Ciência Rural, Santa Maria, v.45, n.10, p.1768-1773, out, 2015 http://dx.doi.org/10.1590/0103-8478cr20140974
ISSN 0103-8478 CROP PRODUCTION

Honey bees (*Apis mellifera*) visiting flowers of yellow melon (*Cucumis melo*) using different number of hives

Visita de abelhas melíferas (*Apis mellifera*) em flores de melão amarelo (*Cucumis melo*) usando diferente número de colmeias

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ABSTRACT

*Honey bees (**Apis mellifera**) pollinate melon (**Cucumis melo**) and improve production and quality of fruits. However, little is known about bee behavior and number of hives required. The aims of this study were to compare bees visiting flowers in crop areas with different number of hives (0, 1, 2, and 3), and to evaluate which is the best number. Flowers were observed (n=78) from 5 am to 6 pm, for five consecutive days, in four experimental areas (0.5ha each). Comparisons were made for male (MF) and hermaphrodite (HF) flowers, number of hives and fruit production. The HF were always more visited than MF. Most comparisons made for three hives presented significant differences, since visits increased drastically, competition among bees for floral resources became stronger and reduced the production of commercial fruit (93.4%). On the other hand, the highest percentage of commercial fruit was obtained (99%) with two hives, setting the ideal number of hives as four hives ha^{-1}.*

Key words: *honey bees, **Apis mellifera**, number of hives, crop pollination, melon, **Cucumis melo**.*

RESUMO

*As abelhas melíferas (**Apis mellifera**) polinizam o melão (**Cucumis melo**) e melhoram a produção e qualidade dos frutos. Entretanto, pouco é conhecido sobre seu comportamento e o número de colmeias necessário. Os objetivos deste trabalho foram comparar a visitação das abelhas nas flores em áreas de cultivo com diferente número de colmeias (0,1, 2 e 3) e avaliar a produção de frutos em cada situação. Nas quatro áreas experimentais (0,5 ha cada), foram observadas flores (n=78), de 5 às 18h, por cinco dias consecutivos. Foram realizadas comparações para as flores masculinas (FM) e hermafroditas (FH), número de colmeias e produção de frutos. Os resultados mostraram que sempre as FH foram mais visitadas que as FM. A maioria das comparações feitas para três colmeias apresentaram diferenças significativas, já que as visitas aumentaram drasticamente. Provavelmente, a competição entre as abelhas pelos recursos florais foi maior e reduziu a produção de frutos comerciais (93,4%). Por outro lado, com duas colmeias, obteve-se a maior porcentagem de frutos comerciais (99%), indicando que o número ideal é de quatro colmeias ha^{-1}.*

Palavras-chave: *abelhas melíferas, **Apis mellifera**, número de colmeias, polinização de culturas agrícolas, melão, **Cucumis melo**.*

INTRODUCTION

Melon production (***Cucumis melo***) has been remarkable in Brazil in recent years, reaching 478,431 tons in 2010 (IBGE, 2010). In fact, currently this is one of the ten fresh fruit most exported. The increase in production (18.7% compared to 2009) has occurred mainly due to the development of crop systems. Moreover, in the Northeast semiarid region, farmers also have chosen for plantations in irrigated areas, which turn them into the most productive areas in the country. The largest melon producers are the states of Rio Grande do Norte, Ceará, Bahia and Pernambuco, which contribute with more than 90% of the national production (MAIA et al., 2010). Melon is cultivated by small and large farmers, and the crop areas vary from less than 10ha up to 200ha respectively (RIBEIRO et al., 2012). This activity creates jobs, increases income, and collaborates with men fixation at the field. In this way, it has a great social and economic importance. On the other

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Received 06.30.14 Approved 01.28.15 Returned by the author 05.07.15
CR-2014-0974.R1

hand, the need for constant phytosanitary control and non-friendly management practices may directly affect natural habitats and pollinator conservation, which may cause insufficient pollination and lower productivity in the future.

Melon plants are self-compatible, but the hermaphrodite flowers need pollinators (mainly ***Apis mellifera***) which are responsible for the deposition of pollen grains on the stigma. According to MUSSEN & THORP (2003), for fruit formation it is necessary that at least 500 viable pollen grains be deposited on the stigma. There are a few practical studies showing the need for introducing honey bee hives in melon crops. However, this practice is still uncommon among melon growers in the Pole Petrolina (PE) - Juazeiro (BA). Moreover, in this region there is almost no information on bee behavior on flowers and on the adequate number of hives to supply the crop with sufficient number of pollinators. Therefore, the aims of this study were to compare visitation of bees to male and hermaphrodite flowers in a crop area in Petrolina (Northeast Brazil) using different number of hives, and to estimate the adequate number of hives for best production and quality of fruit.

MATERIAL AND METHODS

The present study was conducted simultaneously in experimental areas located at Petrolina, Pernambuco State. The climate is dry, with average annual rainfall of 600mm, concentrated in practically 3 months of year, characterizing a semiarid region. The experimental areas belong to Embrapa Semiárido: Experimental Field of Bebedouro (09°08'07"S 40°18'17"W), and Embrapa Serviços Produtos e Mercado (SPM) (09°03'08"S 40°17'49"W), which were about 9km distant from each other. For the experiments each of these areas was subdivided into two parts of 0.5ha. All four crop experimental areas underwent the same preparation and fertilization of soil, drip irrigation system, black plastic cover, and with vegetated surroundings. Two direct plantations were established in the last two months of 2012, with an interval of 26 days in order to avoid simultaneous flowering. Thus, Bebedouro and SPM, received respectively, 0 and 1 hive in November, and SPM and Bebedouro, received respectively, 2 and 3 hives in December. Seeds of hybrid yellow melon 10/00 F1 were used, with 0.4m spacing between plants and 2m between rows, totaling 6,250 plants $0.5ha^{-1}$ and 25,000 plants in the four areas, i.e., in 2ha.

Apis mellifera Langstroth hives used in the experiment had uniform characteristics concerning brood amount (60% of brood area) and estimated number of foragers (around 40,000 individuals). Thus, the first area received no hive, as a control, and the three other areas received 1, 2 or 3 hives, respectively. As usually the amount of hives is calculated per ha, the number of hives should be multiplied by two, since each experimental area had 0.5ha. The hives were placed simultaneously with the appearance of hermaphrodite flowers, i.e., around the 15th day after sowing. They were maintained there up to the end of the flowering period, which lasted for about 25 days. The hives were placed at an edge of the crop, under the shade, and at a safe distance (about 300m) in such a way they offered no risk to the workers during crop practices.

Flowers chosen for observation were in the middle rows of the crop areas, and each day new flowers were observed, since they last only for a day. The number of observed flowers was 18 (1 hive) or 20 (0, 2, 3 hives), for each floral type (male and hermaphrodite), being two flowers observed by each observer, in such way ten people were involved in the observations. The observations concerning the number of bees present at the flowers were performed from 5 am to 6 pm, for five consecutive days, in November and December 2012. The comparisons were made between flowers and number of hives, including all possible combinations. Thus, male and hermaphrodite flowers were compared separately and together, with the number of hives: 0x1; 0x2; 0x3; 1x2; 1x3; 2x3 (Mann-Whitney test, ZAR 1999). Moreover, a general comparison was carried out on fruit production in the experimental areas, including commercial (i.e., well-formed and with commercial value) and non-commercial fruit (i.e., badly formed and without market value), and the number of hives (Chi-square test, ZAR, 1999).

RESULTS

Results referring to bee visitation in the areas with and without the introduction of honeybee hives (Figure 1) showed the same general pattern for male and hermaphrodite flowers during the whole day. In other words, bees began to visit the flowers early in the morning about 5 am, increasing progressively up to 9 am, keeping more or less stable up to 2-3pm, and reducing after 5 pm.

In general, there were more visits to hermaphrodite than tomale flowers. These differences were significant for 1 (P=0.041), 2 (P=0.005), and 3 (P=0.000) hives, but not for the area without the introduction of hives (P=0.081), as shown in table 1.

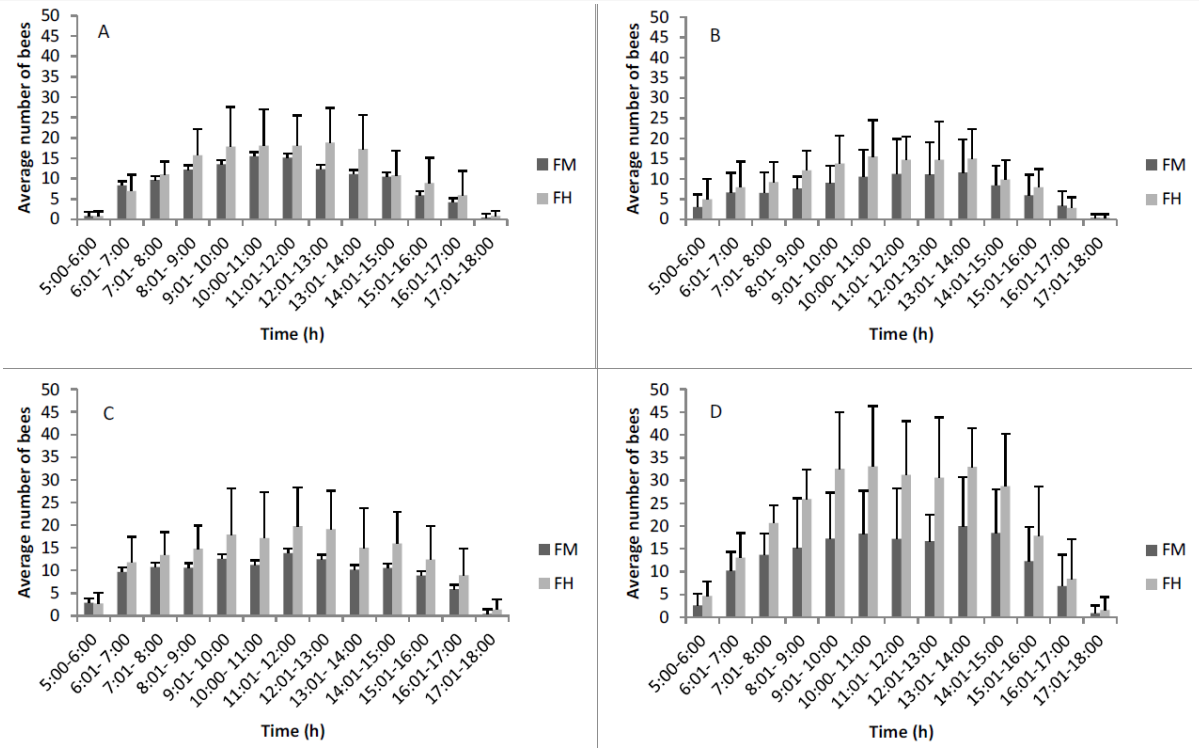

Figure 1 - Average number of honeybees (***Apis mellifera***) on male (■) and hermaphrodite (■) flowers of melon (***Cucumis melo***) during the day: (A) with 0 hive (n=20 MF and 20 HF); (B) with 1 hive (n=18 MF and 18 HF); (C) with 2 hives (n=20 MF and 20 HF); (D) with 3 hives (n=20 MF and 20HF). (MF= male flower; HF= hermaphrodite flower).

When the visitation to flowers (hermaphrodite, male and both), and the situations (0, 1, 2 or 3 hives) were compared pairwise (Table 2), it was possible to observe that with no hive and with 1 hive, the results were not significantly different. On the other hand, all comparisons with 3 hives presented significant differences, demonstrating that the number of bees visiting flowers was much higher with 3 hives. In the comparison with 1 and 2 hives, the differences were not significant for the floral types analyzed separately, but rather when these were considered together (Table 2).

In relation to fruit production (Table 3), all of the experimental areas showed high values: on average 17,983.40 ± 1,171.15kg area^{-1} (n=4 areas). The differences found for each area in fact were not statistically significant (Chi-square, P=0.25).

Considering the number of commercial fruit produced in each area (Table 3), the percentage increased from 96.4 up to 99.0% in areas with 0 and 2 hives, respectively, but the production was smaller when 3 hives were used (93.4%). Simultaneously, the amount of non-commercial fruit produced under the same situation decreased gradually with increasing number of hives (3.6 to 1%), but increased in areas with 3 hives (6.6%). Once more the differences were not significant (Chi-square, P=0.25 and P=0.10, respectively for commercial and non-commercial fruit).

DISCUSSION

Other studies using honeybee for pollination of melon and other crops (cashew, guava, cotton and castor beans) observed similar foraging behavior (HOLANDA-NETO & FREITAS, 2000; SOUSA, 2003; ALVES & FREITAS, 2006; SILVA, 2007; RIZZARDO et al., 2012).

In the present research, honeybees were present even in the area where no hives have been introduced, probably due to natural nests in the surroundings. According to BROWN & ALBRECHT (2001), crops should be planted near to areas where there is vegetation, since they can benefit from the presence of wild bee nests that will contribute for their pollination. Moreover, a recent and extensive research (KENNEDY et al., 2013) considered diverse aspects of pollination of 39 crops and the importance of surrounding areas and landscape management, and evidenced that the surroundings are extremely

Table 1 - Comparison between the number of honeybee (*Apis mellifera*) visiting flower types (hermaphrodite and male flowers considered together: HM) of melon (*Cucumis melo*) in areas with different number of bee hives (0, 1, 2 and 3). The number of observed flowers was different in areas with 1 (n=18 flowers) or 0, 2 and 3 hives (n=20).

Comparison of flowers and hives	P values (Mann-Whitney)
HM x 0	0.081
HM x 1	0.041
HM x 2	0.005
HM x 3	0.000

relevant for their productive success, since they contribute with richness and abundance of bees (potential pollinators).

There was a gradual increase in the number of bees visiting the flowers, as a greater number of hives was added to the crop (Figure 1). However, probably this is not always progressive. REYES-CARRILLO et al. (2006) evaluated the density of bees on melon flowers and found that six hives ha^{-1} promoted a significant reduction in the number of bees when compared to the situation with three and four hives. Thus, the number of bees on flowers should saturate from a given point.

In this research, in all situations of number of hives, there was more visits to hermaphrodite than to male flowers, although the first type is produced in much lower number (1:16 up to19, SIQUEIRA et al., 2011). This preference of bees must be related to the floral resource, since hermaphrodite flowers offer more nectar than male ones. According to SIQUEIRA et al. (2011), hermaphrodite flowers contain 5.028µL to 8.700µL of nectar throughout the day, while male flowers, a much lower amount (1.851µL to 3.850µL), so the first ones are much more attractive for the bees.

The results showed that with no hive or 1 hive, visitation did not increase strongly, indicating that there might be another resource in the surroundings that was attracting the bees in a more effective way. Nevertheless, the strongest effect on bee visitation occurred with the addition of 3 hives, showing that there could be a super population of bees for the local resources.Therefore, all comparisons made with 3 hives presented remarkable differences, showing that the number of visits increased drastically when they were added to the crop.

These results found for fruit production corroborate the idea that there should be a stronger competition among bees for floral resources when 3 hives were added. Probably, with a greater number of visitors, there was a reduction in the number of pollen grains available for fecundation of ovules in hermaphrodite flowers, decreasing thus the number of fruits. In fact, in the field there was aggressiveness among bees on flowers in the area with 3 hives, confirming the high competition for floral resources. Still, although the area with 2 hives did not present the highest total fruit production, it presented the best results concerning the production of commercial (largest percentage) and non-commercial (smallest percentage) fruit (Table 3). Nevertheless, these results were not significantly different from the other situations.

According to MACGREGOR et al. (1965), the quantity and quality of melon are related to the number of bee visits. With the introduction of hives, the population of natural pollinators is enhanced and, consequently, there is an increase in fruit set (SOUSA et al., 2009). However, as mentioned above, in case of a super population of pollinators, the inverse effect may occur.

In the present research, the results showed that the adequate number of hives is 4 ha^{-1}, which is not consistent with other studies performed previously in other regions (REYES-CARILLO et al. (2006) and several studies cited by these authors) where the optimal number is 3 hives ha^{-1}. This divergence

Table 2 - Comparison between the visitation of honeybees (*Apis mellifera)* on melon (*Cucumis melo*) flower types (hermaphrodite and male flowers considered separately: H and M, and together: HM) in areas with different number of bee hives (0, 1, 2 and 3), in pairs. The number of observed flowers was different in areas with 1 (n=18 flowers) or 0, 2 and 3 hives (n=20).

Comparison of hives	P values for H (Mann-Whitney)	P values for M (Mann-Whitney)	P values for HM (Mann-Whitney)
0x1	0.299	0.219	0.105
0x2	0.372	0.871	0.579
0x3	0.000	0.003	0.000
1x2	0.055	0.118	0.038
1x3	0.000	0.000	0.000
2x3	0.000	0.000	0.000

Table 3 - Production of melon (***Cucumis melo***) fruits according to the number of honeybee (***Apis mellifera***) hives introduced in the studied areas (0.5ha each) and number and percentage (%) of commercial and non-commercial fruit.

Number of honey bee hives	Production (kg)	Commercial fruit kg (%)	Non-commercial fruit kg (%)
0	17,148.0	16,528.1 (96.4%)	619.0 (3.6%)
1	19,692.0	19,302.1 (98.0%)	389.9 (2.0%)
2	17,788.0	17,663.5 (99.0%)	124.5 (1.0 %)
3	17,983.4	16,163.4 (93.4%)	1142.2 (6.6%)

can be due to differences in climate, melon variety (Cantaloupe), and/or number of natural bee nests in the surrounding areas, etc. Although a detailed survey of wild nests was not performed in the surroundings of the experimental area in this research, the results showed that even in the area where no hive was introduced, there was a high fruit production (around 17,000kg 0.5ha^{-1}, Table 3). In this way, it is of extreme relevance to conduct survey studies in each area in order to determine the optimal amount of hives to be introduced, considering the visitation that already occurs before any hive introduction and the productivity of the area. In case of a large deficit of natural pollinators, and/or if this number is already satisfactory, the number of hives must be adjusted.

In conclusion, there was a preference of honeybees for hermaphrodite flowers, independently of the number of hives placed in the melon crop (due to a greater concentration of nectar in those flowers). The optimal number of hives in this study was four ha^{-1}, but it is also important to consider that this number may vary according to the surroundings which can contribute with natural pollinators in a larger or smaller amount. Moreover, it is necessary also to consider the total number of plants, since the spacing between them may vary among the crops. Thus, by adjusting the necessary number of hives it will be possible obtaining a good productivity with a larger amount of commercial fruit.

ACKNOWLEDGMENTS

The authors are grateful to Dr. Nivaldo Duarte Costa (Embrapa Semiárido) for the melon seeds and support for the cultivation, Dr. Katia M. Medeiros de Siqueira (Universidade do Estado da Bahia - UNEB), for the suggestions and support during the experiments, Mr. Francisco Camilo de Sousa for the help with honey bee hives, Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Food and Agriculture Organization (FAO) for financial support, and Erica M. T. de Alencar, for language advice.

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