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The Use of Diverse Plant Species for Increasing *Osmia cornifrons* (Hymenoptera: Megachilidae) in Field Cages

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ABSTRACT: With the exception of rosaceous tree fruit species, few plant species have been identified as suitable forage for rearing the univoltine megachilid bee, *Osmia cornifrons* (Radoszkowski). Alternative forage might be useful for supplementing the resources available to the bee during orchard crop pollination. At the North Central Regional Plant Introduction Station, different plant species grown in field cages were investigated for their usefulness as *Osmia cornifrons* forage. Of the Brassicaceae spp. tested, *Brassica napus* L. was superior as forage for *O. cornifrons.* However, *B. rapa* L. and *Sinapis alba* L. also were suitable forage for the bee. *Coriander sativum* L., *Cucumis sativus* L., and *Cucumis memo* L. were unsuitable as forage for this bee.

Introduction

Osmia cornifrons (Radoszkowski) is a univoltine megachilid bee successfully introduced into the United States from Japan in 1977 (Batra, 1979). During the 1940's, after excessive insecticide use reduced feral orchard pollinator populations, *O. cornifrons* was managed on orchard crops grown in Japan. These bees were effective pollinators and were particularly useful for rosaceous tree fruits because the flowering time of the crop coincided with the emergence and active foraging time of the bee. The bee's effectiveness as an orchard pollinator and its acceptance of artificial nests led to its eventual widespread management in Japan (Yamada et al., 1971).

The orchard crops pollinated by *O. cornifrons* also were used to rear the bee from year to year. These plant species have generally been rosaceous tree fruit species such as apple, cherry, peach, pear, and plum (Kitamura and Maeta, 1969; Maeta and Kitamura, 1974; Tsugawa et al., 1967). While trying to establish *O. cornifrons* in the United States, Batra (1979) observed *O. cornifrons* visiting other plant species within the Rosaceae plant family. These included a *Chaenomeles* sp. (quince) and *Amelanchier canadensis* (L.) Medik.

Batra (1979) also observed *O. cornifrons* working two honeysuckle species (*Lonicera tatarica* L. and *L. fragrantissima* Lindl.: Caprifoliaceae) and maple (*Acer rubrum* L.: Aceraceae). Maeta (1974) noted that *O. cornifrons* was used for pollinating Ladino clover (*Trifolium repens* L.: Leguminosae) in Japan. However, it is uncertain if *O. cornifrons* females used pollen and nectar from these non-Rosaceae plant species for rearing progeny.

Finding an alternative forage for the bee could be beneficial for a number of reasons. For example, in an orchard pollination system, an alternative forage could sup-

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plement the resources available to the bee, particularly as fruit blossoms are dwindling, in order to maximize bee reproduction for pollination the following season. Also, if the alternative forage species is a crop, the bee could be used for the agronomic production of this crop.

We have been using *O. cornifrons* in comparative pollinator studies and for control pollinating Brassicaceae spp. plant germplasm under field cages at the North Central Regional Plant Introduction Station (NCRPIS) since 1992. This paper reports plant taxa we have used to rear *O. cornifrons* at the NCRPIS.

Materials and Methods

OSMIA CORNIFRONS INCREASE IN BRASSICACEAE SPP. FIELD CAGES: Two accessions of *Brassica rapa* L. (PI 278766 and PI 392025), one accession of *Sinapis alba* L. (PI 209022), and one accession of *Brassica napus* L. (PI 469944), were each planted in 5.1 cm^2 diameter peat pots (135 total) in the greenhouse from 16 February to 7 March 1995. The seedlings were transplanted into field plots from 17 to 24 April 1995 at plant densities of ~130 plants/plot. The plots were covered with field cages (6.4 m × 1.6 m × 1.6 m) before the onset of flowering.

The *O. cornifrons* used for this study were purchased from Orchard Bees (Auburn, IN), January, 1995. The bees were held at 1–2°C (Wilson and Abel, 1996). When voucher specimens were taken, we identified *Osmia lignaria lignaria* Say present in some of the nesting straws. Therefore, *O. l. lignaria* may have been present in both of the forage studies we conducted.

A domicile of bees was placed in the northwest corner of each cage at the onset of flowering. The domicile consisted of a 5.1-cm PVC pipe that contained 6 filled nesting straws (~8 bees/straw; ~5 males and ~3 females) and enough empty nesting straws (10–12) to tightly fill the PVC pipe. The nesting straws purchased from Orchard Bees were 30-cm-long × 7-mm-diameter cardboard tubes bent in half, thus forming two 15-cm-long nests. The cardboard tube wall was 1 mm thick. The empty nesting straws (Custom Paper Tubes, Inc., Cleveland, OH) were 40-cm-long × 7-mm-diameter cardboard tubes with each tube bent in half forming two 20-cm-long nests. The cardboard tube wall was 1.5 mm thick. A hole (approximately 30 cm diameter × 50 cm deep) was dug directly in the soil under each domicile to provide the bees with the mud that they must have to partition their nests, forming brood cells.

The bees were introduced into the field cages on 18 May for the *S. alba* accession and the two *B. rapa* accessions and on 26 May for the *B. napus* accession. The experiment was discontinued for all four accessions on 3 July, 1995. The straws were examined at the end of the experiment and those that had a mud cap sealing the end were believed to be filled with new bees and given a value of 1. Straws that were not sealed at the end of the straw but were partially filled were given a value of ½. Newly filled straws were differentiated from "old" filled straws, where the bees did not emerge, by the color of the mud that sealed the straw's end. Filled straws originally placed in the cages had a light clay plug, and newly sealed straws had a dark silt-loam soil plug.

Later in the year, during the completion of the *Coriander sativum* and *Cucumis* spp. forage study, the authors discovered that counting plugged nests was a relatively poor indication of how well a hole-nesting bee species, such as *Osmia cornifrons,* has reproduced. At this time, the Brassicaceae spp. straws had been combined and could no longer be analyzed. However, we X-rayed (Faxitron Shielded X-ray System, model 43855A) sealed nesting straws obtained in 1996 from *B. napus, B. rapa,* and *S. alba* accessions that were being grown under field cages to obtain seed increases.

The experiment was conducted as a randomized complete block design with four replications. This experiment was conducted during a comparative pollinator study of three bee species on selected Brassicaceae. Data were analyzed using the FACTOR analysis function of MSTAT-C (MSTAT Development Team, 1989). When the F-value for treatments was significant ($P < 0.05$), means were separated with the least significant difference (LSD) test (alpha = 0.05) using the RANGE program of MSTAT-C.

OSMIA CORNIFRONS INCREASE WITHIN *CORIANDER SATIVUM* AND *CUCUMIS* SPP. FIELD CAGES: One accession of *Coriander sativum* (A-18501), one accession of *Cucumis sativus* (Pl 257486), and one accession of *Cucumis melo* (Pl 500362) were planted in the greenhouse. The *Coriander sativum* was planted in 5.1-cm^2-diameter peat pots on 12 April, whereas the *Cucumis* accessions were planted in 7.6-cm-diameter peat pots on 8 May. The plants were transplanted into field plots on 3 June. Plant densities were ~75 plants per plot for the *Coriander sativum* and 24 plants per plot for the *Cucumis* accessions. Some of the *Coriander sativum* began flowering in the greenhouse and their flowers were removed before being transplanted to field plots. Field plots were caged the day of transplanting to exclude potential plant pests.

The *O. cornifrons* used for this study were purchased from Orchard Bees (Auburn, IN), January, 1995. The bees were held at 1–2°C (Wilson and Abel, 1996). *Osmia cornifrons* was introduced into the northwest corner of each cage at the onset of plant flowering. The bees were introduced on 11 July for the *Coriander sativum* and *C. sativus* accessions and from 25 July to 7 August, as female flowers appeared, for the *C. melo* accession. Each cage received one *O. cornifrons* domicile, as described earlier. At 10- to 14-day intervals, new, nonemerged nesting straws were added to replace empty nesting straws from which bees had emerged. This was to ensure a continuous supply of bees during plant flowering. A total of ~28 straws were added to each cage during the study. The experiment was discontinued on 9 August for the *Coriander sativum* accession and on 31 August for the *C. sativus* and *C. melo* accessions. The straws were examined at the end of the experiment, as previously described in the Brassicaceae spp. experiment.

The experiment was conducted as a randomized complete block design with four replications, and was conducted concurrently with another experiment comparing the pollination efficacy of honey bees (*Apis mellifera* L.), bumble bees (*Bombus bimaculatus* Cresson), alfalfa leafcutting bees [*Megachile rotundata* (Fabricius)], and *O. cornifrons* on the three plant species tested. Data were analyzed using the FACTOR analysis of MSTAT-C (MSTAT Development Team, 1989). When the F-value for treatments was significant ($P < 0.05$), means were separated with the least significant difference (LSD) test (alpha = 0.05) included in the RANGE program of MSTAT-C.

Results

The ANOVA from the Brassicaceae spp. test showed that there was a significant difference among treatments tested ($F = 7.28$; d.f. = 3, 8; $P < 0.05$). The range test (Table 1) shows that the *B. napus* (PI 469944) accession produced a significantly higher increase of filled *O. cornifrons* nesting straws than all other accessions tested.

Table 1. Comparison of the number of filled straws of *Osmia cornifrons* produced from each of the Brassicaceae spp. accessions tested.

Plant species	Accession I.D.	Mean filled straws per cage[a]
Brassica napus	PI 469944	20.9a
Brassica rapa	PI 278766	16.0b
Brassica rapa	PI 392025	14.7b
Sinapis alba	PI 209022	13.5b

[a] Means followed by the same letter are not significantly different according to the LSD test ($P = 0.05$). Values represent the mean of 4 replications.

All accessions tested increased the number of filled nesting straws at least 2× compared with the number of filled, purchased nesting straws that were used initially.

The average number of diapaused adult bees within sealed nesting straws that were obtained in 1996 from *B. napus, B. rapa,* and *S. alba* accessions that were grown under field cages to obtain seed increases were: *B. napus,* 8.6 bees ($n = 28$ straws X-rayed); *B. rapa,* 6.9 bees ($n = 26$ straws X-rayed); and *S. alba,* 6.3 bees ($n = 19$ straws X-rayed).

The ANOVA from the *Coriander sativum* and *Cucumis* spp. test showed that there was a significant difference among treatments tested ($F = 7.27$; d.f. = 2, 6; $P < 0.05$). The range test (Table 2) shows that the *C. sativus* (PI 257486) accession produced a significantly higher increase of filled *O. cornifrons* nesting straws than all other accessions tested.

Discussion

Results from the number of diapaused adult bees within sealed nesting straws obtained in 1996 from *B. napus, B. rapa,* and *S. alba* accessions that were being grown under field cages to obtain seed increases, indicate that the newly sealed nesting straws designated as filled during the Brassicaceae test were indeed filled with developing bees. *Osmia cornifrons* have been successfully reared on Brassicaceae spp. and used as pollinators the following season at NCRPIS for three consecutive years.

Osmia cornifrons reproduces significantly more prolifically on *Brassica napus* than on *B. rapa* and *Sinapis alba* (Table 1). The reason(s) for this difference is (are) uncertain. Perhaps pollen and/or nectar is easier for *O. cornifrons* to obtain from *B. napus* as compared to the other species. Floral differences between the Brassicaceae spp. (e.g., flower morphology, nectar, and pollen production, etc.) might have played a role in producing these results.

One difference between *B. napus* and *S. alba* flowers is the amount of nectar produced per flower. Average nectar secretion by individual *B. napus* flowers ranges widely. Petkov (1963) found 0.6 μl, Kubisova et al. (1976) found 2.4 μl, and Haragsimova-Neprasova (1960) found 3.6 μl. Sugar concentrations in *B. napus* flowers ranged from 29% to 38%. In contrast, individual *S. alba* flowers secrete an average of 0.2–0.6 μl of nectar (Ermakova, 1959; Haragsimova-Neprasova, 1960), with sugar concentrations fluctuating between 20% to even 90% with the nectar becoming stringy and difficult for honeybees to use at the higher sugar concentrations (Corbet, 1978). Similar data for *B. rapa* nectar production were not available.

Table 2. Comparison of the number of filled straws of *Osmia cornifrons* produced from each of the *Cucumis* and *Coriander sativum* accessions tested.

Plant species	Accession I.D.	Mean filled straws per cage[a]
Cucumis sativus	PI 257489	26.4a
Coriander sativum	A-18501	15.3b
Cucumis melo	PI 500362	14.1b

[a] Means followed by the same letter are not significantly different according to the LSD test ($P = 0.05$). Values represent the mean of 4 replications.

Torchio (1985) observed that the nesting ability of *Osmia lignaria propinqua* Cresson is greatly affected by the nectar/pollen ratio, with limited available nectar reducing the ability of this bee to provision nests, make a palatably moist pollen dough for the developing larvae to eat, and correctly attach eggs to the pollen dough for proper eclosion by the neonate. The nesting habits of *O. l. propinqua* and *O. cornifrons* are similar. Possibly, higher nectar production by *B. napus* makes this plant more suitable for *O. cornifrons* to make larval provisions than the other Brassicaceae spp. tested.

The amount of pollen produced by the plant species tested is unknown. Pollen production differences would be important in this test, because the small plots grown under field cages had relatively few plants (~130) available for the bees to use for provisioning their nests.

The number of filled straws produced by the bees on *B. napus* possibly could have been even greater. Within three field cages of *B. napus,* the empty nest straws given at the beginning of the experiment were all filled by the end of the experiment. If more straws had been available to the nesting females, the number of filled or at least partially filled straws may have increased.

Even though the *B. napus* accession produced significantly more bees, the B. *rapa* and *S. alba* accessions were suitable forage plants for the bee. At the NCRPIS, we have used the *B. rapa* variety 'Parkland' as an *O. cornifrons* forage crop, and have harvested an increase in filled nesting straws.

Table 2 shows that the number of filled nesting straws produced was significantly higher on *Cucumis sativus* than on *C. melo* and *Coriander sativum* in field cages. However, when the filled straws were removed from the domiciles, many of the nesting straws were very light in weight. X-rays of samples of the filled straws were conducted to determine the number of developing larvae within the straws. Of 42 straws X-rayed, the average numbers of developing bees within the straws for *C. sativus, C. melo,* and *Coriander sativum* were 0.0, 0.0, and 0.5, respectively. Consequently, all three of these plant species are unsuitable host plants for rearing *O. cornifrons.*

Possibly, the pollen and nectar produced by these plant species were unsuitable for the bee. Another explanation may be the asynchronous flowering time of these crop species with the normal activity time of the bee. The storage method described in Wilson and Abel (1996) provided *O. cornifrons* for pollination in July and August; however, the bees that were stored longer and used later in the year (July–August) for pollinating *Coriander sativum* and *Cucumis* spp. appeared to be less active than those bees that were used earlier in the year on the Brassicaceae spp. Higher temperatures during this study also may have reduced the vigor and life span of the bees. The shortened life span of the bees required us to add additional bees to the cages throughout the pollinating period.

Initial data from a comparative pollinator study, conducted concurrently with the present study, show that even weakened *O. cornifrons* was as effective pollinating *Coriander sativum* and the two *Cucumis* spp. as were honey bees, bumble bees, and alfalfa leafcutting bees (unpubl. data). Even though *O. cornifrons* was an effective pollinator of *Coriander sativum* and the two *Cucumis* spp., the reduced vigor of the bees or possibly the unsuitability of the nectar and/or pollen produced by these three plant species made these plants unsuitable hosts for rearing *O. cornifrons*.

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