium* treatment (Table 2).

Table 2. Effect of diet on survival and growth of *Nezara viridula* nymphs reared on a standard diet until the start of the second instar then fed other diets to adulthood.

Diet	Average % mortality ± SE[a]	Average # days to adult molt ± SE	Average weight (mg) as ≈ 1 day old adult ± SE
Commelina diffusa	100.0 ± 3.2 a	—	—
Desmodium tortuosum	16.7 ± 3.2 b	28.7 ± 0.3 b	128.5 ± 2.2 b
Desmodium ovalifolium	71.8 ± 3.9 a	42.3 ± 0.6 a	83.7 ± 4.2 c
Ricinus communis	23.3 ± 3.2 b	39.2 ± 0.3 a	116 0 ± 2.3 b
Standard diet (green bean & peanut)	3.3 ± 3.2 b	27.2 ± 0.3 b	159.7 ± 2.0 a

[a]. Means in the same column followed by the same letter are not significantly different [ANOVA; $P > 0.05$; Tukey multiple comparison test (Neter *et al.* 1991)].

DISCUSSION

Numerous studies have demonstrated that performance of *N. viridula* nymphs and adults is related to host plant suitability (Panizzi & Meneguim 1989, Panizzi & Slansky 1991, Velasco & Walter 1992, Velasco & Walter 1993). In those studies, host plants affected many aspects of *N. viridula* biology including development time, survival, fecundity, and fertility. Despite its polyphagous attributes, *N. viridula* abundance has clearly been shown to be affected by the plant species and plant parts it feeds on (Panizzi & Meneguim 1989, Panizzi & Slansky 1991, Velasco & Walter 1992). Not all plants it feeds on are suitable host plants, nor are good host plants always suitable if lacking preferred plant parts to feed on (Velasco & Walter 1992, Panizzi & Alves 1993).

We showed that plants used in this study could affect *N. viridula* abundance in the field. Three of the plant species chosen for this study, *R. communis*, *D. tortuosum*, and *C. diffusa*, are common in Hawai'i. Both *R. communis* and *D. tortuosum* have previously been investigated for *N. viridula* host plant suitability (Corpuz 1969, Panizzi & Meneguim 1989, Panizzi & Slansky 1991, Velasco & Walter 1992). *R. communis* was investigated in this study because *N. viridula* nymphs and adults were often observed on this plant in areas adjacent to macadamia orchards and because of conflicting results concerning its host plant suitability exist in the literature. For example, Drake (1920) and Corpuz (1969) report that *R. communis* is a good host plant for *N. viridula* while others indicate it is a poor host plant (Panizzi & Meneguim 1989, Velasco & Walter 1992). Both Panizzi & Meneguim (1989) and Velasco & Walter (1992) indicated that nymphs had high mortality when fed *R. communis*. Studies conducted by Panizzi & Meneguim (1989) reported that adult *N. viridula* had low survival and egg production when adult *N. viridula* were fed *R. communis* fruit, while Velasco & Walter (1992) reported high adult survival and egg production.

In this study, the results of the suitability of *R. communis* as a host plant for *N. viridula* are not in agreement with any one previous study. Combined mortality for both *N. viridula* sexes was 80% in our study compared with 70–80% in the study conducted by Panizzi & Meneguim (1989) and ≈10% mortality in the study by Velasco & Walter (1992). In this latter study, the percentage of females ovipositing was 95% compared with 0% (Panizzi & Meneguim 1989) and 40% in our study. Likewise, both Panizzi & Meneguim (1989) and Velasco & Walter (1992) reported high mortality when *N. viridula* nymphs were fed *R. communis*. However, nymph survival in our study was ≈77% making *R. communis* a suitable host plant for immature *N. viridula* based upon criteria (>60% survival to adult stage) developed by others (Velasco & Walter 1993). These findings suggest that

nutritional quality or allelochemicals may have different affects on various life stages of *N. viridula* (Panizzi & Meneguim 1989, Velasco & Walter 1992)or that *R. communis* or *N. viridula* are highly variable species. It is also possible that *R. communis* is a complex of sibling species.

Two *Desmodium* spp. were compared with each other in this study. One, *D. ovalifolium*, was tested because it is being considered as an orchard ground cover in Hawai'i. Its suitability as a *N. viridula* host plant was compared with *D. tortuosum*, a common weed that was investigated elsewhere (Panizzi & Slansky 1991). Based upon our study, it appears that *D. ovalifolium* is not a suitable host plant for *N. viridula* because of high mortality of nymphs and low adult reproductive output. These results are somewhat surprising because all stages of *N. viridula* are common on *D. ovalifolium* when it is fruiting profusely in the field. It is possible that the laboratory assay used in this study did not adequately reflect field conditions. Regardless, *D. ovalifolium* cannot be considered as a suitable ground cover for macadamia orchards if it attracts *N. viridula* into the orchard on a temporary basis. When *D. ovalifolium* is no longer attractive to *N. viridula*, this pest will disperse, and possibly cause additional damage to the crop.

In comparison, *D. tortuosum* appears to be a suitable host plant because both survivorship of nymphs and reproductive output of adult females were high. These results are in marked contrast with those of Panizzi & Slansky (1991) that used a similar assay. In that study, Panizzi & Slansky reported that nymphal mortality was high in laboratory assays yet adults and nymphs were consistently found on *D. tortuosum* in the field. These discrepancies between field observations and laboratory assays may have resulted from variation between local populations of *N. viridula* in the field (Panizzi & Slansky 1991)

Although *N. viridula* is primarily a seed and pod feeder, it will feed on fleshy plant parts including stems (Drake 1920). Stem feeding has been attributed to *N. viridula*'s searching for water (Panizzi & Rossi 1991). If so, then *C. diffusa* appears to be a suitable "water-source" plant because its stems are very succulent (Wagner *et al.* 1990). *C. diffusa* is a common weed in Hawai'i and its abundance in some macadamia orchards warranted its inclusion in this study. Results from this study indicate this plant is not a suitable *N. viridula* host plant by itself. No nymphs given this plant to feed on survived to adult and adult mortality was 80% when given this plant to feed on. However, further research is needed to determine if *C. diffusa* can enhance other *N. viridula* diets by contributing as a water source.

Removing *N. viridula* host plants in and around macadamia orchards is recommended as a way to reduce *N. viridula* damage to macadamia nuts (Bittenbender & Hirae 1990, Jones & Shearer 1994). This study supports those recommendations by demonstrating that certain weeds associated with macadamia orchards can contribute to population increases of *N. viridula*. Thus, using selective herbicides or frequent mowing is recommended to minimize both plant species and plant parts preferred by *N. viridula*. Planting non-host plant ground covers should also be explored where orchard ground cover is desired.

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