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Vincent J. Tepedino

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AN OPEN-FIELD TEST OF *MEGACHILE ROTUNDATA* AS A POTENTIAL POLLINATOR IN HYBRID CARROT SEED FIELDS

VINCENT J. TEPEDINO
Bee Biology and Sytematics Laboratory, Agricultural Research Service, USDA, Utah State University, Logan, Utah 84322, USA

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Summary

Approximately 15 000 alfalfa leafcutting bees, *Megachile rotundata*, were released in a 0·4-ha planting of hybrid carrots to assess their potential as pollinators. Bees began nesting soon after release and constructed more than 5000 nests in a 7-week period. However, they visited the surrounding carrot flowers only rarely, and used mostly alfalfa pollen to provision their cells. The predominant insects recorded on carrot flowers were flies, especially syrphids, which were abundant on both male-fertile and sterile varieties. Flies, rather than *M. rotundata*, may be a useful alternative to the honeybee for carrot pollination.

Introduction

The production of hybrid carrot (*Daucus carota* L.) seed from plantings of male-fertile and male-sterile varieties has met with limited success (Erickson & Peterson, 1979). One of the important factors implicated in unexpectedly low hybrid seed yields is inadequate pollination. Carrot pollen must be transported from fertile to sterile varieties by insects. In most hybrid seed areas, populations of the numerous native insect species that visit carrot flowers (334 species recorded by Bohart and Nye, 1960 in Utah) have been decimated by pesticide applications, and honeybee (*Apis mellifera*) colonies are imported for pollination. Honeybees, however, can discriminate between varieties, and individual foragers tend to remain constant to a single variety in commercial fields; the crossing-over from fertiles to steriles necessary to achieve pollination is minimal (Erickson et al., 1979).

The alfalfa leafcutting bee, *Megachile rotundata* (F.) has been considered as a possible alternative to the honeybee as a carrot pollinator. Although this species is a semi-domesticated pollinator of alfalfa (*Medicago sativa* L.) in northwestern USA (Parker & Torchio, 1980), it will utilize a variety of flower species for nectar and pollen and, indeed, reproduces successfully when confined to cages with flowering carrot plants (N. Waters, personal communication; F. D. Parker, V. J. Tepedino, unpublished). Additional advantages to developing the use of this bee as a carrot pollinator are that its biology and nesting habits have been fairly well worked out, and that it is commercially available in quantity (Parker & Torchio, 1980). The present paper describes the results of an open-field release of *M. rotundata* in a hybrid carrot planting in northern Utah.

Methods

Approximately 0·4 ha of male-sterile (antherless type) and male-fertile carrot stecklings (supplied by the Crookham Seed Co.) were planted by hand between 30 April and 4 May 1981 at Greenville Farm Agricultural Experiment Station, Utah State University, North Logan. Stecklings were planted in a 5 blocks, each 107 × 7·6 m in area. Each block comprised 2 adjacent rows of fertiles (variety 80P676) followed by 1 row of biennial yellow sweet clover (*Melilotus officinalis* L. (Lam)) to provide leaf material for bees to use for lining their nests and enclosing their offspring, and 7 adjacent rows of steriles (variety 80P600). Rows were planted approximately 76 cm apart. Except for the inclusion of the sweet clover, these are the specifications typically followed in commercial plantings. The field was weeded by hand, and irrigated once a week. No pesticides were applied.

The amount of carrot bloom was estimated every 3-4 days as number of plants per row with open flowers. The same 3 rows each of steriles and fertiles were used throughout the season.

Overwintering prepupae of *M. rotundata* were incubated at 32°C in the last week of June. After 2 weeks' incubation, cells were transferred to an emergence box, and bees were allowed to emerge within a 'bee shelter' centrally located in the carrot field. The shelter, constructed of plywood and pine, had a raised roof to allow ventilation (Undurraga, 1978) and was equipped with 'bee boards' (Parker & Torchio, 1980) for nesting material. Paper soda straws (67 × 5 mm inside diameter) were placed in pre-drilled holes in the bee boards to facilitate handling of the progeny. Approximately 5000 females and 10 000 males were released.

Completed nests (those with leaf plugs) were counted every 3–4 days. Periodically they were removed and replaced with unused straws. Nests were returned to the laboratory and held at room temperature in petri dishes, or they were dissected and the individual cells placed in gelatin capsules. *Megachile rotundata* has a partial second generation, i.e. some of the progeny of overwintering bees develop directly to the adult stage and emerge in late summer instead of entering prepupal diapause. Nests returned to the laboratory were closely monitored, and all emergent individuals were returned to the carrot field for release at the shelter.

Insects visiting carrot flowers were counted twice weekly throughout the season. On each census day all insects on flowers in the same 3 fertile and 5 sterile rows were counted visually once each morning (10.00–12.00h) and afternoon (13.00–15.30h) by a single observer. Except for *M. rotundata* individuals, insects were identified only to the broad taxonomic group (bees, flies, wasps). Differences in the incidence of bees and flies on flowers were compared by variety and time period over the 14 sampling dates using the Wilcoxon signed rank test (Snedecor & Cochran, 1967).

To ascertain the kind of pollen used by *M. rotundata* females to provision their cells, pollen samples were taken from 48-62 randomly selected cells on each of 4 nest-collection dates in late July and early August. Samples were treated as in Beattie (1971): 100 pollen grains per cell were examined and compared with a reference collection of pollen from the area.

Results

Male-sterile and fertile varieties began blooming in mid-July (Fig. 1*a*). Steriles reached peak bloom approximately 1 week before fertiles, and the number of plants in flower began declining about 10 days prior to the decline of fertiles. Erickson and Peterson (1979) also reported that bloom periods of sterile and fertile varieties were not well synchronized, but in their study fertiles usually bloomed earlier. At any given time there were many more sterile plants in bloom per row than fertiles, because of comparatively low emergence of the latter from the soil. The cause of this differential mortality between steckling varieties was not evident.

Individuals of *M. rotundata* began emerging soon after transfer to the field and began nesting by mid-July (Fig. 2). The number of completed nests reached a peak in early August, 3–4 weeks after the nests were placed in the field. The number of nests collected during the week ending 15 August was abnormally low, because of a severe windstorm that toppled the bee shelter and scattered many of the nests. Bees returned to the shelter after it was re-erected the following day.

The number of bees and flies recorded on carrot flowers during biweekly censuses are shown for variety and morning or afternoon in Fig. 1(*b, c*). So few individuals of *M. rotundata* were recorded visiting carrots (only 14·6% of all bees) that their numbers have been combined with those of other bee species for purposes of illustration. The following observations on flower visitors are pertinent:

1. Flies were much more abundant on carrot flowers than were bees (see also Bohart & Nye, 1960) when comparisons were made by variety and period of the day ($P<0{\cdot}01$ for fertiles in the morning, fertiles in the afternoon and steriles in the morning, and $P>0{\cdot}05$ for steriles in the afternoon.
2. Flies were also much more abundant on the fertiles than on the steriles ($P<0{\cdot}01$ for both periods) and more abundant in the morning than in the afternoon ($P<0{\cdot}025$ for both varieties)
3. Surprisingly, bees—although present in low numbers—tended to be more abundant on the steriles than on the fertiles ($P>0{\cdot}05$ in the morning and $P<0{\cdot}01$ in the afternoon), and in the afternoon than in the morning ($P>0{\cdot}05$ for fertiles and $P<0{\cdot}01$ for steriles).

Wasps were only slightly more abundant than bees and have been excluded from the analysis.

In agreement with the low level of visitation of carrot flowers by *M. rotundata* recorded during insect censuses, analysis of pollen taken from 224 cells provisioned between 23 July and 10 August revealed that no carrot pollen was supplied to the offspring for food. The bees collected pollen mostly from alfalfa plants (59·2% with SD=35·3, of the pollen in the cells examined). Since alfalfa was in bloom at the station only beginning in mid-August, bees must have flown at least 500 m for forage up to that time, despite the availability of carrots around the shelter.

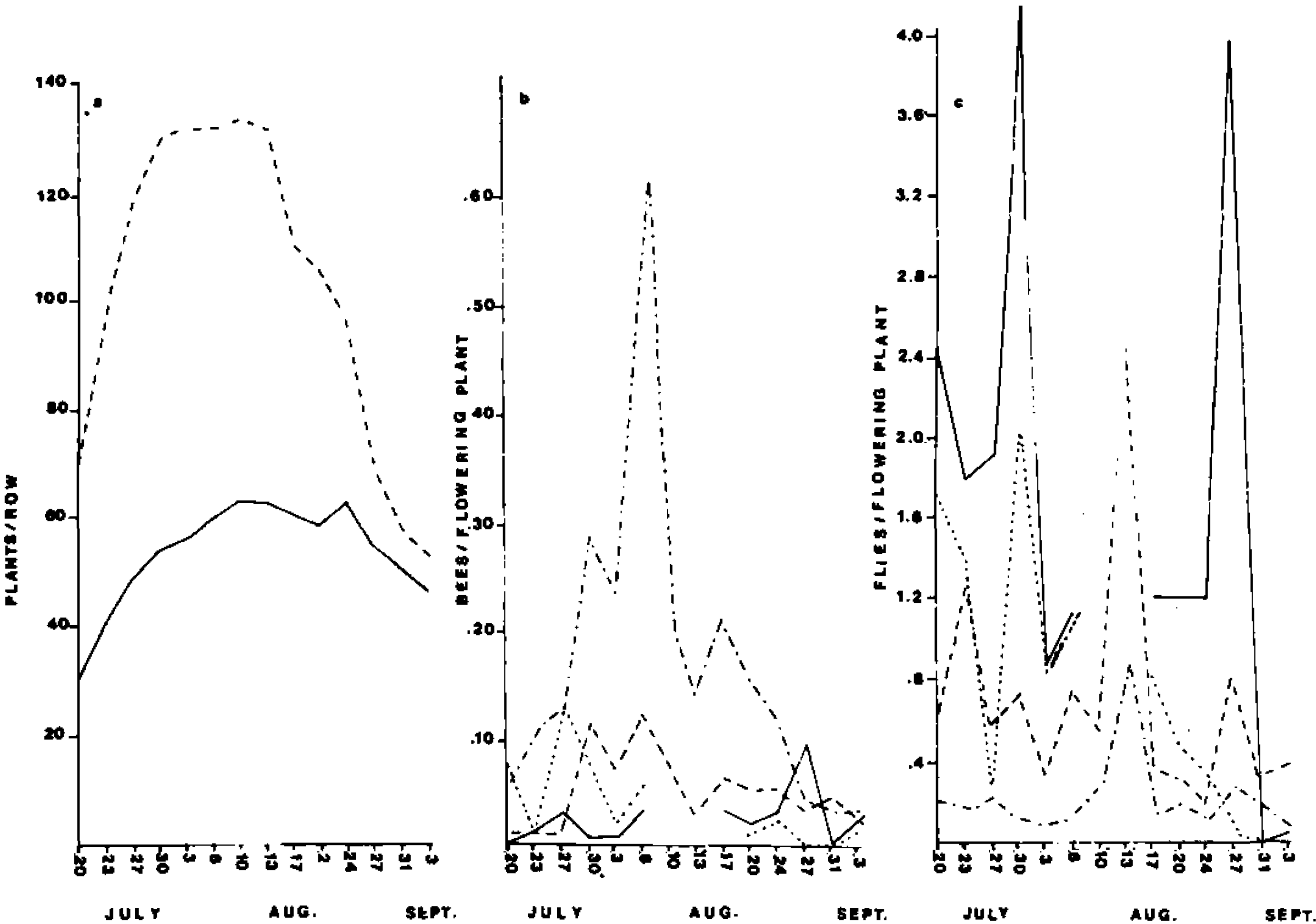

FIG. 1 *a*. Numbers of carrot plants in bloom by date.
b. Numbers of bees per flowering plant for male-fertile and male-sterile varieties for morning and afternoon: solid line = fertiles–morning, dashed line = fertiles–afternoon, dotted line = steriles–morning, dotted and dashed lines = steriles–afternoon
c. Data as in *b*, but for flies
A census was not taken in the morning of 10 or 13 August because of inclement weather.

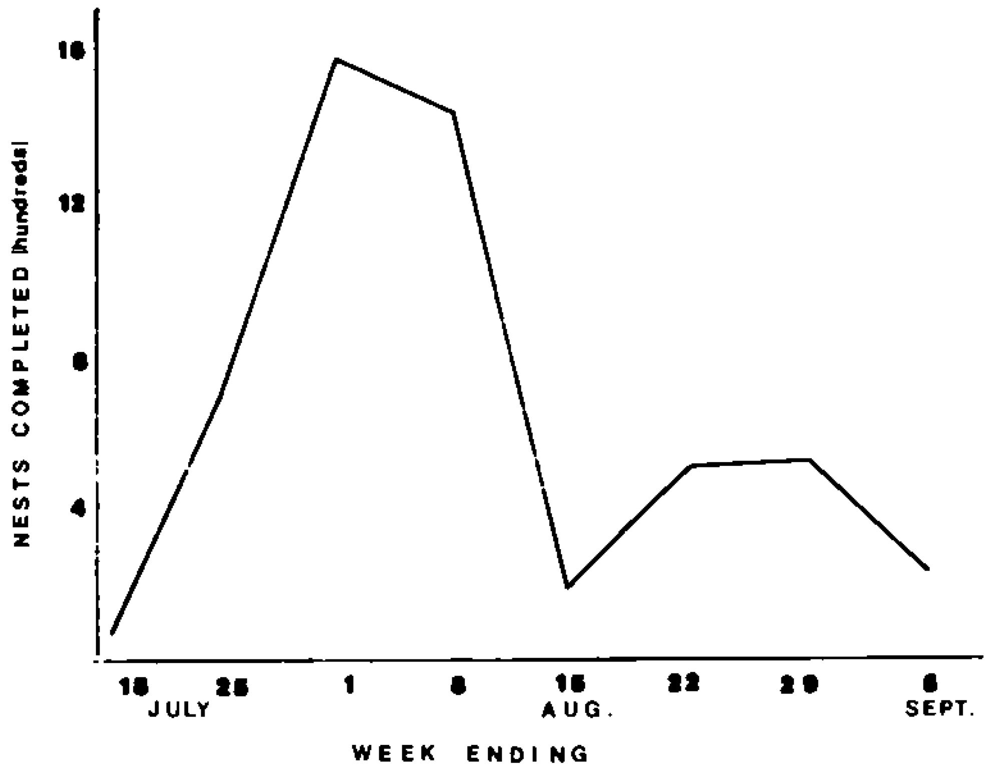

FIG. 2. Weekly numbers of nests completed by *Megachile rotundata*. The unusually low number for the week ending 15 August was due to wind damage.

Discussion

Although *M. rotundata* will reproduce successfully when forced to forage on carrots in field cages (N. Waters; F. D. Parker and V. J. Tepedino, unpublished data), the species appears to have little potential as a carrot pollinator in open fields. Few individuals visited either male-fertile or sterile varieties, and no carrot pollen could be detected in any of the 224 cells examined. Indeed, so few *M. rotundata* visited the planting that the estimation of seed yield was deemed superfluous. These results confirm those of Waters (unpublished) in a similar test.

Several complicating factors render such tests with *M. rotundata* less than conclusive with respect to carrot pollination in general. First, *M. rotundata* incorporates pollen with nectar as food for immatures. Pollen was relatively scarce because only 2 of 10 rows in each block were pollen-producing male-fertiles (industry procedure), and because many fewer fertile than sterile plants emerged per row. Thus, it is possible that some bees ignored the carrots because of insufficient pollen or because steriles altered the attractiveness of fertiles, although it is unlikely that these factors explain their complete aversion to the crop.

Secondly, although bees were not attracted to the carrot varieties used in this or in Water's (unpublished) study, it is possible that other varieties would be more attractive. Erickson and Peterson (1979) and Waters (unpublished) have shown substantial intervarietal difference in quantity and quality of nectar. Nectar samples were not taken in the present study, so comparisons with other varieties are not possible. Thus, it is possible that the bees ignored these varieties because of poor nectar production.

A more reasonable approach to solving seed production problems in hybrid carrot fields might be to utilize flies as pollinators. Flies, especially non-pestiferous syrphids, were in much greater abundance than bees or wasps on both sterile and fertile varieties in this study. Syrphid flies, very abundant on parsley (Burgett, 1980) and on carrots, have been found to be adequate pollinators (Bohart & Nye, 1960). Flies have also been used extensively as pollinators of onions, carrots, and other crops in cages (Free, 1970). Unfortunately no attempt seems to have been made to manage syrphids or other unobjectionable species in open fields, though such a study seems warranted by available data.

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