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RESEARCH, REVIEWS, PRACTICES, POLICY AND TECHNOLOGY

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ABSTRACT. Sticky traps were used to measure how tree shelterbelts influence the abundance of crop insect pests and beneficial arthropods in muskmelon (*Cucumis melo* L.) plots in eastern Nebraska. Abundance of striped cucumber beetles {*Acalymma vittatum* Fabricius (Coleoptera: Chrysomelidae)}, southern corn rootworms {*Diabrotica undecimpunctata howardi* Barber (Coleoptera: Chrysomelidae)}, and northern corn rootworms {*D. barberi* Smith & Lawrence (Coleoptera: Chrysomelidae)} was similar in exposed and sheltered plots. Western corn rootworms {(*D. virgifera* LeConte (Coleoptera: Chrysomelidae)} were significantly more abundant in exposed plots. More lady beetles (Coleoptera: Coccinellidae) and ichneumonid wasps (Hymenoptera: Ichneumonidae) were caught on traps in sheltered plots than exposed plots, especially during June. Few spiders (Aranae), lacewings (Planipennia), or braconid wasps (Hymenoptera: Braconidae) were caught in either treatment. *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-342-9678. E-mail address: getinfo@haworth.com]*

KEYWORDS. *Cucumis melo*, chrysomelid pests, shelterbelts, insect ecology, cucurbitaceae

Tree shelterbelts increase crop yields and reduce adverse climatic conditions by modifying wind profiles, increasing available moisture, and influencing temperature and other microclimate factors (Heisler and DeWalle, 1988; Kort, 1988). Shelterbelts also provide beneficial and pest insects with food, shelter, and egg-laying and overwintering sites (Dix and Leatherman, 1988; Pasek, 1988; Unwin and Corbet, 1991).

In Great Britain, hedgerows modify wind speeds and create a sheltered area where many flying insects aggregate (Lewis, 1970). Pollinators use the sheltered zone in the lee of windbreaks as flyways. Significantly more apple blossoms are pollinated in sheltered areas than in unsheltered areas (Lewis and Smith, 1969). In China, pond cypress (*Taxodium ascendens* Brongn.) is planted around rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.) fields to reduce adverse climatic factors and provide alternative habitat for spiders (Arachnida: Araneae) that keep leafhopper (Homoptera: Cicadellidae) populations in check (Shi and Gao, 1986). In Texas, boll weevils {*Anthonomus grandis* Boheman (Coleoptera: Curculionidae)} overwinter in leaves and other debris under shelterbelt trees. Removing this debris reduced the number of overwintering weevils (Slosser et al., 1984).

Clearly, shelterbelts adjoining agricultural lands influence the arthropods that affect the crops. Conceivably, the gains accrued from improved site conditions could be negated if the shelterbelts contribute to elevated populations of crop-damaging insects. Conversely, these same site conditions could improve abundance of beneficial arthropods that prey on crop pests. However, the degree to which shelterbelts influence arthropod abundance and distribution on croplands of the central Great Plains has not been thoroughly studied and information is limited.

In 1991, we began studying how shelterbelts affect muskmelon production. A bacterial wilt caused by *Erwinia tracheiphila* (E. F. Smith) infected many vines in our study and reduced muskmelon yields (personal observations). This wilt is transmitted primarily by striped cucumber beetles {(*Acalymma vittatum* Fabricius (Coleoptera: Chrysomelidae)}, southern corn rootworm beetles {(*Diabrotica undecimpunctata howardi* Barber (Coleoptera: Chrysomelidae)}, and western corn rootworm beetles {*D. virgifera* LeConte (Coleoptera: Chrysomelidae)} (Einemann and Steadman, 1986). We found that the incidence of wilt and the number of beetle vectors varied with plot (unpublished data). Conceivably, shelterbelts adjoining muskmelon fields could influence the movement of adult beetles, elevating total beetle populations and increasing the occurrence of wilt. In 1992, we began monitoring the presence of these beetles, plus arthropods that prey on muskmelon pests. Our primary objective was to obtain baseline information to evaluate how shelterbelts influence the abundance of the beetles and arthropod enemies in or near muskmelon fields.

MATERIALS AND METHODS

Location

We established sheltered and exposed muskmelon plots at the University of Nebraska-Lincoln Agricultural Research and Development Center near Mead, Nebraska (41° 29′ N, 96° 30′ W). The soil is a Typic Argiudol (Sharpsburg silty loam). Plots were 17.1 m by 33.1 m. Sheltered plots were located 10-13 m north of the shelterbelt and were within each shelterbelt's zone of maximum protection (one to three times the height of the windbreak). Shelterbelts consisted of two rows of mixed green ash (*Fraxinus pennsylvanica* L.), Austrian pine (*Pinus nigra* Arnold), and eastern red cedar (*Juniperus virginiana* L.). Average tree height increased from 11.9 m to 12.5 m over the two-year study. In 1992, one replication was protected by two rows of alternating pairs of eastern red cedar and Scotch pine (*P. sylvestris* L.) with an average height of 9.1 m. The prevailing winds were from the south-southwest during the sampling period. Sheltered and exposed plots were arranged in a completely randomized design and were replicated three times in 1992 and four times in 1993. In both years muskmelon growing in the sheltered area flowered earlier. In 1992, there was no significant difference in the number of marketable fruit between sheltered and exposed locations. In 1993, there was 70% more marketable fruit in the sheltered plots.

Typical of muskmelon crops throughout Nebraska and much of the Midwest, our plots were interspersed with other crops, especially corn (*Zea mays* L.). All plots were encircled by 3 m of alfalfa (*Medicago sativa* L.). Sheltered plots with their alfalfa borders were surrounded by winter wheat (*Triticum aestivum* L.) in 1992 and by alfalfa and soybeans {*Glycine max* (L.) Merr.} in 1993. Exposed plots, with their alfalfa borders, were at least 200 m from the nearest windbreak and were surrounded by wheat and corn in 1992 and by alfalfa and soybeans in 1993. Different border crops between sheltered and exposed plots were assumed to have negligible importance on corn rootworm catches because corn (continuous and in rotation) was the predominant crop within a radius of 3.2 km, and alfalfa, soybeans, and wheat are widely planted throughout this area. Adult rootworms are highly mobile and can rapidly disperse over large distances, seeking corn pollen, corn silks, and other pollen (Coats et al., 1986; Naranjo, 1991, 1994). Planting and maturation of corn and other crops within the section and surrounding area were staggered; consequently, suitable corn in attractive growing stages was available from July through August. Furthermore, in both years large plots of late maturing corn, designed to attract adult corn rootworms to specific fields for feeding and subsequent egg-laying, were planted within 0.4 km of all sites. Corn rootworm beetles will select corn pollen and corn silks over pollen from other crops or broadleaf weeds and are attracted to volatiles produced by corn silks and corn pollens (Cinereski and Chiang, 1968; Hill and Mayo, 1980; Lance and Fisher, 1987; Ludwig and Hill, 1975). For these reasons, large numbers of corn rootworms were expected throughout the study area.

Muskmelon Production

Three-week-old transplants of muskmelon (*Cucumis melo* L. cv. Hiline) were transplanted into the plots on May 20, 1992. Due to inclement weather in 1993, six-week-old transplants of cv. Hiline were transplanted into the plots on June 9, 1993. Muskmelons were planted 70 cm apart within rows on raised beds 10 cm high, 1.6 m wide, and 5 m long, with 3 m between the centers of the rows. Production practices followed those of commercial growers in Nebraska for non-irrigated muskmelons. We harvested melons between August 23 and September 11, 1992 and between August 19 and September 17, 1993.

Plots were sprayed at regular intervals with the pyrethroid insecticide Asana XL™ (esfenvalerate, DuPont[1]) at 0.03-0.05 kg/ha active ingredient to control striped cucumber beetles and southern corn rootworm beetles, the principal vectors of bacterial wilt in muskmelon. Traps were in place 2.5 days before each spray application. In 1992, Asana XL™ was applied to muskmelon plots on May 26, June 12, July 11, July 17, July 31, and August 13. In 1993, Asana XL™ was applied on June 11, June 21, and July 1. The 1993 treatments were followed by a single application of Sevin™ (carbaryl, Rhone-Poulenc[1]) on August 24, using 1.12 kg/ha active ingredient.

Insect Data Collection and Analysis

Three yellow 15 × 25-cm sticky traps (Pherocon AM, Trece[1]) were placed equal distances apart in the muskmelon plots. The traps

1. The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. No official endorsement or approval by the U.S. Department of Agriculture or the University of Nebraska, Institute of Agriculture and Natural Resources, of any product to the exclusion of others which may be suitable is intended.

were selected because they are preferred by certain species of coccinelids, chrysomelids and chrysopids (Prokopy and Owens, 1983; Hein and Tollefson, 1985: Maredia et al., 1992b). No chemical attractants or pheromones were used in the traps. One trap was placed in the east row, one in the west row, and one in the center of the plot. The base of the trap was 30 cm above the soil line or approximately at canopy height of the mature muskmelon vines. Traps were collected and replaced with new traps each week, 14 times in 1992 and 13 times in 1993. Traps were refrigerated until insects could be removed, identified, and counted, usually within 3 days of collection.

Microclimate Data Collection

All microclimate data were continuously recorded on CR-10 automatic dataloggers (Campbell Scientific, Inc.) placed in the center of each plot, approximately 11.7 m or 1 times the height of the shelterbelt (1H) from the nearest row of trees. Wind speed was measured slightly above the height of the muskmelon canopy, ca 50 cm above the ground. Rainfall was measured by the University of Nebraska's Agricultural Meteorology weather station located near two exposed plots and within 800 m of the most distant sheltered location.

Data Analysis

Species counts were totaled by date, replication, and site. Data were ranked to address non-normality and heterogeneous variance problems. The transformed data were compared using the GLM procedure of SAS (Statistical Analysis Systems, 1992). Normality of the ranked data was evaluated with the UNIVARIATE procedure. A one-factor analysis of variance framework was used to compare responses to exposed/sheltered conditions. When appropriate, repeated observations in different months were included as a split-plot time factor. The TTEST procedure of SAS was used to compare total annual catches of the different beetles in sheltered versus exposed plots. All tests were interpreted as significant at $P \leq 0.05$.

RESULTS

Microclimate at Canopy Height

Rainfall for the period May 20 to August 23, 1992 was 283 mm, below the normal of 343 mm for the comparable time period. A record rainfall of 351 mm was recorded for the period June 9 to August 19, 1993 (normal for the period is 245 mm). Especially notable was the nearly daily occurrence of measurable rainfall during July, 1993.

In both years, daily average temperature for the entire muskmelon season at canopy height did not differ significantly between sheltered (1992 = 20.3°C; 1993 = 23.1°C) and exposed (1992 = 20.0°C; 1993 = 23.1°C) sites when compared by TTEST. Across the growing season the average daytime and nighttime temperatures did not differ significantly between the sheltered and exposed locations.

Wind speeds in the sheltered plots were significantly lower ($P \leq 0.05$) than those in exposed plots (Table 1). Shelterbelts reduced the frequency of winds greater than 2 m/s by 69% and 84% in 1992 and 1993, respectively. More important, winds exceeding 4 m/s, the physiological threshold for many vegetable crops (Zhang et al., 1995), were eliminated in shelter in 1992 and reduced by 99.9% in 1993.

Beetle Abundance

Approximately 60% more chrysomelid beetles, adjusted for the number of traps, were caught in 1993 than in 1992. In 1992, significantly fewer beetles were caught in the sheltered plots than in the exposed plots (88 and 293, respectively ($P \leq 0.05$)). However, in 1993, trap catches in the sheltered and exposed plots were not significantly different (388 and 409, respectively).

In 1992, four important crop-damaging beetles (Coleoptera), all in the family Chrysomelidae, were caught. The striped cucumber beetle (*Acalymma vittatum* Fabricius), the western corn rootworm beetle (*Diabrotica virgifera* LeConte), and the northern corn rootworm beetle (*D. barberi* Smith & Lawrence) were significantly

TABLE 1. Wind speed and frequencies at sheltered and exposed sites at Mead, Nebraska throughout the muskmelon growing seasons in 1992 and 1993.

		1992		1993	
Treatment		Sheltered	Exposed	Sheltered	Exposed
Total hours	< 2 m/s (%)	2106 (76.3)	1250 (45.3)	2076 (84.0)	1525 (61.7)
Total hours	2-4 m/s (%)	254 (9.2)	671 (24.3)	141 (5.7)	808 (32.7)
Total hours	> 4 m/s (%)	0 (0)	144 (5.2)	3 (0.1)	104 (4.2)
Missing hours	(%)	400 (14.5)	695 (25.2)	255 (10.3)	38 (1.4)
Total hours		2760	2760	2475	2475
Average hourly wind speed (m/s)		0.88	1.76	0.73	1.71

($P \leq 0.05$) less abundant in the sheltered plots (Table 2). Abundance did not vary significantly between sheltered and exposed plots for the southern corn rootworm beetle (*D. undecimpunctata howardi* Barber). In 1993, the abundance of the western corn rootworm beetle was significantly ($P \leq 0.05$) lower in the sheltered plots. In both years trap catches varied significantly with sample date (Figures 1 and 2).

For all species, in both years, beetle numbers were very low or zero during June. Southern corn rootworm beetles were the first to appear. In 1992, striped cucumber beetles and southern and western corn rootworm beetles were significantly ($P \leq 0.05$) more abundant on the exposed traps during July than on the sheltered traps. In 1993, the same three species were slightly more abundant on the exposed sites during August, but this difference was significant for only one date. Striped cucumber beetles collected in September were significantly more abundant on traps in the sheltered sites.

Abundance of Natural Enemies

Lady beetles (Coleoptera: Coccinellidae) were the most common beetle predator caught on the traps (Table 2). Other natural enemies included spiders (Araneae), lacewings (Neuroptera: Planipennia), ichneumonid wasps (Hymenoptera: Ichneumonidae), and braconid wasps (Hymenoptera: Braconidae). In 1992, the abundance of lady beetles did not vary with the amount of shelter, but in 1993 significantly more were caught on traps in the sheltered sites ($P \leq 0.05$). In both years beetle abundance often varied with date ($P \leq 0.05$) (Figure 3). Peak populations of lady beetles occurred mostly in June and were greatest in the sheltered plots.

In 1993, ichneumonid parasites were significantly more abundant on traps in sheltered sites than on traps in exposed sites (Table 2). The abundance varied significantly with sample date, with the most wasps caught during June (Figure 4).

A few spiders and lacewings were caught on the traps. Spider abundance did not vary with year, treatment (Table 2), or sample date. Numbers of lacewings fluctuated greatly and were not significantly affected by shelter in 1992, but were significantly greater in exposed sites in 1993 (Table 2).

TABLE 2. Pest and beneficial arthropod abundance in muskmelon plots sheltered by trees and exposed.

	1992		1993	
	Sheltered	Exposed	Sheltered	Exposed
Pest or beneficial arthropod	Insects/trap (mean ± SE)	Insects/trap (mean ± SE)	Insects/trap (mean ± SE)	Insects/trap (mean ± SE)
Striped cucumber beetle	0.21 ± 0.08 a*	0.54 ± 0.06 b	2.61 ± 0.62 a	2.71 ± 0.39 a
Southern corn rootworm	0.98 ± 0.28 a	1.00 ± 0.13 a	1.46 ± 0.18 a	1.80 ± 0.17 a
Western corn rootworm	0.45 ± 0.16 a	1.22 ± 0.26 b	0.08 ± 0.04 a	0.34 ± 0.09 b
Northern corn rootworm	0.23 ± 0.07 a	0.48 ± 0.09 b	0.13 ± 0.02 a	0.14 ± 0.11 a
Lady beetles	1.67 ± 0.42 a	1.47 ± 0.30 a	3.79 ± 0.12 a	2.66 ± 0.36 b
Lacewings	0.04 ± 0.02 a	0.19 ± 0.04 a	0.08 ± 0.04 a	0.17 ± 0.04 a
Ichneumonid parasites	—	—	0.61 ± 0.06 a	0.28 ± 0.05 b
Braconid parasites	—	—	0.12 ± 0.03 a	0.07 ± 0.01 a
Spiders	0.05 ± 0.01 a	0.07 ± 0.01 a	0.11 ± 0.03 a	0.10 ± 0.02 a

* Means in the same row in 1992 or 1993 followed by different letters are significantly different ($P \leq 0.5$, SAS GLM and TTEST procedures after a rank transformation).

FIGURE 1. Mean number per trap of corn rootworm beetles and cucumber beetles captured on sticky traps in exposed and sheltered muskmelon plots during 1992 by trap collection date.

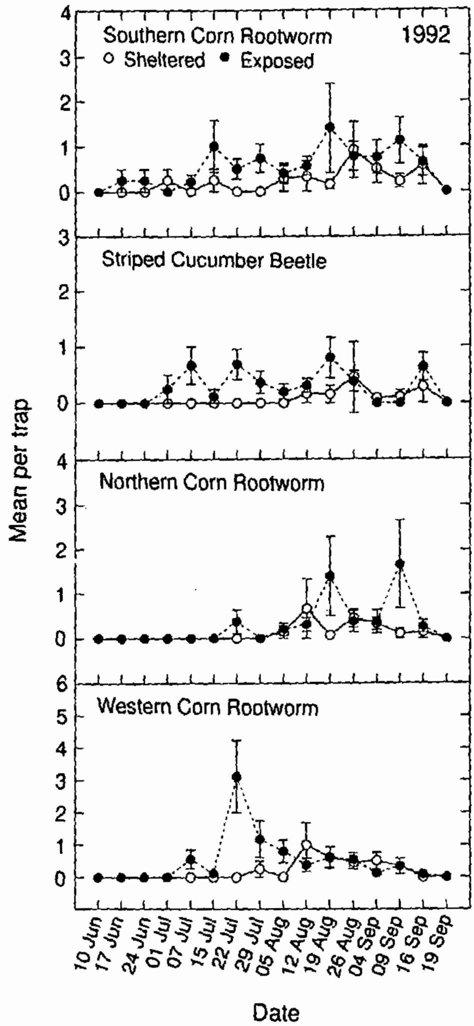


FIGURE 2. Mean number per trap of corn rootworm beetles and cucumber beetles captured on sticky traps in exposed and sheltered muskmelon plots during 1993 by trap collection date.

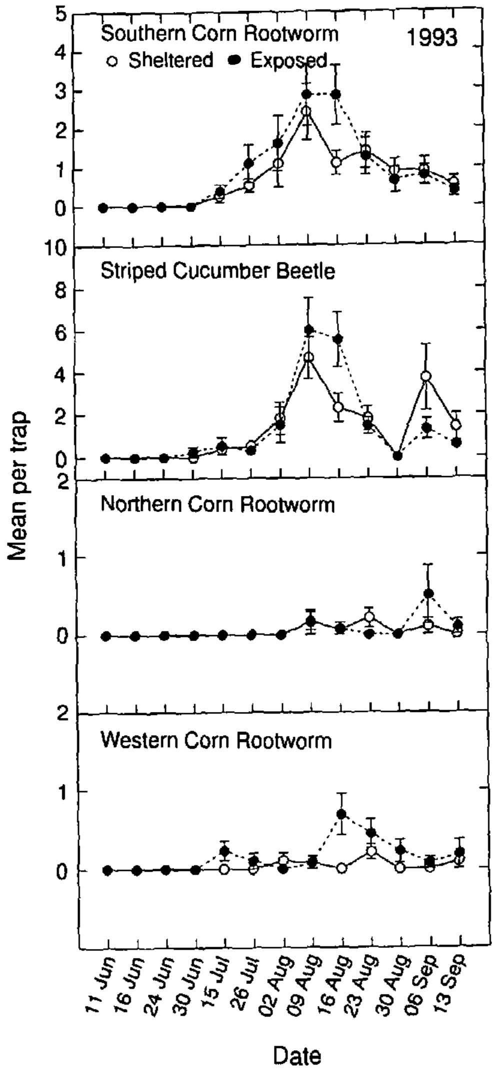
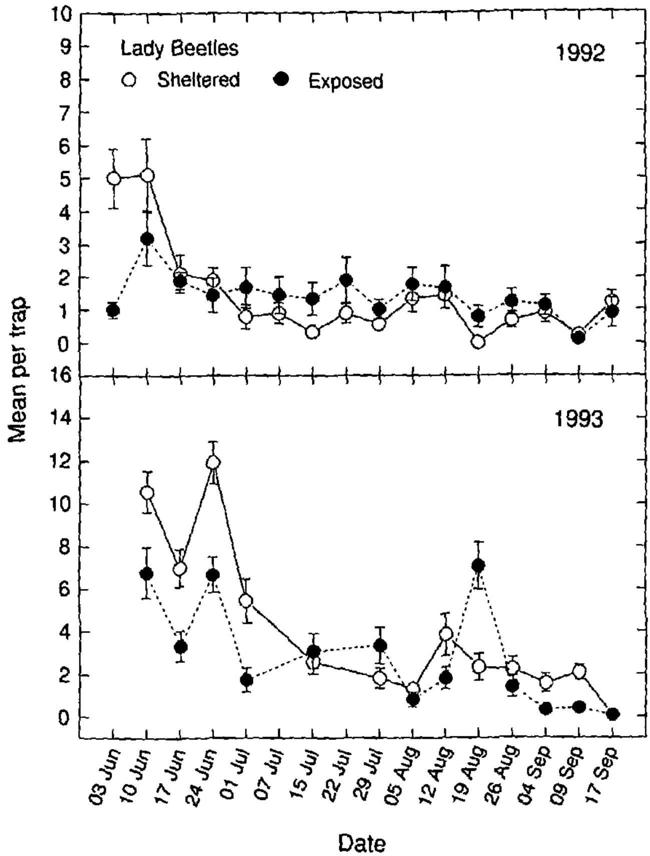


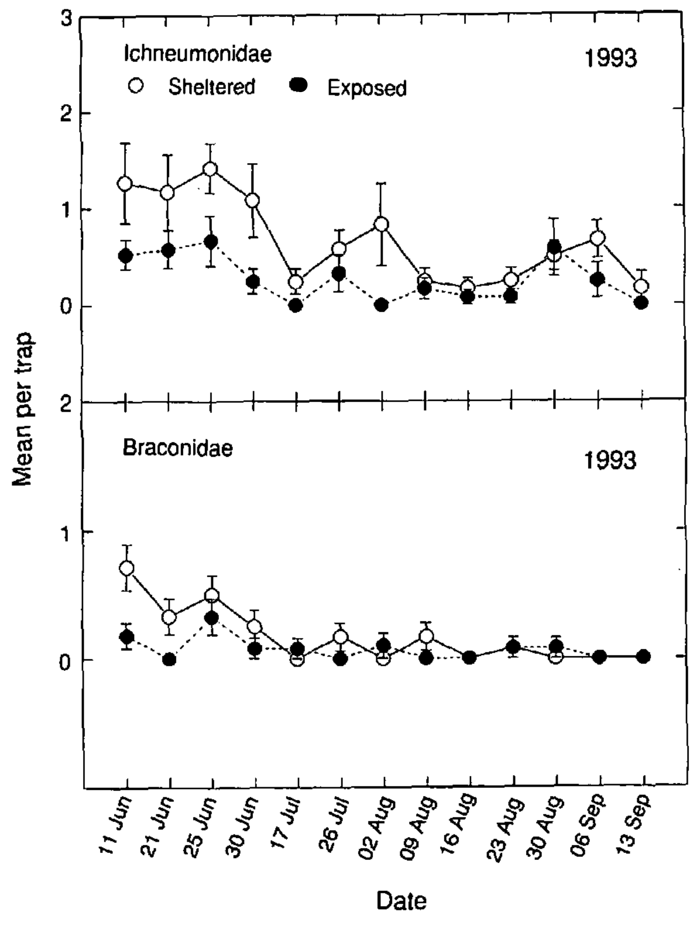
FIGURE 3. Mean number per trap of lady beetles captured on sticky traps in exposed and sheltered muskmelon plots during 1992 and 1993 by trap collection date.



DISCUSSION

The striped cucumber beetle attacks muskmelon, cucumber, watermelons, and other cucurbit crops in the United States. Adults destroy small seedlings early in the spring, and feed on mature plants throughout the summer. The beetles also transmit *Erwinia*

FIGURE 4. Mean number of parasitic wasps (Ichneumonidae and Braconidae) captured on sticky traps in exposed and sheltered muskmelon plots during 1993 by capture date.



traceiphila, the bacterium that causes bacterial wilt of cucurbits. The larvae seriously damage plant roots. The species produces two generations each year. Adults overwinter under the bark of trees and leaf cover in shelterbelts and wooded areas, and in clumps of grass along fence rows, shelterbelts, or other sheltered areas (Balduf, 1929; Gould, 1944; York, 1992).

The northern, southern, and western corn rootworms are all serious pests of corn in the central Great Plains of North America. However, only the southern and western rootworm beetles are known to transmit the wilt bacterium to cucurbits, and fewer than 10% of these beetles actually carry the disease (Einemann and Steadman, 1986). Both the northern and western corn rootworms overwinter as eggs in corn fields in eastern Nebraska. Most southern rootworm adults must migrate north each spring before laying eggs in Nebraska (Peters et al., 1987). During July and August, adult beetles feed on fresh corn pollen and corn silks. As the corn matures and dries down, the beetles migrate to other, younger fields with fresh pollen (Pavuk and Stinner, 1994). Although corn pollen and corn silks are the preferred food of all three species, both the northern and southern species will readily feed on pollen from other crops (soybeans, alfalfa, wheat, pumpkins, squash, muskmelons) and common forbs (smartweed, sunflowers, Russian thistle, stiff-leaf golden rod, kochia) (Ludwig and Hill, 1975; Hill and Mayo, 1980). Species of Cucurbitaceae are known to contain compounds that serve as attractants, locomotory arrestants, and feeding stimulants that can influence the feeding and flight behavior of striped cucumber beetles and rootworm beetles (Ferguson et al., 1983; McAuslane et al., 1986; Lewis et al., 1990).

In 1992, muskmelon fruit set was initiated in late June and early July in the sheltered plots with fruit set 5-7 days later in the exposed plots. The muskmelon pollen and flowers in these plots may have served as food for southern rootworm adults and might have attracted them into the sheltered plots from adjacent corn fields. However, beetle abundance in sheltered and exposed plots did not differ early in the season. By late July, corn pollen and corn silks were available as food sources, and the significantly higher numbers of rootworm beetles on the traps in the exposed plots may be due in part to the attraction of other nearby food sources.

In 1993, crop maturation was delayed due to cooler, wetter weather. During July, measurable precipitation in the plots every day probably slowed beetle development, delayed their emergence, and resulted in larger numbers during August. Although western rootworm adults were significantly ($P \leq 0.05$) more abundant during July 1993 in the exposed plots than in the sheltered plots, no difference between sheltered and exposed plots was found for the northern rootworm beetle.

Wind speeds in sheltered plots averaged less than 1 m/s (1992 = 0.88 m/s; 1993 = 0.73 m/s) and should have had negligible effect on beetle flight. In contrast, average wind speeds in exposed plots were 1.76 m/s (1992) and 1.71 m/s (1993), slightly above the threshold wind speed (1.5 m/s) for controlled flight of western corn rootworm beetles (Van Woerkom et al., 1983). Naranjo (1994) suggested that both western and northern rootworm beetles initiated directed flight at slightly higher wind speeds. In either case, wind speeds greater than 2 to 3 m/s tend to favor downwind flight patterns.

Lady beetles, lacewings, and spiders are generalist predators that feed on other arthropods. They are highly mobile and move freely among fields and vegetation (Mahr and Ridgway, 1993). Lady beetle abundance varied with year, sample date, and shelter. Their abundance may have been influenced by weather conditions, plant phenology, and the availability of prey in the plots or in surrounding crops such as alfalfa, corn, or soybeans (Banks, 1955; Kieckhefer and Elliot, 1990; Kieckhefer et al., 1992).

Lady beetles tend to congregate in areas with high prey populations (Ives et al., 1993). In Michigan, winter wheat and alfalfa supported 30-50% of the total population of lady beetles for six weeks beginning in early spring because these crops contained the earliest vegetation and prey base in the agroecosystem (Hazzard and Ferro, 1991; Maredia et al., 1992a). After alfalfa was harvested in mid-July, the alfalfa could no longer support adult lady beetles, so they moved to other crops with suitable prey. Similar behavior was observed during this study in Nebraska, with the lady beetles feeding on prey in wheat early in the season and then migrating to alfalfa, corn, and soybeans to feed on aphids, insect eggs, and pollen (unpublished data).

Ichneumonid and braconid wasps usually have very narrow host ranges (Mahr and Ridgeway, 1993). Their capture on the traps may reflect their searching for hosts. The ichneumonids were more abundant in the sheltered plots, possibly because the shelterbelts provided either hosts or protection from the wind, or both.

CONCLUSIONS

Although bacterial wilt was found first in sheltered plots in 1991 and our preliminary observations indicated greater numbers of cucumber beetles in sheltered plots, weekly trapping in 1992 and 1993 did not show increased beetle numbers in sheltered plots compared to exposed plots. The movement of rootworm beetles onto alternative host plants during the maturation and dry-down stages of corn production described in the literature is supported by our data. Since this stage of corn growth corresponds to muskmelon fruit maturation and high melon susceptibility to wilt, control of these beetles may be necessary during this time period. Biological management may be feasible by providing an acceptable alternative trap crop of vegetation and pollen source, such as broadleaf forbs or flowers, adjacent to corn fields proximal to muskmelon production.

Sticky traps are a passive method to determine the presence of aerial insect pests and arthropod natural enemies. This information can be used to time control practices for specific pests. The presence of predators and parasitic wasps on the traps also indicates the availability of natural enemies in the system that might feed on the beetles and other muskmelon pests. In general, more lady beetles and ichneumonids were caught in sheltered plots. Abundance of these natural enemies in muskmelon plots may be further increased by manipulating crop and vegetative species near the shelterbelts to provide protection and alternative sources of food.

REFERENCES

Balduf, W.V. 1929. Hibernation of the striped cucumber beetle (Coleoptera: Chrysomelidae). Entomological News, October 1929; 40:260-262

Banks, C.J. 1955. An ecological study of Coccinellidae (Col) associated with *Aphis fabae* scop. on *Vicia faba*. Bull. Entomol. Res. 46:561-587.

Coats, S.A., J.J. Tollefson, & J.A. Mutchmor. 1986. Study of the migratory flight of the western corn rootworm (Coleoptera: Chrysomelidae). Environ. Entomol. 15:620-635.

Cinereski, J.E. & H.C. Chiang. 1968. The pattern of movement of adults of the northern corn rootworm inside and outside of corn fields. J. Economic Entomol. 61:1531-1536.

Dix, M.E. & D. Leatherman. 1988. Insect management in windbreaks. Agriculture, Ecosystems and Environment 22/23:501-512.

Einemann, L. & J. Steadman. 1986. Population dynamics of four Diabroticina beetle vectors of bacterial wilt of curcubits. Phytopathology 76:956.

Ferguson, J.E., R.A. Metcalf, R.L. Metcalf, & A.M. Rhodes. 1983. Influence of cucurbitacin content in cotyledons of Cucurbitaceae cultivars upon feeding behavior of Diabroticina beetles (Coleoptera: Chrysomelidae). J. Econ. Entomol. 7:47-51.

Gould, G.E. 1944. The biology and control of the striped cucumber beetle. Bull. Ind. Agric. Exp. Stn. 490:3-28.

Hazzard, R.V. & D.N. Ferro. 1991. Feeding responses of adult *Coleomegilla maculata* (Coleoptera: Coccinellidae) to eggs of Colorado potato beetle (Coleoptera: Chrysomelidae) and green peach aphids (Homoptera: Aphididae). Environ. Entomol. 20: 644-651.

Hein, G.L. & J.J. Tollefson. 1985. Use of the Pherocon AM trap as a scouting tool for predicting damage by corn rootworm (Coleoptera: Chrysomelidae) larvae. J. Econ. Entomol. 78:200-203.

Heisler, G.M. & D.R. DeWalle. 1988. Effects of windbreak structure on wind flow. Agriculture, Ecosystems and Environment 22/23:41-69.

Heisler, G.M. & M.E. Dix. 1988. Effects of windbreaks on local distribution of airborne insects, pp. 5-12. *In*: Proceedings of the Conference "Insects of windbreaks and related plantings: Distribution, importance, and management." USDA Forest Service General Technical Report RM-204, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO 80526.

Hill, R.E. & Z.B. Mayo. 1980. Distribution and abundance of corn rootworm species as influenced by topography and crop rotation in eastern Nebraska. Environ. Entomol. 9:122-127.

Ives, A.R., P. Kareiva, & R. Perry. 1993. Response of a predator to a variation in prey density at three hierarchical scales: Lady beetles feeding on aphids. Ecology 74:1929-1938.

Kieckhefer, R.W. & N.C. Elliot. 1990. A 13-year survey of the aphidophagous Coccinellidae in maize fields in eastern South Dakota. Can. Entomol. 122:579-581.

Kieckhefer, R.W., N.C. Elliot, & D.A. Beck. 1992. Aphidophagous Coccinelids in alfalfa, small grains, and maize in eastern South Dakota. The Great Lakes Entomologist 25:15-23.

Kort, J. 1988. Benefits of windbreaks to field and forage crops. Agriculture, Ecosystems and Environment 22/23:165-190.

Lance, D.R. & J.R. Fisher. 1987. Food quality of various plant tissues for adults of northern corn rootworm (Coleoptera: Chrysomelidae). J. Kansas Entomol. Soc. 60:462-466.

Lewis, P.A., R.L. Lampman, & R.L. Metcalf. 1990. Kairomonal attractants for *Acalymma vittatum* (Coleoptera: Chrysomelidae). Environ. Entomol. 19:8-14.

Lewis, T. 1970. Patterns of distribution of insects near a windbreak of tall trees. Ann. Appl. Biol. 65:213-220.

Lewis, T. & B.D. Smith. 1969. The insect faunas of pear and apple orchards and the effect of windbreaks on their distribution. Ann. Appl. Biol. 64: 11-20.

Ludwig, K.A. & R.E. Hill. 1975. Comparison of gut content of adult western and northern corn rootworms in northeast Nebraska. Environ. Entomol. 4:435-438.

Mahr, D.L. & N.M. Ridgway. 1993. Biological control of insects and mites. North Central Regional Publication 481, 91 pp.

Maredia, K.M., S.H. Gage, D.A. Landis, & J.M. Scriber. 1992a. Habitat use patterns by the seven-spotted lady beetle (Coleoptera: Coccinellidae) in a diverse agricultural landscape. Biological Control 2:159-162.

Maredia, K.M., S.H. Gage, D.A. Landis, & T.M. Wirth. 1992b. Visual response of *Coccinella septempunctata* (L.), *Hippodamia parenthesis* (Say), (Coleoptera: Coccinellidae) and *Chrysoperla carnea* (Stephens), (Neuroptera: Chrysopidae) to colors. Biological Control 2:253-256.

McAuslane, H.J., C.R. Ellis, & P.E. A. Teal. 1986. Chemical attractants for adult northern and western corn rootworms (Coleoptera: Chrysomelidae) in Ontario. Proc. Entomol. Soc. Ont. 117:49-57.

Naranjo, S.E. 1991. Movement of corn rootworm beetles, *Diabrotica* spp. (Coleoptera: Chrysomelidae), at cornfield boundaries in relation to sex, reproductive status, and crop phenology. Environ. Entomol. 20:230-240.

Naranjo, S.E. 1994. Flight orientation of *Diabrotica virgifera virgifera* and *D. barberi* (Coleoptera: Chrysomelidae), at habitat edges. Ann. Entomol. Soc. Am. 87: 383-394.

Pasek, J.E. 1988. Influence of wind and windbreaks on local dispersal of insects. Agriculture, Ecosystems and Environment 22/23: 539-553.

Pavuk, D.M. & B.J. Stinner. 1994. Influence of weeds within *Zea mays* crop plantings on populations of adult *Diabrotica barberi* and *Diabrotica virgifera virgifera*. Agriculture, Ecosystems and Environment 50:165-175.

Peters, L.L., L.J. Meinke, & J.F. Witkowski. 1987. Corn Rootworm Control, 4 pp. NebGuide G87-839, Cooperative Extension Service Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln.

Prokopy, R.J. & E.D. Owens. 1983. Visual detection of plants by herbivorous insects. Annual Review Entomology 28:337-364.

Shi, Z. & Z. Gao. 1986. On the ecological efficiency of shelterbelt network and its yield-increasing effect in paddy fields. J. Ecology 5:10-14.

Statistical Analysis Systems. 1992. SAS technical report P-229 SAS/STAT Software: Changes and Enhancements Release 6.07, 620 pp. SAS Institute Inc., Cary, NC.

Slosser, J.E., R.J. Fewin, J.R. Price, L.J. Meinke, & J.R. Bryson. 1984. Potential of shelterbelt management for boll weevil (Coleoptera: Curculinonidae) control in the Texas rolling plains. J. Econ. Entomol. 77:377-385.

Unwin, D.M. & S.A. Corbet. 1991. Insects, plants, and microclimate. Naturalists Handbook No. 15, Richmond Publishing Co., Slough, England.

VanWoerkom, G.J., F.T. Turpin, & J.R. Barrett, Jr. 1983. Wind effect on western corn rootworm (Coleoptera: Chrysomelidae) flight behavior. Environ. Entomol. 12:196-200.

York, A. 1992. Pests of cucurbit crops: marrow, pumpkin, squash, melon, and cucumber, pp. 139-161. *In:* McKinlay, B.G. (ed.), Vegetable Crop Pests. CRC Press, Inc., Boca Raton.

Zhang, H., J.R. Brandle, G.E. Meyer, & L. Hodges. 1995. A model to evaluate windbreak protection efficiency. Agroforestry Systems 29:191-200.

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