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Original article

The Carpenter Bee *Xylocopa pubescens* as an Agricultural Pollinator in Greenhouses*

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Abstract – Many greenhouse crops depend on bees for pollination. Global declines of honeybee populations, and their limited efficiency in pollinating some greenhouse food-plants, motivate the search for additional pollinators. We evaluated the carpenter bee *X. pubescens*, a local species to Israel, as a pollinator of greenhouse-grown honeydew melons, in comparison to honeybees. We recorded the bees' daily and seasonal activity patterns in relation to floral nectar levels, frequencies and durations of flower visits, and fruit quantity and quality. The bees' daily foraging schedule on melon did not correlate with nectar yield and nectar production patterns by the flowers. Visit durations per flower were shorter for *X. pubescens* than for honeybees. Pollination by both bees resulted in similar fruit mass and seed numbers, but *X. pubescens* pollination increased fruit set threefold as compared to honeybee pollination. We conclude that *X. pubescens* can effectively pollinate melons in enclosures.

carpenter bee / greenhouse / honeybee / honeydew melon / pollination

1. INTRODUCTION

Agricultural pollination is the first indispensable step in a process that results in the production of fruit, vegetables, nuts and seeds. Agriculture is highly dependent on insect pollination, in particular by the honeybee, *Apis mellifera* L. (Cunningham et al., 2002). The economic value of insect pollination to agriculture can be estimated on the basis of the abundance and market value of insect-pollinated crops. In the United States, for example, the value of crop pollination by insects is estimated at US$14.6 billion (Morse and Calderone, 2000). $3 billion's worth of this pollination service is provided by native pollinator species (Losey and Vaughan, 2006), and the remaining agricultural output is due to pollination by honeybees.

Pollination is thus one of the most important ecosystem services provided to agriculture. This critical ecosystem service has been degrading in recent years, as honeybee colonies are declining in abundance because of habitat loss, diseases, pesticides, and other impacts (Kremen et al., 2002). An expert review panel recently confirmed that the last years of losses of honeybee colonies in North America leave us with fewer managed pollinators than at any time in the past 50 years, and that the management and protection of wild pollinators is an issue of paramount importance to the food supply system (Allen-Wardell et al., 1998).

Native bee communities also provide pollination services, but the extent of these services, and how they vary with land management practices, are largely unknown. In a pioneering study, Kremen et al. (2002) documented the individual species and aggregate community contributions of native bees to crop pollination, on farms that varied both in their proximity to natural habitat

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and in management type (organic versus conventional). Native bee communities provided full pollination services on organic farms near natural habitat even for a crop with heavy pollination requirements (e.g., watermelon, *Citrullus lanatus*). All other farms, however, experienced greatly reduced diversity and abundance of native bees, resulting in insufficient pollination services. While this study demonstrates the importance of native bees to crop pollination, only three species of native solitary bees (*Nomia melanderi*, *Megachile rotunda* and *Osmia cornifrons*) are produced on a commercial scale to provide pollination services. These pollinators are mainly used for alfalfa and orchard crops (Velthuis and van Doorn, 2006).

In recent decades, insect pollinators have been actively introduced into greenhouses and nethouses. This effort was initiated in the Netherlands, where honeybees were first introduced into tomato greenhouses to replace hand pollination (de Ruijter, 1999). Honeybees were also shown to efficiently pollinate sweet peppers in enclosures (de Ruijter et al., 1991). Additional experiments demonstrated the superiority of bumblebees over honeybees in pollinating greenhouse tomatoes and eggplants (Pessarakli and Dris, 2004; Velthuis and van Doorn, 2006). Honeybees remain the main greenhouse pollinator for crops that do not require mechanical buzzing of the anthers. Insect pollination in greenhouses is now practiced worldwide, but is generally limited to honeybees and bumblebees. The domestication and use of additional pollinator species in enclosures is desirable as a countermeasure to the decreases in honeybee populations. In the present research, we tested the feasibility of adding the carpenter bee *Xylocopa pubescens* (L.) to the arsenal of agricultural greenhouse pollinators. We compared *X. pubescens*' pollination efficiency with that of the honeybee, the standard pollinating insect.

The genus *Xylocopa* consists of about 469 species (Michener, 2002), predominantly distributed in tropical and subtropical climates, and occasionally in temperate areas (Hurd and Moure, 1963). *X. pubescens*, a local species to Israel, is of Ethiopian origin, and has reached Israel via the Syrian-African rift valley (Gerling et al., 1989; Hogendoorn and Leys, 1993; Leys et al., 2000, 2002). Females of this species typically dig branched nests in dead wood (Ben Mordechai et al., 1978). They hibernate in the nests from the end of October until the middle of March. During the activity season (March–October), females are engaged in preparing brood cells, while males form non-resource mating territories (Gerling et al., 1983). *X. pubescens* is multivoltine, and may produce 4–5 generations per year. Females are extremely long-lived and may be reproductively active for up to 120 days (Gerling et al., 1981). Ovipositing females provision each brood cell with nectar and pollen, lay a single egg in the cell, seal it and proceed to construct the next cell. The development from egg to adult takes 27–35 days. Young adults that remain in the maternal nest before dispersal are provisioned with pollen by their mother (Velthuis and Gerling, 1983; Van der Blom and Velthuis, 1988), and obtain nectar by trophallaxis (Gerling et al., 1983).

In natural habitats, *X. pubescens* foragers feed on a wide variety of flower species, and remain active at temperatures up to 40 °C (Gerling et al., 1989). This heat resilience makes *X. pubescens* an attractive candidate pollinator for greenhouses in hot climates, where temperatures often exceed the thermal window of honeybees and bumblebees (Corbet et al., 1993). Initial favorable results, regarding the success of native Australian *Xylocopa* in pollinating greenhouse tomatoes, provide an additional incentive for a quantitative evaluation of their performance (Hogendoorn et al., 2000).

2. MATERIALS AND METHODS

2.1. General methods

Observations were conducted in a small (8 × 4 × 4 m) greenhouse between April and October, 2005. Temperature in the greenhouse ranged 11–38 °C during the study period, relative humidity ranged 5–86%, and radiation levels were between 3 and 353 lux. The greenhouse was not illuminated, and provided no humidity control. We grew honeydew melons in the greenhouse, and introduced *X.*

pubescens and honeybees in alteration into it (11 introductions of *X. pubescens*, 7 introductions of honeybees). Preliminary observations indicated that *X. pubescens* foragers seem to behave normally within a few hours of introduction into the greenhouse. The condition of honeybee colonies, on the other hand, started deteriorating after a few days in the enclosure. These factors favoured short observation sessions within the greenhouse. We therefore started observing the bees on the morning following introduction, with no period of acclimation. We recorded nectar yields in the flowers, bee activity, and crop yields for both types of visitors.

2.2. Bees

2.2.1. Xylocopa pubescens

We collected palm branches containing wild nesting *X. pubescens* from four locations in Israel in 2004 and 2005. We number-marked and transferred the nests to the experimental greenhouse. The nests were housed outside the greenhouse between observation sessions, and the bees were allowed to exit and reenter the nests without restriction. Nests were moved into- and out of the greenhouse at night only, to minimize disturbance to the bees. We introduced the nests into the greenhouse for observation periods of 2–3 days. Preliminary observations revealed that females forage more intensively than males, therefore only females were observed (Sadeh, 2006). *X. pubescens* is unique in having intra-specific plasticity in social organization, which changes according to environmental conditions. That is, both solitary and social nests often coexist in a population (Gerling et al., 1981; Hogendoorn and Leys, 1993). Solitary nests contain a single adult female, while social nests contain a reproductive foraging female, and a helper female that guards the nest entrance. Despite differences in foraging behavior, pollination of honeydew melons by both nesters results in similar fruit mass, fruit seed numbers and fruit set (Keasar et al., 2006). To reduce behavioral variability arising from differences in social organization, we included only solitary nesters in the greenhouse observations. We observed the nests for the presence of a guard one day before each introduction into the greenhouse, and subsequently introduced only nests without a guard. Individual bees were not marked, because the marking procedure causes some mortality. We introduced 4–10 nests into the greenhouse in each observation session, depending on the availability of active, single-female nests.

2.2.2. Apis mellifera

Honeybees are the standard pollinators of greenhouse melons in Israel, and were therefore used as a reference for the evaluation of pollination performance. Two mini-nucleus honeybee colonies, originally developed for queen-rearing, were used for observations. These colonies typically contain a queen and ca. 400 workers. They survive up to several months with high levels of worker foraging, and are as effective as regular-sized honeybee colonies in pollinating honeydew melons in enclosures (Keasar et al., in press). Their advantages include their small population size (suitable for the low carrying capacity of the experimental greenhouse), low weight, ease of handling, and low worker aggression. We monitored the mini-hives once a week for stored honey and pollen, presence of eggs and brood, and queen activity. Dead queens were replaced. The bees were fed once a week, or as needed, with ca. 100 mL of 62% inverted sucrose solution.

The bees were allowed to forage without restriction outside the greenhouse before and after observation sessions. Observation sessions in the greenhouse lasted 2–3 days, and were alternated with observations on *X. pubescens*. The bees were unmarked.

2.3. Forage plants

Cucumis melo (L.) *var*. Gallia (honeydew melons), *Ocimum basil* (L.), *Portulaca oleracea* (L.), *Leucophyllum frutescens* (Berland) and *Solanum rantonnetii* (C.) were grown in the greenhouse throughout the study period. 150 melon plants were maintained throughout the experimental period as the model crop. This was done by removing plants that have stopped blooming, and adding blooming plants in replacement, throughout the experimental period. *Portulaca oleracea* and *Solanum rantonnetii* supplemented the bees' diet with pollen (preliminary observations showed that no pollen was collected from melon flowers). *Ocimum basil* and *Leucophyllum frutescens* provided an additional nectar supply when melon blooming was insufficient. When the blooming of nectariferous plants in the greenhouse was insufficient, we also placed a 40% sucrose solution feeder inside the greenhouse.

Melon flowers are either male or hermaphrodite, and their sex can be easily determined morphologically. Hermaphrodite flowers have receptive ovaries and viable pollen, therefore self-pollination is possible. However, self-pollination does not occur spontaneously, as hand- or insect-pollination is required for successful fertilization (Orr, 1985). Individual flowers bloom for 24 hours. They open in early morning, and remain receptive throughout the day. This feature allowed us to determine whether a flower has been pollinated by *Xylocopa* or honeybee, depending on the visitor species that was introduced into the greenhouse on the day of its bloom. We used tags of different colors to mark flowers that bloomed during observations on *X. pubescens* and observations on honeybees.

2.4. Nectar measurements

We tested for correlations between the bees' patterns of foraging activity and the amount of nectar available to them in melon flowers. Nectar production is the total volume secreted by a flower in the absence of exploitation of nectar by insects. To measure production, we depleted 40 randomly selected flowers of nectar (using 1 μL pipettes), and covered them with a fine mesh net. The netting allowed air and light, but not insects, to get through. Netting was performed at dawn (0600 h), before the start of bee foraging. At 0900 h, 1200 h and 1500 h we measured the nectar content of one third of the initial sample (i.e., 13–14 flowers per sample). The flowers were picked after the second nectar sampling, which was therefore a destructive sample. We repeated this sampling procedure once a month, between April and October, 2005.

Nectar yield is the volume of nectar available to bees, and depends on nectar production by the plant and its consumption by insects. To determine yield, we measured nectar from 20 randomly selected uncovered flowers per sample, using 1 μL pipettes. The first measures were conducted before the bees started foraging. Sampling was repeated at two-hour intervals between 0600 h and 1200 h without destruction of flowers. The sex of each sampled flower was recorded. Nectar yields were recorded 2–3 times a month throughout the study period.

Nectar concentrations were determined in samples taken for determination of nectar yield and nectar production, using a hand-held Refractometer (Bellingham-Stanley). Only nectar volumes higher than 0.17 microliters could be used for concentration measurements.

2.5. Bee behavioral parameters

We sampled the bees' daily and seasonal flight activity by counting the number of active individuals that were outside the nests at ten haphazardly determined time points every hour. The data were collected at two-week intervals throughout the study period. We alternated between a whole-day observation (0500 h–1800 h), and an observation at peak activity hours only. We selected the observation hours for the peak activity record based on the bees' daily activity pattern in the previous whole-day observation. We also recorded the total number of bee exits from the nests for 15 minutes at hourly intervals, once a month. We used these data to estimate nest exit rates per foraging individual (see Data Analysis section).

We assessed the bees' daily pattern of foraging on melon flowers by counting the number of visits of all the active bees in 100 melon flowers in a ten-minute observation period. These data were recorded once a month, between 0600 h and 1200 h at two-hour intervals.

For pollination to occur, bees must fly and transfer pollen from male to hermaphrodite flowers. We tested whether *X. pubescens* bees (a) have a preference for one of the flower sexes, and (b) switch between flowers of different sexes at random. To this end, we recorded the sex of flowers visited by a single bee during 45–312 consecutive visits in melon flowers. We recorded eight visit sequences, each by a different bee. We tested for goodness of fit between the bee's flower selection of male vs. female flowers and the proportions of male and female flowers in the greenhouse on the day of observation. We also tested whether the frequencies of the possible transitions between flower sexes (male-male, male-female, female-female and female-male) conformed to the product of the proportions of males and females in the greenhouse.

2.6. Crop yield parameters

We weighed the melons and counted their seeds when the fruits became yellow, as measures of yield quality (McGregor, 1976). We calculated the proportion of flowers, pollinated by different bee types, which set fruit as a quantitative and comparative measure of the bees' pollination success in the greenhouse.

2.7. Data analysis

Most of the observations were combined into seasons, defined as spring (March–May), summer (June–August), and autumn (September–October). Each season includes 2–4 observation periods of each bee species. The number of individual bees monitored varied greatly between observations: the honeybee colonies contained several hundred individuals (albeit not all of them foraging at once), while each *Xylocopa* nest only contained one female. The number of *Xylocopa* nests introduced into the greenhouse varied between observations as well. To allow comparisons between observations, we standardized them in two ways:

(a) When calculating daily activity patterns, we calculated an hourly frequency distribution of all individuals/visits recorded in an observation day (no matter by how many bees), such that all frequencies summed up to 1. We then calculated average frequency distributions for each season and each bee species.

(b) When calculating nest exit frequencies, we counted the number of exits observed in a 15-minute observation period, and multiplied the count by four to obtain an estimate of the number of exits per hour. We then divided this estimate by the mean number of active bees observed outside the nest during the same hour, to obtain a nest exit rate per foraging bee. This estimate is independent of the number of bees introduced into the greenhouse. After checking for homogeneity of variances, we used two-way ANOVA to test the effects of bee species and season on nest exit rates.

We used the Z-test to check whether the proportion of male flowers visited by a *X. pubescens* female differs from the proportion of males in the greenhouse. We used χ^2 tests for independence to check whether the frequency of male- female flower transitions within a series of visits is consistent with random choice of flower sex. We obtained a *P*-value for each of the eight sequences of visits, and combined them using Fisher's combined probability test.

We used SPSS™ version 13 for statistical analyses, such as ANOVAs, correlations, t-tests, and χ^2 tests.

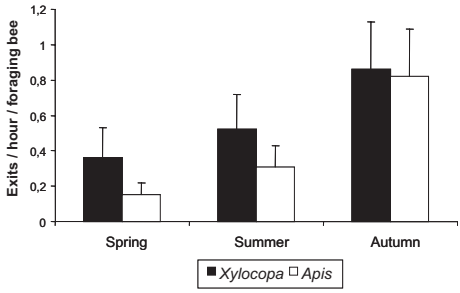

Figure 1. Mean (+SE) number of bee exits from the nests for *X. pubescens* and *A. mellifera*. The figures are based on 266 observations, of 15 minutes each, of nest exits.

3. RESULTS

3.1. General activity patterns

Both *X. pubescens* and *A. mellifera* were active in the greenhouse between April and October, 2005. The frequency of exits from the nest per foraging bee increased for both bee species from spring to autumn, and was consistently higher for *X. pubescens* than for *A. melllifera* (Fig. 1). These trends were only partially statistically significant: The frequency of nest exits per forager was significantly affected by season for *A. mellifera* (ANOVA: $F_{2,129} = 4.613$, $P = 0.012$), but not for *X. pubescens* (ANOVA: $F_{2,129} = 1.415$, $P = 0.247$). The frequency of nest exits per forager did not differ significantly between bee species in any season (ANOVA: spring, $F_{1,88} = 1.212$, $P = 0.274$, summer, $F_{1,90} = 1.049$, $P = 0.361$, autumn, $F_{1,79} = 0.083$, $P = 0.774$). Neither was the difference significant when data from all seasons were combined (ANOVA: $F_{1,262} = 1.041$, $P = 0.309$).

3.2. Foraging on melon flowers

Although both visitor species showed a wide seasonal and daily activity range, they foraged on melon plants only part of the time. Both *X. pubescens* and honeybees foraged on melon only during the morning hours (0600 h–1200 h). In spring, *X. pubescens* started foraging earlier than the honeybees. Foraging rates

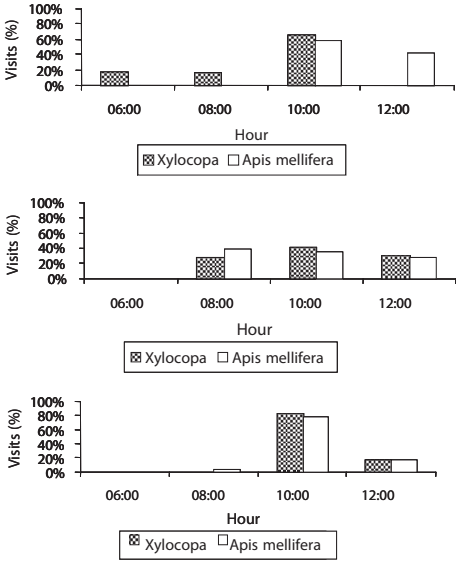

Figure 2. Frequency distribution of visits to melon flowers along the activity hours, for *X. pubescens* and *A. mellifera*, in spring (top), summer (middle) and autumn (bottom). Data are based on 18, 28 and 16 observation days in spring, summer and autumn, respectively.

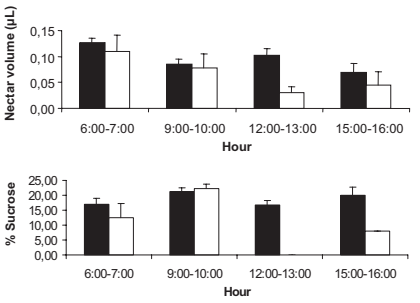

Figure 3. Mean (+SE) nectar production rates (top) and sucrose concentrations (bottom) of male (black bars) and female (white bars) flowers. Nectar production was recorded in 240 flowers. Concentrations were determined in 101 flowers.

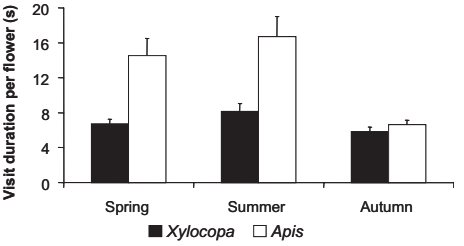

Figure 4. Mean (+SE) duration of visits of *X. pubescens* (dark bars) and *A. mellifera* (white bars) on a melon flower (seconds) in each season. Data are based on 497 recorded visits.

varied significantly between hours of observation, but were not significantly affected by bee species (GLM: Bee: $F_1 = 0.092$, $P = 0.764$, Hour: $F_3 = 6.941$, $P = 0.001$, Fig. 2). Neither hour nor bee species affected foraging rates in melon in summer and in autumn (GLM: summer: Bee: $F_1 = 2.298$, $P = 0.145$, Hour: $F_5 = 0.444$, $P = 0.812$; autumn: Bee: $F_1 = 0.059$, $P = 0.812$, Hour: $F_3 = 1.249$, $P = 0.812$). Combined over both bee species, the daily distribution of visits did not differ between seasons (ANOVA: $F_{2,21} = 0.000$, $P = 1.000$).

The daily distribution of visits to melon flowers was not significantly correlated with nectar yield at any season, for either of the bee species. Nectar production rates were maximal at 6 am, and somewhat decreased towards noon, while nectar concentrations did not show a clear trend over the morning hours (Fig. 3). Thus, the timing of bee foraging activity did not coincide with peak periods of nectar secretion or concentration. Nectar production was significantly affected by flower sex, but not by season (two-way ANOVA: $F_{1,245} = 245.07$, $P < 0.001$ for flower sex, $F_{2,245} = 0.481$, $P = 0.696$ for season). Flower sex and season did not significantly affect nectar concentration (two-way ANOVA: $F_{1,97} = 0.696$, $P = 0.41$, $F_{2,97} = 0.181$, $P = 0.83$ for season).

Average visit duration per flower was significantly higher for *A. mellifera* than for *X. pubescens* (GLM: $F_1 = 31.990$, $P < 0.001$). The differences in visit durations between the bees were less marked in autumn than in spring and summer (Fig. 4). Accordingly, the interaction between bee and season was highly significant (GLM: $F_2 = 5.524$, $P = 0.004$). Visit durations of *A. mellifera* were significantly affected by season (GLM: $F_2 = 6.250$, $P = 0.002$), but the effect of season on visit durations for *X. pubescens* was not significant (GLM: $F_2 = 2.849$, $P = 0.059$).

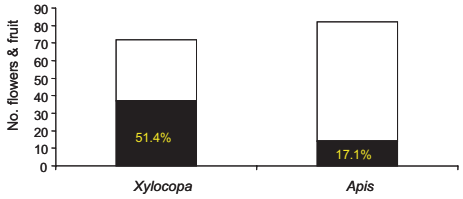

Figure 5. Number of ripening fruits (shaded part of bars) as a percent of the total number of flowers available (whole length of bars) for pollination by *X. pubescens* and *A. mellifera*.

The proportions of foraging visits made by *X. pubescens* to male flowers did not deviate significantly from the proportions of male flowers in the greenhouse ($Z_7 = -0.33$, $P = 0.63$). The bees' selection of flower sex in a series of successive visits was independent of their previous selection ($\chi^2_{16} = 18.31$, $P = 0.31$). This indicates that the bees switched randomly between male and female flowers during successive visits.

3.3. Melon crop

Mean (±SD) fruit mass was 206.37 ± 60.44 (n = 37) and 201.53 ± 73.72 (n = 14) for melons arising from pollination by *X. pubescens* and *A. mellifera*, respectively. The mean seed number per fruit was 59.14 ± 48.87 for melons arising from *X. pubescens* pollination, and 39.86±44.37 for fruit arising from *A. mellifera* pollination. These yield parameters were not significantly affected by pollinator type ($t_{49} = -0.240$, $P = 0.811$ for fruit mass and $t_{49} = -1.288$, $P = 0.204$ for seed number). Melon fruit set was, however, significantly higher for flowers that were pollinated by *X. pubescens* than for flowers that were pollinated by *A. mellifera* ($\chi^2_{(1)} = 13.702$, $P < 0.0001$, Fig. 5).

4. DISCUSSION

Apis mellifera is well known as an agricultural pollinator of many crops (Cunningham et al., 2002). In the present study we evaluated *X. pubescens* as an alternative/additional pollinator for greenhouse crops in hot climates, in comparison to honeybees. Both species were active in the greenhouse for several hours a day throughout spring, summer and autumn. Exit frequencies were consistently higher for *X. pubescens* than for *A. mellifera* in each season, but these differences were not statistically significant.

Thus, comparison of general activity in the greenhouse does not reveal a clear advantage of either of the pollinators over the other. Records of visits to melon flowers revealed that *A. mellifera* spent significantly more time visiting each flower than *X. pubescens*. Visit duration to melon flowers is expected to correlate positively with pollination efficiency, because bees may collect more pollen from a flower the longer they stay in it (Castellanos, 2003; Kudo, 2003). The difference in visit duration thus suggests a possible advantage to *A. mellifera* in pollination. Contrary to this prediction, however, fruit set was three times higher in flowers that were pollinated by *X. pubescens* than by *A. mellifera*. This highly significant difference suggests that honeybees are less efficient pollinators than *X. pubescens*, despite their longer durations of visits in flowers, and the large workforce in the colony. It should be noted, however, that the fruit set due to both pollinator species in our study was much lower than in commercial melon greenhouses. This is probably due to a large number of arthropod pests (mites, aphids and whiteflies), which infested the greenhouse and reduced plant vigor.

Several explanations for *X. pubescens*' greater success in pollination come to mind. First, *X. pubescens*' larger body size may enable better dusting with floral pollen. Second, *X. pubescens* may orient and navigate in enclosures better than honeybees. We observed many disoriented honeybee foragers outside the colony, while disorientation was only rarely observed in *X. pubescens* (unpubl. data). Third, honeybees accumulate excessive amounts of pollen, which may cause clogging of the stigmas in the pollen recipients. Finally, honeybees may remove pollen accumulated on their bodies while cleaning themselves, while *X. pubescens*' grooming may be less efficient. It is less likely that *X. pubescens*' success owes to their adaptation to the climatic conditions in

the greenhouse, because both species were active at similar hours and seasons.

The temporal distribution of visits did not correlate with the patterns of floral nectar production and yield for both pollinators, suggesting that the bees' activity schedule was not affected by the temporal pattern of food available to them. Possibly, the bees' activity pattern is affected by abiotic factors, such as temperature, humidity and light intensity (Gottlieb et al., 2005). An additional possibility is the bees' activity patterns are regulated by an intrinsic circadian rhythm, as was already demonstrated for honeybee foragers (Bloch and Robinson, 2001). It is also possible that the bees were not allowed enough time to learn optimal timing for collection of nectar, as they were introduced into the greenhouse for 2–3 days only in each observation session.

We also observed no preference for male or female melon flowers, and no tendency to visit flowers of the same sex in succession. Such random foraging in respect to flower sex should enable pollen transfer from male to female flowers, and thus increase the plants' reproductive success.

Our observations spanned *X. pubescens*' annual activity period. The bees hibernate in winter (Ben Mordechai et al., 1978; Gerling et al., 1983), and therefore could not be compared with honeybees during this period. Possible future domestication and commercial rearing of *X. pubescens* may lead to changes in the bees' pattern of activity. A similar change in activity pattern was achieved for *Bombus terrestris*: queens of this species hibernate in winter under natural conditions, but domesticated queens can be induced to reproduce year-round (de Ruijter, 1999; Velthuis and van Doorn, 2006). Similar modification of *X. pubescens*' activity pattern is likely possible, because females occasionally break their hibernation on warm winter days in their natural habitat (Michener, 1990). Year-round activity, if feasible, may further increase *X. pubescens*' usefulness for agricultural pollination.

We conclude that *X. pubescens* and *A. mellifera* are similar in many of their foraging parameters, but the bottom line is that *X. pubscens* was the better pollinator in terms of crop yield. We propose to extend the comparison between honeybees and carpenter bees to other types of agricultural enclosures, and to open fields. Owing to its large body size, *X. pubescens* may also provide effective pollination to flowers that require sonication of the anthers, such as tomatoes. Its pollination efficiency should be compared to other buzz pollinators, such as *Bombus terrestris*.

The present study extends previous work that demonstrates the feasibility of using local pollinator species for agricultural greenhouse pollination (Hogendoorn et al., 2000, 2006; Cauich et al., 2004; Del Sarto et al., 2005). A major obstacle to the commercial use of native pollinators in agriculture is the need to mass-rear them, rather than collect them from nature. Devising efficient and cost-effective mass-rearing protocols for *X. pubescens* is a necessary step in this direction.

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L'Abeille charpentière *Xylocopa pubescens* comme pollinisateur des cultures sous serre.

Xylocopa pubescens* / *Apis mellifera* / pollinisation / culture protégée / *Cucumis melo

Zusammenfassung – Die Holzbiene *Xylocopa pubescens* als landwirtschaftlicher Bestäuber in Gewächshäusern. Viele Nutzpflanzen sind von Bienen als Bestäubern abhängig, besonders in Gewächshäusern. Die Populationen von Honigbienen haben über die vergangenen Jahrzehnte durch den Verlust von Habitaten, Krankheiten, Bekämpfungsmittel und andere Einwirkungen abgenommen. Als Folge leiden viele landwirtschaftliche Pflanzen wegen unzureichender Bestäubung unter verminderter Menge oder Qualität des Ertrags. Die begrenzte Bestäubungsleistung von Honigbienen bei vielen Gewächshauspflanzen ist ein zusätzlicher Anstoß, weitere potentielle Bestäuber zu untersuchen. Die

in Israel heimische Holzbiene *Xylocopa pubescens* (L.) stellt einen möglichen Kandidaten für die Einführung als landwirtschaftlicher Bestäuber dar. Unsere Untersuchung zielte darauf ab, das Bestäubungspotential von *X. pubescens* mit dem Standardbestäuber Honigbiene zu vergleichen. Im Gewächshaus angebaute Honigmelonen wurden von März bis Dezember 2005 als Modellpflanzen untersucht. Für jeden der Bestäuber untersuchten wir (a) die täglichen und saisonalen Aktivitätsmuster der Bienen im Hinblick auf den Nektarertrag der Melonenblüten (b), die Häufigkeit und Dauer von Blütenbesuchen und (c) die Anzahl, Masse und Samenanzahlen der reifenden Früchte. Sowohl *X. pubescens* als auch *A. mellifera* waren in allen Jahreszeiten zumeist in den Morgenstunden aktiv. Die zeitliche Verteilung der Besuche korrelierte bei beiden Bestäuberarten zu allen Jahreszeiten nicht mit dem zeitlichen Verteilungsmuster des Nektarertrages der Blüten, was darauf hinweist, dass das Aktivitätsmuster der Bienen nicht von der Verfügbarkeit ihrer Nahrung beeinflusst wurde. *X. pubescens* brachte auf jeder Blüte eine kürzere Zeit zu als *A. mellifera*. Es gab keinen signifikanten Unterschied in der Masse der Melonen oder der Anzahl von enthaltenen Samen zwischen von *A. mellifera* und *X. pubescens* bestäubten Blüten. Der Fruchtansatz war demgegenüber bei von *X. pubescens* bestäubten Blüten dreimal so hoch wie bei von *A. mellifera* bestäubten Blüten. Dieser hochsignifikante Unterschied weist darauf hin, dass *X. pubescens* für Melonen in Zelten oder Gewächshäusern einen effizienten Bestäubungsdienst erbringen können. Unsere Daten stellen zum ersten Mal eine quantitative und vergleichende Erfassung der Bestäubungseffizienz von *X. pubescens* in einem landwirtschaftlichen System dar und tragen weiterhin zu der steigenden Anzahl von Belegen für die Nutzbarkeit lokaler Bienen zur Bestäubung von Gewächshausnutzpflanzen bei.

Holzbienen / Gewächshäuser / Honigbienen / Honigmelonen / Bestäubung

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