NOTE

Incidence of Wildflower Visitation by Hymenopterous Parasitoids of Southern Pine Beetle, *Dendrotonus frontalis* Zimmermann[1]

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J. Entomol. Sci. 34(4):484-488 (October 1999)

Key Words Bark beetles, parasitoids, wildflowers, *Dendroctonus frontalis*.

Southern pine beetle, *Dendroctonus frontalis* Zimmermann (Coleoptera: Scolytidae), is the most important insect pest of mature pine forests in the southeastern United States (Price et al., 1992, Southern Forest Insect Work Group, Georgia For. Comm., Macon, GA.). It has been suggested that in recent years the intensity and duration of its cyclic outbreaks are increasing (Turchin et al., 1991, Environ. Entomol. 29: 401-409). Silvicultural and chemical techniques currently used to control *D. frontalis* infestations are frequently unsatisfactory, especially in locations sensitive to human disturbance (e.g., Wilderness Areas). Natural enemies of *D. frontalis,* including hymenopterous parasitoids, have become a focal point in the search for a safe, effective control strategy.

Research in a variety of ecosystems has provided evidence that flower nectar can increase the longevity and/or fecundity of synovigenic parasitic wasps (Leius, 1967, Can. Entomol. 99: 444-446; Syme, 1975, Environ. Entomol. 4: 337-346; Foster and Ruesink, 1984, Environ. Entomol. 13: 664-668; Mendel, 1988. Environ. Entomol. 17: 294-298; Idris and Grafius, 1995, Environ. Entomol. 24: 1726-1735). Leius (1967) found that 18 times as many tent caterpillar pupae were parasitized in apple orchards with a wildflower ground cover than in orchards without flowers. No observations of bark beetle parasitoids visiting flowers have been published (Jervis et al., 1993, J. Natural Hist. 27: 67-105). The artificial diet Eliminade™ (Entopath Inc., Easton, PA), however, has been shown to increase mature and immature egg load of all species of the *D. frontalis* parasitoid complex investigated in our study (Hanano, 1996, M. S. Thesis, Univ. of Arkansas). Individual parasitoids of all species, when fed the diet, lived longer than unfed individuals (Mathews and Stephen, 1997, Environ. Entomol. 26: 961-965). Eliminade™ provides sugars, proteins and other nutrients simulating natural food sources (L. E. Browne, Entopath Inc., pers. commun.), namely wildflow-

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[1] Received 30 September 1998; accepted for publication 12 January 1999.

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ers, thought to formerly occur in the parasitoids' environment. The dramatic success of this artificial diet in enhancing parasitoid longevity and egg load has led to further speculation about the potential of wildflowers in increasing effectiveness of parasitoids as *D. frontalis* control agents.

Changes in forest structure throughout the southeastern United States seem correlated with increases in *D. frontalis* infestations. During the past 25 yr in Arkansas, there has been a decrease of 694,000 ha of naturally regenerated pine forests and a corresponding increase of 653,000 ha in pine plantations (Beltz et al., 1992, USDA For. Ser. Research Bull. SO-169). The shift to managed pine forests has resulted in a reduction in forest diversity, particularly the flowering plants associated with nectar production, owing to the dense layer of pine straw on the forest floor and increased canopy cover (Hunter, 1990, Prentice Hall, Paramus, NJ). Historically, *D. frontalis* parasitoids evolving with flowering plants would have had greater opportunity for feeding on nectar which may have contributed to increased longevity, fecundity, and effectiveness as *D. frontalis* control agents. Our research objective was to investigate visitation of wildflowers and use of nectar as a food source by *D. frontalis* parasitoids in the laboratory and in six active *D. frontalis* infestations. The *D. frontalis* parasitoid guild considered in our study included *Coeloides pissodis* (Ashmead), *Dendrosoter sulcatus* Muesebeck, *Spathius pallidus* Ashmead [all Braconidae]; and *Dinotiscus dendroctoni* (Ashmead), *Heydenia unica* Cook and Davis, and *Roptrocerus xylophagorum* Ratzeburg [all Pteromalidae], all of which are synovigenic.

We selected six *D. frontalis* infestations located in the Ouachita National Forest of central Arkansas during June and July 1996. The infestations, composed primarily of shortleaf pine (*Pinus echinata* Miller), appeared normal in terms of abundance of parasitoids, number of trees infested, and range of *D. frontalis* life stages present (F. M. Stephen, unpub. data).

For the laboratory tests, *D. frontalis*-infested bark was removed from infested trees, and adult parasitoids were reared and collected daily. Greenhouse-grown and field-collected wildflowers were cut within 0.5 h before tests were conducted and placed in individual observation chambers with 2 to 5 starved adult male and female parasitoids. Wildflowers were held in vases containing a 10% sugar solution throughout the trials (Elliott et al., 1987, J. Kansas Entomol. Soc. 60: 25-29). Parasitoids were selected based on daily availability resulting in a total of 85 individual parasitoids observed throughout the study (Table 1). Individual wildflowers and parasitoids were used once. Parasitoid activity was observed and recorded every 15 min for 4 h. Feeding was assumed if a wasp applied its mouthparts to the nectary of a flower (Jervis et al. 1993).

Additionally, in each active infestation one flat containing 8 to 10 potted wildflower plants was set at the base of *D. frontalis*-infested trees on which parasitoids were seen actively flying near the bark surface. Wildflowers were made available to parasitoids in each infestation for 4 to 24 h. Flowers used were *Coreopsis tinctoria* Nuttall, *Coreopsis* species, *Gaillardia pulchella* Fougeroux de Bondaroy (Compositae), *Cleome* species (Capparaceae), *Salvia* species (Labiatae), *Silene armeria* Linnaeus, and *Silene maritima* (Moench) (Caryophyllaceae). Flower species were selected based on shade tolerance and availability for purchase from local greenhouses. Flowers were visually checked, and arthropods seen on flowers were collected by aspiration. Sticky traps were placed within the flats to capture additional arthropods.

During laboratory tests, the parasitoids were not very active after a brief period of

Table 1. *D. frontalis* parasitoid and wildflower combinations investigated in laboratory studies of parasitoid nectar feeding. Number indicates the quantity of individual parasitoids confined in an observation chamber with each wildflower species

	Parasitoids*						
Plant species	CECB-female	COEP-female	COEP-male	DENS-female	HEYU-female	ROPX-female	ROPX-male
Family Campanulaceae							
Lobelia spicata	–	–	–	–	–	2	1
Family Caryophyllaceae							
Silene armeria	1	–	–	1	1	–	–
Family Commelinaceae							
Tradescantia sp.	–	–	–	–	–	2	1
Family Compositae							
Anthemus cotula	–	2	4	–	–	3	–
Aster pilosus	–	2	4	–	–	5	1
Carduus nutans	–	–	3	–	–	2	–
Centaurea cyanus	–	–	–	–	4	–	–
Chrysanthemum leucanthemum	–	3	1	–	–	1	–
Coreopsis sp.	–	–	–	–	3	–	–
Coreopsis tinctoria	1	–	–	–	1	–	–
Gaillardia pulchella	–	–	1	–	3**	2	–
Parthenium integrifolium	–	–	–	–	–	5	3
Taraxicum officinale	–	–	1	–	–	1	1

Table 1. *Continued.*

Family Labiatae							
Salvia coccinea	–	–	–	–	1	–	–
Family Umbelliferae							
greenhouse grown *Daucus carota*	–	–	–	–	4	–	–
field collected *Daucus carota*	–	7**	1	–	3	1**	–
Family Verbenaceae							
Verbenatenuisecta sp.	1	–	–	–	1	–	–

* Parasitoid species codes: CECB-*Dinotiscus dendroctoni,* COEP - *Coeloides pissodis,* DENS-*Dendrosoter sulcatus,* HEYU-*Heydenia unica,* ROPX-*Roptrocerus xylophagorum*

** Denotes feeding observed by at least one individual.

acclimatization to the observation chamber. Of 1,360 15-min parasitoid observations, parasitoid nectar feeding activity occurred 13 times; 11 times on field-collected *Daucus carota* L. (Umbelliferae) by 5 female *C. pissodis,* once on field-collected *D. carota* by 1 female *R. xylophagorum,* and once on greenhouse-grown *G. pulchella* (Compositae) by 1 female *H. unica.* Although parasitoids were also confined with greenhouse-grown *D. carota,* no feeding activity was observed.

The flower species chosen by the parasitoids belong to the families Compositae and Umbelliferae, which are characterized by clusters of numerous small flowers. Györfi (1945, Erdészeti Kisérietek 45: 100-112) found that a considerable number of species of parasitoids with short mouthparts were restricted to the plants of the family Umbelliferae, which have exposed nectaries. Jervis et al. (1993) also found the greatest numbers of both individual parasitoids and species of parasitoids on flowers of the Umbelliferae family. They concluded that one of the most important factors limiting food plant range of parasitoids is floral morphology, particularly when nectar is the primary food source. Finally, Idris and Grafius (1995) found that female *Diagegma insulare* (Cresson) (Ichneumonidae) showed higher fecundity and longevity when they had access to flowers with morphological characteristics (specifically, reduced corolla length and increased corolla opening width) that increased the accessibility of nectar to the parasitoids.

Although field-collected *D. carota* was acceptable to some species of parasitoids, greenhouse-grown *D. carota* was not. This may have resulted from failure to control ant populations observed on the greenhouse-grown flowers. Nectar sources of these plants may have been depleted by the time they were used in the observation trials.

Observation of *D. frontalis* parasitoids feeding on nectar in the laboratory shows that these parasitoids will use nectar when it is readily accessible. Surprisingly, no *D. frontalis* parasitoids were seen on the wildflower flats or caught on sticky traps during field observations. The lack of feeding on wildflowers by parasitoids in the field may have resulted from a number of circumstances. Introducing small flats into an active *D. frontalis* infestation may not present adequate opportunity for parasitoids to find or respond to this limited food source. Alternatively, *D. frontalis* parasitoid adults may not utilize nectar from forest wildflowers as we had originally hypothesized (Stephen, 1995, *In* F. P. Hain et al. [eds.], Behavior, population dynamics and control of forest insects. Ohio State Univ., OARDC, Wooster, OH.). Situations where wildflowers are more abundant on the forest floor, such as following a controlled burn with re-seeding of wildflowers, may provide an environment in which parasitoid visitation and feeding on wildflowers is more likely. Enhancement of parasitoid populations, through the use of increased food availability, may in turn decrease the potential for future *D. frontalis* infestations.

We thank M. P. Lih, P. L. Mathews, and M. D. Pettit for assistance with field and laboratory techniques and procedures. The Arkansas Forestry Commission and the USDA Forest Service provided support with infestation location and parasitoid collection. Research was supported in part by USDA NRI Competitive Grants Program Grant No. 94-37312-0624; USDA SBIR Grant No. 95-33610-1492 (to Entopath, Inc.) and the University of Arkansas, Arkansas Agricultural Experiment Station; and UA Forest Resources Center, Monticello, AR. Published with the approval of the Director, Arkansas Agricultural Experiment Station.