N O T E

Floral Nectars and Honey Enhance Survival of *Diadegma insulare* (Hymenoptera: Ichneumonidae), a Parasitoid of the Diamondback Moth (Lepidoptera: Plutellidae)[1]

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The diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), is an important pest of *Brassica* crops globally. Studies with *Diadegma insulare* (Cresson) (Hymenoptera: Ichneumonidae) have demonstrated parasitism levels of *P. xylostella* of 75% in cabbage (*Brassica oleracea* var. *capitata* L.) in Canada (Harcourt 1986, Proc. First Int. Workshop Asian Veg. Res. & Develop. Ctr.), 72% in collard (*Brassica oleracea* var. *acephela de Condolle*) in Florida (Mitchell et al. 1997, Florida Entomol. 80: 54-62), and >90% in untreated collard in South Carolina (Muckenfuss and Shepard 1994, J. Agric. Entomol. 11: 361-373).

Floral nectars from wild mustard [*Brassica kaber* (L.)], wild carrot [*Daucus carota* (L.)], yellow rocket (*Barbarea vulgaris* R. Br.) (Idris and Grafius 1997, Environ. Entomol. 26: 114-120), or other carbohydrate sources under laboratory (Foster and Ruesink 1984, Environ. Entomol. 13: 664-668) or field conditions (Idris and Grafius 1995, Biol. Contr. 24: 1726-1735; 1996, Pop. Ecol. 25: 825-833) increased *D. insulare* adult survival and fecundity. Flowers of various types of wild or cultivated plants, including white clover (*Trifolium repens* L.), may serve as a potential source of food in enhancing populations of *D. insulare* in cropping systems. The objectives of this study were, therefore, to determine the effect of floral nectars from selected wild and cultivated plants, as well as honey, on adult *D. insulare* survival and parasitism.

Transplants of selected crucifers were established in a 0.5 ha field plot and were irrigated twice weekly at the Clemson University Coastal Research and Education Center (CREC), Charleston, SC. The plot consisted of ornamental kale, *Brassica*

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oleracea var. *acephala* L. ('Nagoya Mix' and 'Frizzy White'), and 'Vates' edible kale, *B. oleracea* var. *acephala* L. *Diadegma insulare* adults from a colony maintained on collard at the University of Florida, Apopka, FL, were fed a 10% clover honey /90% water solution and allowed to mate for 48-h in rearing cages (35 x 35 x 22 cm) in an environmental chamber (Percival Scientific Inc., Boone, IA) maintained on a 16:8 (L:D) photoperiod and at 26°C and 60 to 80% RH. Larvae of *P. xylostella* were obtained from a laboratory colony at the USDA, ARS, U.S. Vegetable Laboratory in Charleston, SC. The experiment was conducted using plants of 'Vates,' 'Nagoya Mix' and 'Frizzy White' kale, white clover, red clover (*Trifolium pratense* L.), tansy (*Phacelia tanacetifolia* Benth.), and uncultivated wild radish at the CREC. Treatments included exposure to intact flowers on the above listed plant species, intact flowers and water, water as a control, and 15% clover honey solution in water. The test consisted of eight trials with the treatments arranged in a completely randomized design. Each trial consisted of four to six replications. The honey in water solutions were contained in 30-ml plastic cups with lids. A 1-cm hole was punched in the center of the lid, and a cotton dental wick was inserted to allow the parasitoid to feed. Cups were filled with 10-ml of the honey solution, and hooked wire was used to suspend each cup of solution in the field cages. Each field cage was constructed by removing the bottom of a white 360-ml styrofoam cup. A piece of nylon hosiery tubing (30-cm in length) was stretched, then placed over the cup and tied into a knot over the larger (top) opening. Data were subjected to the analysis of variance (ANOVA) procedure and the least significant differences (LSD) test to separate means ($P < 0.05$) among treatments for survival and parasitism (SAS Institute. 1997. SAS/STAT user's guide, SAS Institute, Cary, NC).

Survival. Each field cage was placed over an intact floral bouquet of a plant. Flowers were removed if no nectar source was included (water treatment). Cages were placed at approximately the same height on the plants. Female parasitoids were aspirated from the rearing cages and placed individually into 3-ml vials. Vials were

Table 1. Mean survival in days (±SEM) of *Diadegma insulare* when placed on various food sources for all trials in field cages for 5 d*

Treatment[1]	n	Mean survival (days) ± SEM
15% Honey	4	4.3 ± 0.3a
'Nagoya' Kale	9	3.1 ± 0.6a
'Vates' Kale	26	3.0 ± 0.4a
'Vates' Kale + Water	26	2.5 ± 0.8a
'Frizzy' Kale	14	1.4 ± 0.4b
Wild Radish	44	1.0 ± 0.2bc
Red Clover	44	1.3 ± 0.2bc
Red Clover + Water	18	1.0 ± 0.2bc
Water	44	0.8 ± 0.2bc
Tansy	29	0.5 ± 0.2c
White Clover	44	0.5 ± 0.1c
LSD		0.8

* Female parasitoids were placed on the flowers of the plants. Trials consisted of four to six replications. Means followed by different letters are significantly different (LSD test, $P > 0.05$).

capped with cotton moistened with 10% honey solution, transported to the field, and one female was released into each cage. The cage was then tied off at the bottom opening. At 24-h intervals for 5 d, mortality was checked mid-day and recorded. Each cage was observed and checked for parasitoid mobility by tapping the cage gently. Mean survival was calculated as the total number of days survived by each parasitoid divided by the number of replications. Data were combined for all trials of each treatment for mean survival (in days) of *D. insulare*. Surviving parasitoids at the end of the survival test were transported to the laboratory to conduct a parasitism test.

An additional experiment was conducted on white clover. A plot of white clover 18.3 m long and 4.6 m wide was planted. The plot was irrigated for 1 h twice weekly before testing. Three treatments were white clover nectar, 15% clover honey solution, and water arranged in a completely randomized design. There were 15 replicates per treatment. The liquid treatments were prepared as described in the above-mentioned field test. As described above, adult female *D. insulare* were set up in field cages of each of these three treatments and survival data were collected.

Diadegma insulare parasitoids survived significantly longer ($F = 6.91$; df = 22, 319; $P < 0.0001$) when allowed to feed on flowers of 'Nagoya' kale, 'Vates' kale, 'Vates' kale plus water, or 15% clover honey compared with parasitoids placed on flowers of 'Frizzy' kale, red clover, red clover plus water, wild radish, white clover, tansy, or water (Table 1). Parasitoids provided flowers of 'Frizzy' kale survived significantly longer than those provided flowers of white clover or tansy.

In the white clover field test, *D. insulare* females provided 15% clover honey survived significantly longer (mean = 4.3 d; $F = 25.70$; df = 2, 42; $P = 0.0001$) than those provided with either white clover nectar (mean = 1.9 d) or water (mean = 1.5 d). White clover nectar consists of many different sugars (Davis and Nordin 1983, Plant Physiol. 72: 1051-1055). However, our study suggests that white clover is a poor food source for survival of *D. insulare*. Because irrigation was applied on a regular basis, and the flowers appeared healthy, there may have been other reasons, such as prevalent visitation by bees, which may have resulted in the relatively low survival of *D. insulare* on the white clover flowers.

Parasitism. Each female parasitoid from the field test was placed in a cylindrical carton cage (480 ml). The cage enclosed a young collard bouquet (3-4 leaf stage) and 50 late second- instar *P. xylostella* larvae. One treatment, as described from the field test, was set up per cage. Female parasitoids were allowed to oviposit in *P. xylostella* host larvae in an environmental chamber at 26°C, 60 to 80% RH and a 16:8 (L:D) photoperiod for 24 h. The parasitoids were then removed from the chamber and provided 10% honey. Larvae were removed and placed into 30-ml cups (5 larvae per cup) containing multi-species artificial diet consisting primarily of soybean flour and wheat (Southland Products Inc., Lake Village, AR). Larvae were reared in an environmental chamber at 26°C for 14 d. Parasitism was considered successful when there was complete emergence of a healthy parasitoid. Percent parasitism was recorded for wasps from each treatment.

There were no significant differences ($P = 0.8406$; df = 7, 11) for the mean rates of parasitism for the various treatments of 'Nagoya' kale (28.7%), 15% honey (20.1%), wild radish (20.0%), 'Vates' kale (17.8%), red clover (17.7%), 'Vates' kale plus water (15.5%), 'Frizzy' kale (2.9%), and water (2.3%). High numbers of diamondback larval mortality were recorded during the tests. A total of 342 parasitoids were initially used in the survival test, but few survived in the field after 5 d to conduct the parasitism test. All females produced progeny (range from 1 to 57 parasitoids). In a

related study (Idris and Grafius 1995, 1997), each *D. insulare* female was allowed to feed on Brassicaceae or Umbelliferae flowers and parasitized diamondback moth larvae (ranging from 3.6 to 160.7) depending on the quality of the nectar source. Idris and Grafius (1997) reported that female parasitoids that fed on wormseed mustard (*Erysimum cheiranthoides* L., Brassicaceae), field pennycress (*Thlaspi arvense* L., Brassicaceae), or shepherd's purse (*Capsella bursa-pastoris* (L.) Medic, Brassicaceae) tended to parasitize relatively low numbers of larvae. In contrast, those parasitoids that fed on yellow rocket (Brassicaceae), wild mustard (Brassicaceae), or wild carrot [*Daucus carota* (Umbelliferae)], parasitized relatively high numbers of larvae. Recent research suggested that kale floral nectar and various concentrations of honey resulted in increased parasitism by *D. insulare* that ranged from 50 to 94% parasitism (Gourdine 2002, M.S. Thesis, Clemson Univ.). Overall, many of the nectars tested herein, especially the *Brassica* plants, appear to support parasitism similar to 15% honey.

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