

Intraplant Distribution of Three *Nabis* Species (Hemiptera: Nabidae), and Impact of *N. roseipennis* on Green Cloverworm Populations in Soybean

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ABSTRACT The within-plant distributions of *Nabis americanoferus* (Carayon), *N. roseipennis* Reuter, and *N. rufusculus* Reuter differ in soybean. *N. americanoferus* adults are located in the upper canopy, whereas adults of the other two species are located lower in the plant canopy. Early-instar nymphs of all three species are vertically separated from their respective adult stages. Nabids were observed to feed on a wide variety of arthropods including pest, beneficial, and innocuous species. The seasonal abundance of nymphal *N. roseipennis* and the within-plant overlap of its distribution with early instars of the green cloverworm suggested that it may be an effective predator on this pest species. *N. roseipennis* nymphs were successful in reducing numbers of green cloverworm larvae in the field in the presence of other predators and alternative prey under minimally modified conditions. Starting densities of 20-25 third instars per 0.9-m plot resulted in up to 50% reduction in subsequent green cloverworm populations.

KEY WORDS Insecta, predators, *Nabis americanoferus*, *Nabis rufusculus*

NABIDS ARE generalist predators (Harris 1928) and are often strikingly abundant in many agricultural crops (Dinkins et al. 1970, Wheeler 1977, Pitre et al. 1978, Irwin & Shepard 1980). Laboratory investigations (e.g., Tamaki & Weeks 1972, Tamaki et al. 1978, Martinez & Pienkowski 1982, Sloderbeck & Yeorgan 1983a, Flinn et al. 1985) and field cage studies (e.g., Van den Bosch et al. 1969, Irwin et al. 1973, Richman et al. 1980, Reed et al. 1984) suggested the potential of nabids as predators of a wide variety of pest insects. Although the beneficial effects of nabids, alone or in predator complexes, have been demonstrated in field cage or laboratory studies (e.g., on cotton as predators of *Heliothis virescens* (F.), Thead et al. [1987] and the references therein), the effectiveness of these predators under naturally occurring field conditions is largely unknown. Current pest management decision making based on economic injury levels does not include the benefits conferred by predators (Ostlie & Pedigo 1987), in part because of the lack of knowledge concerning the actual impact of specific predators on known pest species under field conditions.

Nabis americanoferus (Carayon), *Nabis roseipennis* Reuter, and *Nabis rufusculus* Reuter are the three most abundant nabid species in central Kentucky alfalfa and soybean (S.K.B. & K.V.Y., unpublished data). Here we report the intraplant distributions of adults and nymphs of these three nabid species and compare those distributions with what is known of the distributions of different instars of the green cloverworm, *Plathypena scabra* (F.), a noctuid defoliator causing occasionally serious damage to soybean in the midwest (Pedigo et al.

1972). We also report the impact of *N. roseipennis*, the nabid species which produces the greatest nymphal populations in soybean in central Kentucky (S.K.B. & K.V.Y., unpublished data), on *P. scabra* in the presence of other predators and alternative prey under minimally modified field conditions.

Materials and Methods

Intraplant Distribution of *Nabis* spp. Observations of the intraplant distribution of nabids and predation were made at weekly intervals during the 1983 and 1985 soybean growing seasons. Plants within a designated area in a soybean field were searched carefully for nabids at specific times of the day for 2-h periods. Care was taken to create as little disturbance as possible as the observer moved through the field on hands and knees. When a nabid was spotted, it was collected and taken to the laboratory for positive identification. Its exact location on the plant (height to the nearest 1.3 cm and plant structure occupied) and any prey item it held at the time of observation were recorded. Regular observations were made from 0700 to 0900, 1100 to 1300, 1500 to 1700, and 1900 to 2100 hours EDT on each of 12 dates during the two seasons. Plant growth stages (Fehr & Caviness 1977) during these weekly sampling dates were: V11, R2 to V15, R5 between 21 July and 19 August 1983 and V7 to V16, R5 between 12 July and 22 August 1985.

During 1985, a visual census of insect species present on 20 additional plants was taken on each date of observation using the direct observation

technique described by Mayse et al. (1978a,b). Plants were randomly selected in the area where nabid observations were made.

Following a significant analysis of variance (ANOVA), the Tukey-Kramer method of multiple comparisons among pairs of means based on unequal sample sizes (unplanned comparisons [Sokal & Rohlf 1981]) was used to identify significant differences ($\alpha = 0.05$) in mean relative height on the plant among species and stages of nabids. Relative height refers to the height of the nabid on the plant divided by the total height of the plant to its highest point in the canopy measured to the nearest 1.3 cm. A test of independence using χ^2 was applied to test the relationship between the number of predation events observed and the time of day during which observations were made relative to the total number of nabids observed during the time period.

Assessment of the Predatory Capability of *N. roseipennis*. A quantitative assessment of the impact of *N. roseipennis* on the green cloverworm was made during 1985 and 1986. Soybean planting dates were 24 June 1985 and 20 May 1986. To ensure that numbers of green cloverworms were sufficient to provide a meaningful test, female moths were caged in the field in equal numbers in each of several cages (0.9 by 0.9 by 0.9 m); each cage was placed over about 20 plants in one soybean row. Cages consisted of a wooden frame covered with 20-mesh saran screen.

Moths were allowed to oviposit for 4 d, then the cages were removed. Because oviposition occurred during a 4-d period, subsequent age structure of larvae may have varied by 1–3 d. Barriers (0.3 m high) constructed from heavy wooden stakes and 0.152-mm clear plastic sheeting were built around each plot (0.9 by 0.9 m), thereby preventing movement along the ground into or out of these plots when these barriers were covered inside and out with Stikern Special (Seabright Enterprises, Emeryville, Calif.).

Selected densities of third-instar *N. roseipennis* were introduced into the plots on the morning following cage removal. When degree-day (DD) accumulations indicated that nabids were about to reach the adult stage (Braman et al. 1984), plots were destructively sampled by carefully cutting each plant at its base and shaking it over a plastic sheet which had been placed against the base of the plant stems before cutting. Plants were examined for larvae which, together with those collected from the plastic sheets, were transferred to alcohol and returned to the laboratory, where their numbers were recorded. A 1.83-m section of soybeans had been mowed between blocks to allow easier access to the small plots. Data were subjected to ANOVA, and mean separation was achieved with a least significant difference test.

Soybeans were between full flower (R2) and beginning pod stage (R3 to R4) at the time moths were caged on 22 August 1985. Green cloverworm oviposition increases rapidly in the field on soy-

beans between full bloom and early pod set (Sloderbeck & Yeargan 1983b). Four female green cloverworm moths were released into each cage. There were eight replicates of three nabid densities (0, 10, and 20 per plot) arranged in a randomized complete block design. During 1986, nabid densities tested were 0, 5, 10, 15, 20, and 25 nabids per plot. There were six replicates of each treatment, again arranged in a randomized complete block design. Additionally, six plots were harvested immediately after oviposition by the moths to allow estimation of the average starting density of green cloverworm eggs in the experimental areas.

Eight female moths were released into each of the 42 cages during 1986. Moths were caged when the soybeans were between full flower and beginning pod stage on 25 July 1986.

Results and Discussion

Intraplant Distribution of *Nabis* spp. During 1983 and 1985, the within-plant distributions of 432 adult and 149 nymphal nabids on soybean were recorded. The majority of all nabids collected (76.8%) were on leaves, 12.8% were located on petioles, 4% on stems, and 6.3% on pods or flowers. Distribution of adults was highly dependent on plant stratum, with a majority in the upper portion of the plant (χ^2 , $P < 0.001$). Similar numbers of individuals were collected at all times of the day.

Exact plant height measurements were taken for 492 of the 581 nabids collected. The average relative height on the plant differed by species and stage ($P < 0.001$, Table 1). *N. americanoferus* adults were located high in the soybean canopy, whereas adults of the other two species and nymphs of all three species tended to be located farther down on the plant. In all cases, there is a vertical separation between adults and immatures of the same species; this separation may serve to prevent cannibalism, as was suggested by Wilson & Gutierrez (1980) when discussing predators in the genera *Orius*, *Geocoris*, *Nabis*, and *Chrysopa*.

Nabids were observed to prey upon beneficial as well as innocuous or pest species (Table 2). The greater number of prey items observed for *N. americanoferus* is a reflection of the greater number of that species collected during the course of the observations rather than a higher predation rate by that species. Proportion of nabids feeding at the time of collection (for combined nabid species) was highly dependent on the time period during which the observations were made ($P < 0.01$)—6 of 127 occasions during 0700–0900 hours, 21 of 179 during 1100–1300 hours, 3 of 127 during 1500–1700 hours, and 10 of 148 during 1900–2100 hours. On three occasions during 1985, observations were made between 2300 and 0100 hours of the following day. None of the nabids observed had captured prey or appeared to be active. Donahoe & Pitre (1977) reported very little activity of adult *N. roseipennis* between 2100 and 0500 hours on potted

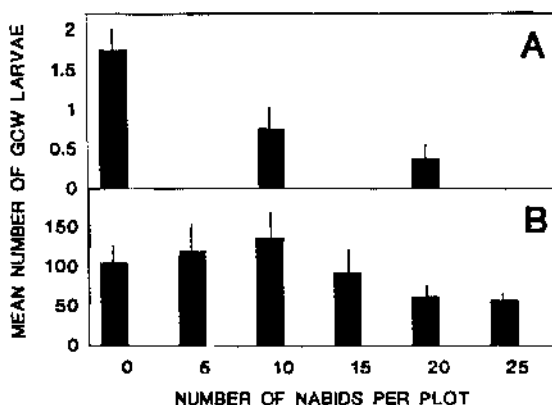


Fig. 1. Effect of increasing nabid densities on subsequent field densities of green cloverworm larvae per 0.9 row-m of soybean during 1985 (A) and 1986 (B). Vertical bars indicate standard errors.

survivorship with increasing predator density (ANOVA, $F = 3.71$; $P < 0.05$). Although these data were encouraging, numbers of green cloverworms were deemed too low to allow the establishment of a quantitative relationship between predator and prey densities.

By conducting a similar, expanded experiment approximately 1 mo earlier in 1986 than in 1985, we reduced the potentially confounding influence of the fungus *Nomuraea rileyi*, a pathogen frequently responsible for the late-season decline in green cloverworm larval populations (Turnipseed & Kogan 1983). Green cloverworm densities before introduction of nabid nymphs ranged from 160 to 339 eggs per 0.9 m of row plot, with 239.8 ± 32.9 ($\bar{x} \pm SF$) eggs per plot for the six plots sampled. It should be noted that the number of eggs sampled in soybean near Lexington, Ky. (Sloderbeck & Yeagan 1983b) peaked at 13–20 per row-meter. The numbers of eggs used in our 1986 study were substantially higher than are usually encountered under endemic conditions in Kentucky.

Mean numbers of green cloverworm larvae recovered at the termination of the exposure period ranged from 58.2 to 136.7 (Fig. 1B). Larvae were primarily fourth instar or larger. Plots that had received the highest number of nabids (20 and 25 per 0.9 m of row) contained the fewest cloverworms, with a 50% reduction over plots receiving lesser densities of nabids. Numbers of cloverworms in those plots receiving the three lowest densities of nabids were not significantly different from plots that received no nabids. A starting density of 20 nabids per 0.9 m of row represents 6–10 times the average number of nymphs collected in soybean near Lexington (S.K.B. & K.V.Y., unpublished data), and it was at this density that significant reductions in green cloverworms occurred. However, as noted above, densities of green cloverworms in the plots also were much higher than normally observed in Kentucky, and predators fed for a limited period (third to fifth nabid instars) in these experiments.

Bechinski & Pedigo (1981) concluded predators contribute to larval mortality, late in the season, predation alone is insufficient to halt outbreaks that occur earlier in the season. Nonetheless, we have demonstrated in the field that nabids, when present in sufficient numbers at an appropriate time, are capable of causing significant reductions in numbers of green cloverworms when in the presence of alternative prey and other predator species. Further work is needed to refine the quantitative relationship between the number of nabids and the associated reduction in green cloverworm populations at different densities of pest and predators.

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Table 1. Mean relative location of various stages of three *Nabis* species on soybean based on total plant height

Species and stage	n	Relative ht on plant ($\bar{x} \pm SE$) ^{a,b}
<i>N. americanoferus</i>		
Male	105	0.80 \pm 0.02a
Female	156	0.83 \pm 0.02a
Instars 1-3	20	0.41 \pm 0.03d
Instars 4-5	26	0.67 \pm 0.04bc
<i>N. roseipennis</i>		
Male	43	0.68 \pm 0.02b
Female	25	0.78 \pm 0.04ab
Instars 1-3	20	0.48 \pm 0.05cd
Instars 4-5	32	0.55 \pm 0.03bcd
<i>N. rufusculus</i>		
Male	10	0.65 \pm 0.06bcd
Female	8	0.70 \pm 0.04ab
Instars 1-3	17	0.48 \pm 0.04cd
Instars 4-5	30	0.50 \pm 0.03cd

^a ANOVA, $P < 0.001$, MSD, Tukey-Kramer pairwise comparisons among all stages of all species.

^b Height of nabid on the plant divided by total height of the plant.

cotton plants. Predator activity (suggesting searching behavior) in their study was crepuscular and peaked at 1900 hours. However, we observed the greatest predation by combined nabid species during midday.

Number of predation events per total number of observations during each time period were further subjected to analysis by species. The number of predation events for *N. roseipennis* and *N. rufusculus* was independent of the time period during which the observations were made, probably because of small sample size. *N. americanoferus* captured prey in a manner that was dependent upon time of day ($P < 0.025$)—5 of 65, 15 of 102, 2 of 87, and 7 of 105 for the time periods 0700-0900, 1100-1300, 1500-1700, and 1900-2100 hours, respectively. Harris (1928) observed that "this species prefers more sunny and drier situations than do most of the other common species of the genus." Our results, which showed that *N. americanoferus* is located high in the soybean canopy and captures more prey during midday, are consistent with this observation.

Individual third-instar *N. roseipennis* were seen to feed on a single third-instar green cloverworm for up to 1.5 h at a time, with an average of approximately 0.5 h on potted V3 soybeans (S.K.B., unpublished data). Reported handling times for *N. americanoferus* feeding on pea aphids or potato leafhoppers were 3.6 h and 0.2 h, respectively (Flinn et al. 1985). *N. alternatus* fifth instars may consume two or three fourth instars of *Lygus* per day (Perkins & Watson 1972, Tamaki et al. 1978) depending upon the amount of obstruction (e.g., alfalfa foliage) in the habitat. Therefore, it is reasonable to assume that nabids may locate and capture two medium-sized prey items during their searching day. Activity patterns recorded for *N. roseipennis*

Table 2. Observed prey items captured by *Nabis* species on soybean

Prey taxa	<i>N. americanoferus</i>	<i>N. roseipennis</i>	<i>N. rufusculus</i>
<i>Orius</i> adult	4	—	—
<i>Orius</i> nymph	1	—	—
<i>Nabis</i> nymph	4	—	1
Potato leafhopper adult	2	1	—
<i>Lygus</i> adult	3	2	—
<i>Lygus</i> nymph	1	—	—
Aphids	4	1	—
Green cloverworm larva	3	1	1
Soybean thrips	4	—	1
Spider mites	1	1	1
Locust leafminer	—	1	—
Misc. Diptera	1	—	—
Whitefly nymph	1	—	—

by Donahoe & Pitre (1977) suggest that the amount of time spent searching is less than 12 h in a 24-h period. If this species spends about 0.5 h handling its prey, an individual might be seen feeding once during a 12-h period. If the 581 nabids observed during this study fed for 1 h in every 12 h, we should have seen 581/12, or about 48 different predation events. This figure is similar to the 40 observations of predation made during this investigation.

Taxa observed in separate visual examination of 20 plants on each date of observations during 1985 included those arthropod species recorded as prey items and other taxa as well. Other arthropods present that might represent potential prey included (from most to least numerous) whitefly adults and nymphs, thrips adults and larvae, potato leafhopper adults and nymphs, minute pirate bug adults and nymphs, green cloverworm larvae, Miridae adults and nymphs, *Nabis* spp. adults and nymphs, and spider adults and immatures. Green cloverworm larvae were present throughout the period of observations yet were less abundant than several other taxa. Nonetheless, they were among the most frequently observed prey in the field (Table 2).

Green cloverworm eggs are distributed throughout the upper, middle, and lower canopy levels. Young green cloverworm larvae also show no preference for soybean plant strata, whereas older larvae prefer upper canopy levels (Pedigo et al. 1973). Thus, the distribution of the various stages of this lepidopterous pest overlap with the distribution of the nymphal stage of *N. roseipennis* in soybean. This fact, combined with observations of consumption of this pest by *N. roseipennis* under laboratory conditions (Sloderbeck & Yeorgan 1983a), as well as field observations of predation by nabids on green cloverworms in the presence of several types of alternative prey, indicate that this host may be commonly encountered and eaten under field conditions.

Assessment of Predatory Capability of *N. roseipennis*. During 1985, the mean number of green cloverworms recovered per plot (Fig. 1A) showed the expected trend of decreasing green cloverworm

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