Seasonal abundance of the leaf-cutting bee, *Megachile minutissima* (Hymenoptera: Megachilidae)

Mohamed A. Shebl, Soliman M. Kamel, Talaat A. Abu Hashesh & Mohamed A. Osman

Abstract. Solitary bees such as bees belonging to the family Megachilidae are most efficient pollinators of alfalfa, *Medicago sativa*. During April to June of the years 2005–2007, artificial nests of leaf-cutting bees were transferred to an experimental farm to study the seasonal abundance of the bees. Samples of bees were taken by a sweeping net in an experimental field of alfalfa, three times per day: at 10 am, 1 pm and 3 pm respectively. The collecting was repeated every 7 to 10 days from the beginning of flowering time till the end of the season. The results revealed that alfalfa had a flowering time in the experimental farm of about 8 weeks starting from late March till the end of May. During the flowering time *Megachile minutissima* (Radoszkowski, 1876) visited and pollinated the alfalfa flowers. Observations also indicate that males of leaf-cutting bees start flying a few days before females but there is no role for males in tripping of alfalfa flowers. Females start to visit alfalfa flowers not before 9 am, the maximum activity was at 1 pm and there is no activity after 5 pm.

Samenvatting. Seizoensgebonden talrijkheid van de bladsnijderbij, *Megachile minutissima* (Hymenoptera: Megachilidae).
Solitaire bijen, voornamelijk bijen uit de familie Megachilidae, zijn de meest efficiënte bestuivers van alfalfa, *Medicago sativa*. Kunstnesten met bladsnijderbijen werden van april tot juni in de jaren 2005, 2006 en 2007 opgesteld in een experimenteel veld om de seizoensgebonden aanwezigheid van de bijen te bestuderen. Stalen van de bijen werden 3 keer per dag (10, 13 en 15 uur) genomen door met een sleepnet door de alfalfa-vegetatie te slepen, en dit met een interval van 7 tot 10 dagen vanaf het begin van de bloei tot het einde van het seizoen. De resultaten tonen aan dat alfalfa gedurende 8 weken bloeit van einde maart tot begin mei. *Megachile minutussuma* (Radoszkowski, 1876) bezocht en bestoof de alfalfa bloemen. Mannetjes begonnen enkele dagen vroeger te vliegen dan vrouwtjes maar zij spelen geen rol in de "tripping" van de alfalfa bloemen. Vrouwtjes starten hun activiteit vanaf 9 uur; de maximale activiteit lag rond 13 uur en na 17 uur stopt de bestuiving.

Résumé. Abondance saisonnière de l'abeille solitaire, *Megachile minutissima* (Hymenoptera: Megachilidae).
Des abeilles solitaires, comme les Megachilidae, sont parmi les meilleurs pollinisateurs d'alfalfa, *Medicago sativa*. Pendant la période d'avril-juin des années 2005–2007, des nids artificiels furent construits et placés dans un champ expérimental d'alfalfa afin d'étudier l'abondance saisonnière des abeilles. Des échantillons d'abeilles furent pris avec un filet trois fois par jour: à 10, 13 et 15 h, et cela tous les 7 à 10 jours pendant la saison des fleurs. Les résultats montrent que l'alfalfa à une période de floraison de 8 semaines, de fin mars jusqu'à fin mai. *Megachile minutissima* (Radoszkowski, 1876) visitait et pollinisait les alfalfa. Les observations ont aussi montré que les mâles commencent à voler quelques jours avant les femelles mais qu'ils ne jouent aucun rôle dans la pollinisation. Les femelles commencent leurs activités à partir de 9 heures; l'activité maximale se situe à 13 h. et qu'après 17 h. il n'y a plus d'activité.

Key words: Artificial nesting – alfalfa pollination – population dynamics – seed production – *Megachile minutissima* – Megachilidae

Shebl, M. A. *et al*.: Dept. of Plant Protection, Faculty of Agriculture, Suez Canal University, Ismailia, Egypt. mohamedshebl@hotmail.com.

1. Introduction

Alfalfa flowers, *Medicago sativa* Linnaeus, 1753, require visiting bees to trip the sexual column, thereby providing pollination and subsequent pot and seed

set. Previous studies have compared the pollination values of different bee species solely by the speed with which they handle flowers and the proportion of visited flowers tripped.

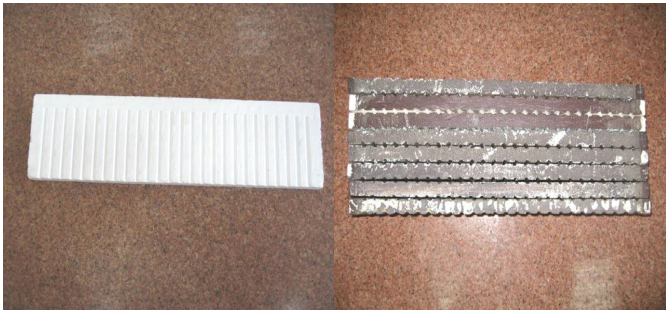

Fig. 1. Foam pieces used for artificial nesting of leaf-cutting bees.

Fig. 2. Complete artificial nest of leaf-cutting bees.

Females of the alkali bee, *Nomia melanderi* (Cockerell, 1906) and the alfalfa leaf-cutting bee *Megachile rotundata* (Fabricius, 1793) tripped 81% and 78% of visited flowers, respectively. Males of these species were significantly less effective (61% and 51 %, respectively), but still significantly superior to the

honey bee *Apis mellifera* (Linnaeus, 1758) (22% of visited flowers tripped). One candidate pollinator, *Osmia sanrafaelae* Parker 1985, shows promise (44% tripped), but not the congeneric *O. aglaia* (Sandhouse, 1939) (13% tripped) (Cane 2002). However, tripping done by a specialized group of bees which enter the flowers and press their keel by their own weight thereby releasing male and female organs to distribute pollen and effect cross- pollination (Abrol 1993).

Leaf-cutting bees are the main pollinators of alfalfa, the activity of these bees are regulated by both temperature and light intensity (Klostermeyer & Gerber 1969). The number of flowers visited per trip, the time spent flying from flowers tripped per unit time are influenced by weather conditions (i.e. temperature and light intensity), agronomic practices (i.e. plant or flower density and irrigation), and the alfalfa cultivar. Females visit from five flowers per minute under cool, partly cloudy weather conditions in a thin plant density, to 25 flowers per minute under hot, clear conditions in a thick plant density. Each flower visit averaged approximately four times longer under the first condition, but the percentage of flowers pollinated under both conditions was similar (Richard 1984).

The flight activity of the bees, *Megachile nana* (Bingham, 1897) and *Megachile flavipes* (Spinola, 1838) on alfalfa were affected by environmental factors, specially cessation of light intensity and solar radiation. Also, Abrol (1990) found a positive correlation with air temperature, light intensity, solar radiation, nectar sugar concentration and negative correlation with relative humidity. Path coefficient analysis revealed that the direct of solar radiation on *M. nana* and solar radiation and light intensity on *M. flavipes* was pronounced. While the direct effect of other factors were negative or negligible, *M. nana* spent less time than *M. flavipes* with an average of 2.35 seconds. However, the mean tripping efficiency was higher in the latter species (89.5 %) than the former (87.5 %) (Abrol 1990). The excessive high temperatures (40° C or above) in the nesting media can kill the eggs and early instar larvae. Poorly constructed shelters can act as heat traps and thus produce lethal temperatures. If nesting media are exposed to direct sunlight this can result in high cell temperatures. Cell temperatures below 4° C can cause immature mortality though it is doubtful whether this occurs in the field (Mayer 1992).

The flight activity of *Osmia cornuta* (Latreille, 1805) started at 7.40–10.20 am and at 9–12° C and ended at 6.00–6.30 pm, often after sunset. Females mark their nest entrance with secretions, probably from the mandibular glands, and individuals with severed antennae are unable to recognize their nesting cavity (Vicens & Bosch 2000). The population dynamics and foraging behaviour of *Megachile rotundata*, as well as the alfalfa bloom and pollination rates in two fields in eastern Oregon were studied by Bosch & Kemp (2005). Despite marked differences in bee management, establishment was very similar in the two fields (0.5 females per nesting cavity) and a lagged peak bloom by 2 weeks. Pollination rates increased from 0–10% in the first 3 weeks to 80–90% in week

4–5. By then, *M. rotundata* females had difficulty finding untripped (non-pollinated) flowers and visited large numbers of already tripped or not fully matured flowers. The mortality of the *M. rotundata* progeny was very high (54–78%). Estimated seed yields were similar in both fields. We contend that similar seed yields, and improved bee production, could be accomplished with smaller bee populations, better timed with alfalfa bloom (Bosch & Kemp 2005). Artificial nests were prepared and moved to the experimental field (Kamel *et al*. 2007). The present work is aimed to study the population abundance of leaf-cutting bees during the season and their relation to the blooming season of alfalfa with the aim to obtain higher rates of pollination and seed yields.

Nesting activities of *Megachile uniformis* (A.) started shortly after the emergence of the females, i.e. during the mating period, and continued to the end of the activity season. The emergency of bees started on 10 April in the two seasons of 2001, and 2003. Females were active from 10 April 10 to 6 June. A female usually hovers around the nests to select a suitable nesting site for herself. After selecting the nest, she starts cleaning it before inhabiting it (Shoukry *et al*. 2004).

2. Material and Methods

2.1. Artificial nesting of *Megachile minutissima* (Radoszkowski, 1876)

Artificial bee nests were prepared during the years 2004, 2005, and 2006 in March and transformed to natural nest sites in Tel El Kebir (30°33'30"N, 31°56' 13"E) about 50 km west of Ismailia in the Delta of River Nile (Kamel *et al*. 2007). The artificial material used for nesting bees was foam. The nests consist of 50 pieces of foam, each piece 50 cm long, 12 cm wide and 2 cm thick. Each piece of foam has 26 holes of 10 cm depth and 6 mm diameter. After sticking the foam pieces upon each other, holes were created in this block and the shelter was performed. Straws of paper tubes 10 cm in length and 5.2 mm internal diameter, one tube was put in each hole. All foam nests were painted in black to imitate natural nests. The artificial nests were transferred to the natural nesting sites in different villages of Tel El Kebir in April till the end of July in the years 2004, 2005 and 2006 (Fig. 1 and 2). By the end of June the foam nests were collected from the natural nest sites and transferred to the experimental field for emergency of bees in the following year, the nests were preserved and kept from any damage by other pests and ants.

2.2. Experimental field preparation

In the beginning of October 2005, 2006 and 2007 the experimental field of the bees research unit, Suez Canal University, Ismailia was prepared for alfalfa seed cultivation. The variety used was Ismailia 1 produced by the Agricultural experimental station in Ismailia. The grown distance between the plants was 30 cm and there were a total number of 1200 plants in the field. Normal nitrogen fertilizer was added to the field. The experimental field was divided into three

parts: nearest to the nest (20 m), near to the nest (30 m), and far from the nest (40 m).

2.3. Population dynamics of *Megachile minutissima* on alfalfa flowers

The experiment conducted at the experimental field of Bee research unit, Suez Canal University, Ismailia, Egypt. Artificial bee nests were installed at the eastern part of the experimental field to be in the front of the sun rise in March of the years 2005, 2006 and 2007. The emergency of *M.* started after the blooming of alfalfa flowers which usually occurs around late March. Samples of bees were taken by a sweeping net in the experimental field of alfalfa, □25 double strokes per sweep□. Samples were taken three times a day of work at 10 am, 1 pm and 3 pm respectively. This was repeated every 7 to 10 days from the beginning of blooming till the end of the season. Numbers of bees were recorded and bees were released again into the field for maintaining the population of bees till the end of the season.

However, samples of *M. minutissima* were taken from three different distances of bees from the artificial nest site, at 20, 30 and 40 m². In each area samples of bees were taken in the same times as in the previous experiment. The number of bees was recorded and the bees were released again.

2.4. Meteorological data at the time of the experiment

The high and low temperature and relative humidity from March to June have been recorded during March until July 2005, 2006, and 2007 using a thermo-hygrograph.

3. Results

3.1. The seasonal abundance of leafcutting bees

The seasonal abundance of leafcutting bees was different at the start and the end of the generation. For the season 2005, the bees started flying at the beginning of April and the season lasted until the last day of May (Fig. 3). For the season 2006, the bees started flying mid April until the first day of June (Fig. 4). In 2007, the bees started flying mid March and the season lasted till mid May. (Fig. 5).

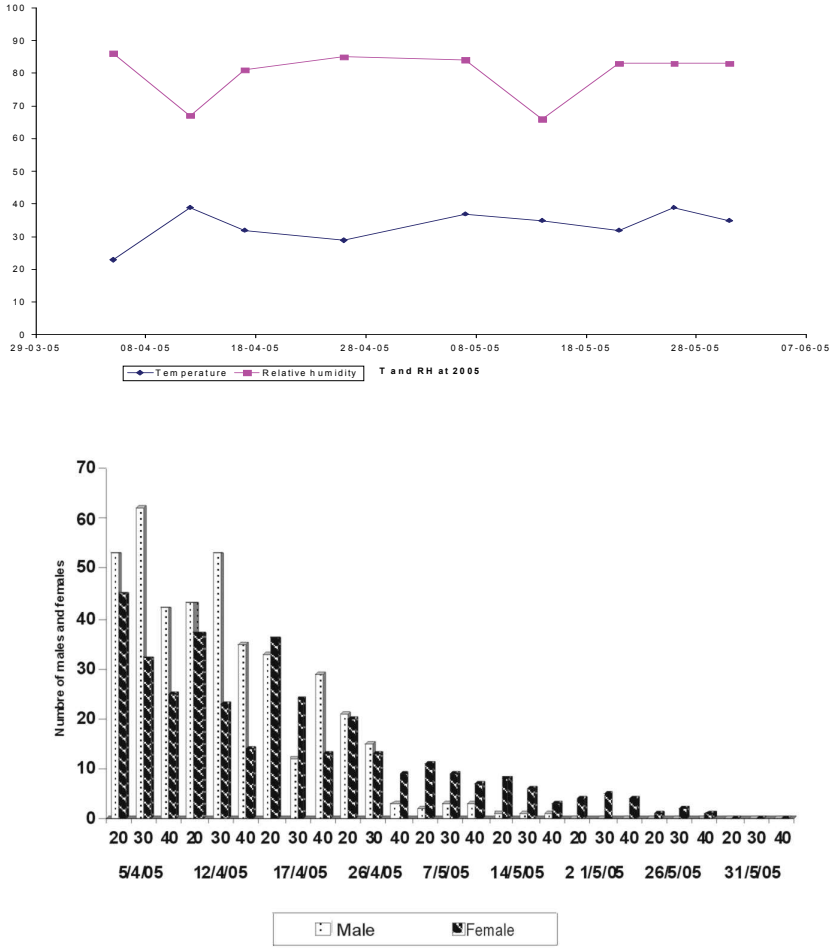

Fig. 3. Seasonal and daily activity, numbers of males, females and the total of *Megachile minutissima* (Radoszkowski, 1876) bees on alfalfa flowers at three different distances: the first distance (20 m), second distance (30 m) and third distance (40 m), away from the nests during 2005.

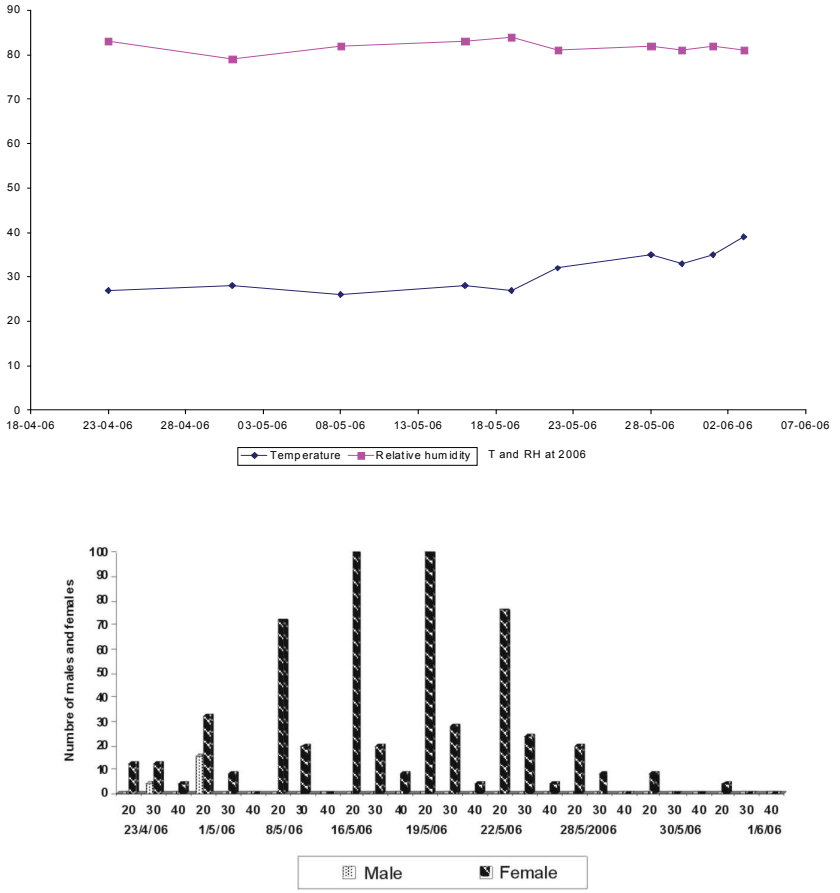

Fig. 4. Seasonal and daily activity, numbers of males, females and the total of *Megachile minutissima* (Radoszkowski, 1876) bees on alfalfa flowers at three different distances: the first distance (20 m), second distance (30 m) and third distance (40 m), away from the nests during 2006.

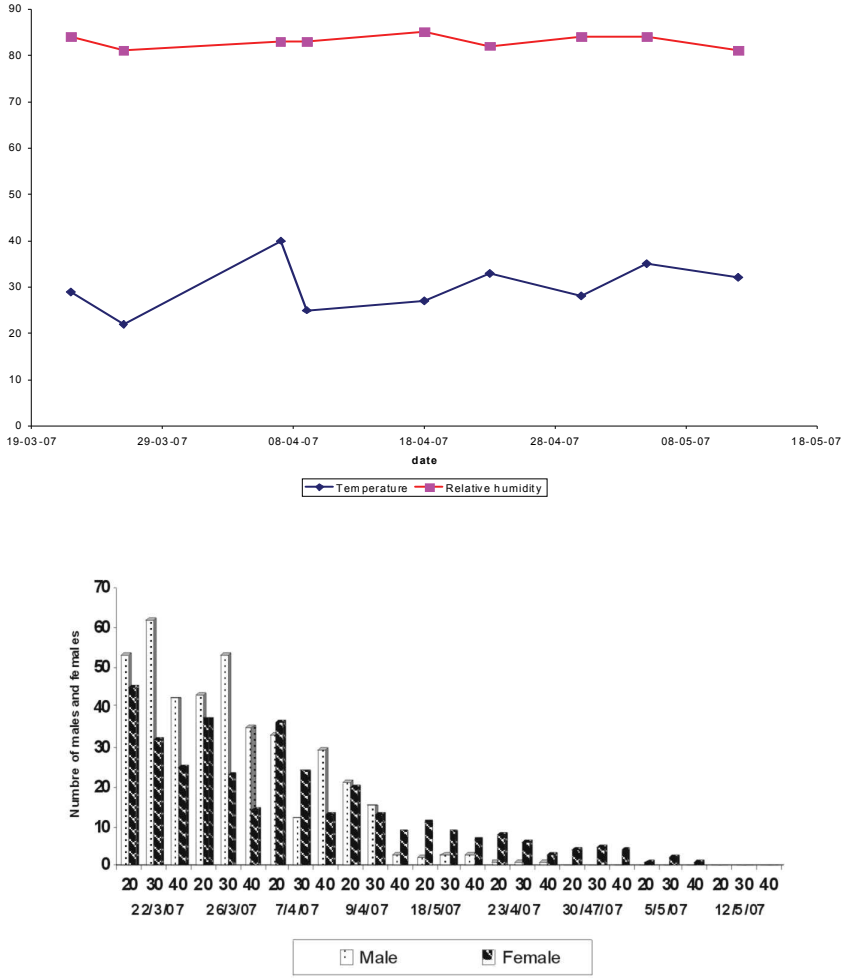

Fig. 5. Seasonal and daily activity, numbers of males, females and the total of *Megachile minutissima* (Radoszkowski, 1876) bees on alfalfa flowers at three different distances: the first distance (20 m), second distance (30 m) and third distance (40 m), away from the nests during 2007.

3.2. The daily abundance of leafcutting bees

The daily activity of bees has been studied for three seasons from 2005, 2006 and 2007. The bee numbers increased from 9 am to reach maximum numbers at 1 pm, after that the activity decreased till sunset (tables 1, 2, and 3, and fig. 6). However, the number of bees were so high in the distances so close to the nest than far. There is a linear relationship between the distance and the number of

bees, increasing the distance is followed by decreasing of bees numbers (table 1, 2, and 3, and fig. 7).

Table 1. Total number of bees at different times and distances in 2005.

Time	Distance 20 m		Distance 30 m		Distance 40 m		Total	
	No	%	No	%	No	%	**No**	**%**
10 am	76	9.9	65	8.5	75	9.9	**216**	**28.3**
1 pm	169	22.1	102	13.3	65	8.5	**336**	**43.9**
3 pm	71	9.3	92	12.0	50	6.5	**213**	**27.8**
Total	**316**	**41.3**	**259**	**33.8**	**190**	**24.9**	**765**	**100.0**

Table 2. Total number of bees at different times and distances in 2006.

Time	Distance 20 m		Distance 30 m		Distance 40 m		Total	
	No	%	No	%	No	%	**No**	**%**
10 am	136	23.8	52	9.1	0	0.0	**188**	**32.9**
1 pm	200	34.9	52	9.1	20	3.5	**272**	**47.5**
3 pm	92	16.1	20	3.5	0	0.0	**112**	**19.6**
Total	**428**	**74.8**	**124**	**21.7**	**20**	**3.5**	**572**	**100.0**

Table 3. Total number of bees at different times and distances in 2007.

Time	Distance 20 m		Distance 30 m		Distance 40 m		Total	
	No	%	No	%	No	%	**No**	**%**
10 am	290	19.4	225	15.1	151	10.1	**666**	**44.6**
1 pm	308	20.6	220	14.7	118	7.9	**646**	**43.2**
3 pm	79	5.3	62	4.1	42	2.8	**183**	**12.2**
Total	**677**	**45.3**	**507**	**33.9**	**311**	**20.8**	**1495**	**100.0**

4. Discussion

Alfalfa, *Medicago sativa*, had a blooming period in the experimental farm of about 8 weeks from late March till the end of May. During the blooming period *Megachile minutissima* visited and pollinated the alfalfa flowers. Observations indicated that males of leaf-cutting bees start flying a few days before the females but there is no role for the males in the tripping of alfalfa flowers. In this way the male has no efficiency in the pollination of alfalfa (Cane 2002). Moreover, the numbers of males were lower in the season 2006 (Fig. 4). This is due to the strong wind in the spring of 2006 destroying some artificial nests. Bees start to visit alfalfa flowers around 9 am, the number of bees increased considerably at 10 am; bees were most active around 1 pm (Fig. 6).

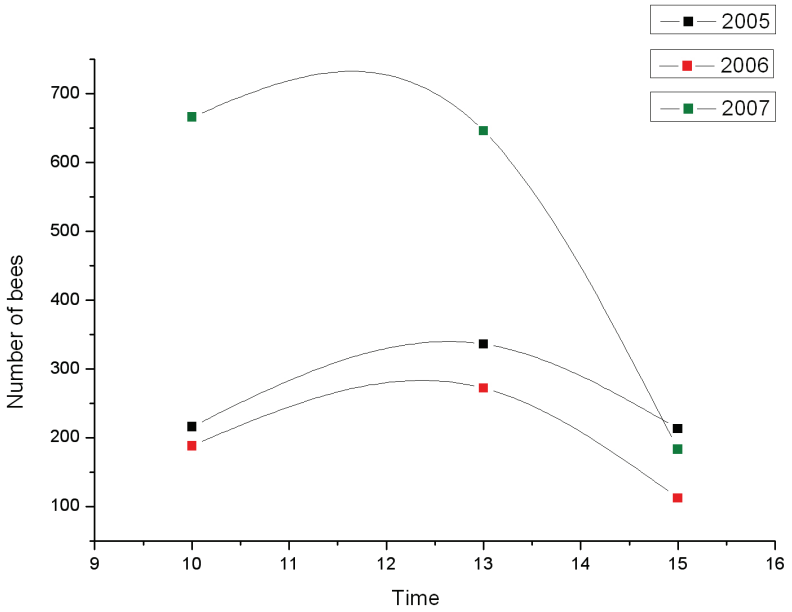

Fig. 6. The total number of bees at three times per day at 2005 (centre), 2006 (below) and 2007 (above).

The influence of temperature and light intensity at the beginning of flight of males and females was studied. Bees start foraging under conditions of low temperature and high light intensity or vice versa. By adapting to new conditions, the bee has become more widely used to pollinate alfalfa. Peak flight occurs during midday and at high temperatures. Decreasing light intensity appears to be the main factor that ends daily foraging, even though summer temperatures during early evening are often above 20°C. The females spend the night in the nest, faced inward. As temperatures rise in the morning, they turn around and face the entrance but do not come out and fly only when the temperature exceeds 20°C and the sun's radiation reaches 0.7 Langley. Bees foraged at 1075 lux when the temperature was 25°C but needed 6450 lux at 17°C. Bees stopped foraging in the evening when radiation dropped to 0.3 Langley and also stopped if clouds reduced radiations to that level. Leaf-cutter bees fly approximately ¼ mile to find food (Peterowski 1991). Alfalfa flower production in commercial fields declines exponentially over the season (after an initial burst of bloom). In addition, standing crop of open flowers declines exponentially at a more rapid rate than open flower production, suggesting that the decline in standing crop of flowers is due in part to increasing pollinator

activity. The more rapid decline in open flowers per raceme close to bee shelters was consistent with this interpretation. The model of alfalfa pollination predicts a similar decline in flower standing crop of open flowers decreases and thus pollination was completed sooner. An exponential decline was standing crop of open flowers provides an explanation for the advantage of using large numbers of bees to pollinate alfalfa rapidly (Strickler 1997). The impact of flower abundance and pollinator movement on seed or fruit yield is of economic importance, and may have implications for crop pollinator management. Field observations of within versus between plant movement of the pollinator, *Megachile rotundata*, indicate that the bees visit more flowers per raceme when standing crop is high than when standing crop is low (Strickler 1999). Fig. 7 shows that increasing distance from the nest correlates with a decreasing number of bees.

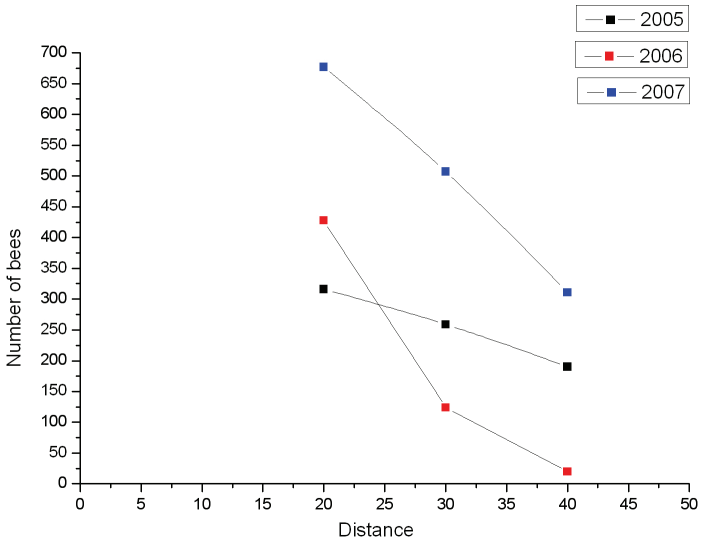

Fig. 7. The total number of bees at three distances from the nest at 2005 (centre), 2006 (below) and 2007 (above).

The number of open flowers and nectar availability declined more rapidly close to bee shelters than at a distance. Interrupted the rapid decline in floral resources partly as a result of steady pollination over time (Strickler & Freitas 1999). The bee patterns of abundance and distribution vary on many scales across years, that patterns were not consistent between years, and raised questions as to what this implies about bee-plant host relationships (Messinger & Griswold 2002). The problems with the seasonal abundance and the plant-

pollinator relationship of leaf-cutting bees and other bee pollinators need more studies in order to understand many remaining questions.

Conclusion

Leaf-cutting bees are considered as one of the most important pollinators of alfalfa worldwide. The emergency of leaf-cutting bees from artificial nests is synchronized with the alfalfa blooming seasons in Ismailia, Egypt. The leaf-cutting bees' activity varied at three different times per day but it reached its maximum at 1 pm. The number of bees decreased by increasing the distance from the artificial nests. So, if farmers use artificial nests with alfalfa leaf-cutting bees it is recommended to distribute the nests to cover the whole field instead of putting the artificial nests at one site of the field only.

Acknowledgments

We are grateful to bee research unit workers and employments at the Faculty of Agriculture, Suez Canal University. Our deep thanks for the chief editor and the reviewers of this journal for valuable suggestions, and for the Egyptian Academy for Science and Technology for financial aid of the work.

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