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Effect of Honey Bee (*Apis mellifera* L.) and Bumblebee (*Bombus terrestris* L.) Pollinators on Yield and Yield Factors in Sunflower (*Helianthus annuus* L.) Production Areas

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Abstract: The objective of this study is to determine and research the effects of both honeybee (*Apis mellifera* L.) and bumblebee (*Bombus terrestris* L.) pollinators on yield and yield factors in the sunflower production areas. Results have revealed that bumblebees have a strong influence on sunflower pollination than the honey bees. The total number of seed (No. head^{-1}), seed yield (g head^{-1}), seed setting efficiency (%), 1000 seeds weight (g), seed oil content (%) and head diameter (cm) in the plots of both bees were determined, respectively as 480, 37, 75, 97, 33, 14 for bumblebees and respectively as 252, 24, 46, 98, 31, 17 for honey bees.

Key words: Bumblebee, honey bee, pollination, sunflower, yield

INTRODUCTION

Sunflower is an important industrial plant, which is produced for its oil all over the world and in our country. Containing 40-50% ratio of oil in sunflower seeds, 57% of the production of the vegetable oil is obtained from sunflower (Anonymous, 2007). According to the data records of Anonymous (2007), the total planting area of sunflower worldwide is 22,332,614 ha and the total production quantity is 27,740,270 tons. In Turkey, the sunflower planting area is 470,000 ha and the total production quantity is 800,000 tons. When we observe the amount of production according to the provinces, 62.5% proportion of the sunflower production is realized, respectively, in Tekirdag, Edirne and Kirklareli. Istanbul, Canakkale, Balikesir, Bursa and Kahramanmaras Provinces follow them, respectively (Anonymous, 2007).

Sunflower is a wild fertilized plant. Even though, the wind is accepted as the main pollinator for flowery plants, it isn't sufficient enough for pollination on many kinds of plants including sunflower because it is not able to provide homogeneous pollination as well as not being able to carry heavy pollens (Free, 1970; Parker, 1981; Freund and Furgula, 1982). Crop pollination has become a model system for the study of ecosystem services (Kremen *et al*., 2007). Animal mediated pollination is required by crop plants accounting for 35% of the global food supply (Klein *et al*., 2007). In many countries, for years honeybee has been used for the pollination of various kinds of fruit, vegetables, fodder plants and industrial plants (Ozbek and Yildirim, 1996; Ozbek and Calmasur, 2001). However, due to some of the physiological and behavioral specialties its usage for pollination is limited in greenhouse production areas (Kaftanoglu *et al*., 1997). Honeybees are not capable of pollinating plants efficiently and do not perform in cold and rainy climate conditions (Goulson, 2003). However, the declines of managed honeybees and solitary wild bees may be compensated by generalist and mobile pollinators such as bumblebees (Corbet, 2000; Kremen *et al*., 2002).

Bumblebees, notably *Bombus terrestris* L., have ben shipped throughout the world in vast numbers (Goka *et al*., 2001) since they were recognised as commercially valuable pollinators of glasshouse crops in the late 1980s (Velthuis, 2002). Bumblebees pollinate a wide range of wild plants and crops in agroecosystems (Corbet *et al*., 1991). For the development of their annual colonies, they require a continuouns supply of food plants from early spring to late summer, as usually is provided in perennial semi-natural habitats (Fussell and Corbet, 1991; Corbet, 1995). The importance of bumblebees increase due to their enhanced fluffy bodies, their long tongues, which allows them to visit upon long tube plants and the fact that they can perform under low temperature and dense light conditions. Bumblebees have an economical importance in most wild and culture plants (Ozbek, 1997; 1998; 2000).

Sunflower has become a rather highly important potential yield due to its increased cultivation areas. In Turkey, although bees are efficient in pollination, there are limited comprehensive studies on bee activity in sunflower pollination or pollinator bees. In this study, we aim to determine the effects of bumblebee and honey bees as pollinators on fertility and fertility actors of sunflower.

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Table 1: Experimental design and treatments

Labels	No. of plants	Treatments
M1	6	Plants were taken into cages to prevent visiting bees
M2*	6	Plants were taken into cages and 2 honey bees for each sunflower were released
M3*	6	Plants were taken into cages and 2 bumblebees for each sunflower were released
M4	6	Nylon net bags were placed over sunflower heads of 6 plants individually to prevent visiting bees and to leave them for self pollination

*The specified number of bees were released into the cages at 08:00 and removed from the cages at 18:00 everyday

MATERIALS AND METHODS

The experiment was conducted according to the randomized block design with 3 replications. Four different treatments were distributed randomly within the blocks. The sunflower variety Inegol that is widespreadly grown in Turkey was planted on the 3rd of May 2006. Honey bees (*Apis mellifera* L.) and bumblebees (*Bombus terrestris* L.) were utilized as pollinating insects. Wooden cages (1×1×2.5 m) incorporated with nylon nets were used to prevent entry of bees and other insects from the outside Net bags were placed over sunflower heads to prevent visiting bees.

After the first flowers were detected, 6 plants for each treatment were chosen randomly and the plants were subject to the treatments in Table 1.

The crops were harvested after the sterile leaves fell and the seeds became hard, then after labeling the sunflower heads were brought into the laboratory in groups of six. After cleaning, the seeds were left in paper bags for drying. Thereafter, before analyzing the oil contents of the seeds, they were brought into the laboratory and the total number of seeds (No. head^{-1}), seed yields (g head^{-1}), seed setting efficiency (%), 1000 seeds weight (g), seed oil contents (%) and head diameters (cm) were determined.

Percentage data were subject to Arcsin transformation for further analysis and were analyzed first by using ANOVA and then the means were subject to the LSD test 5%.

RESULTS AND DISCUSSION

During the field experiment, it was observed that after placing the bombus bees into the cages they started performing right away, while the honeybees waited on the cage walls for a while and began performing after 30-45 min. Due to the fact that honeybees aren't able to perform actively in covered areas (e.g., under a cover, greenhouse) it was distinctly observed that the bees displayed less activity at dawn, increased their movement between 10:00 am to 12:00 pm, following a decrease between 12:00-14:00 pm and as the temperature increased the activity increased repeatedly between 15:00-17:00 pm (Fig. 1). Similar to the study Choi and Oh (1986) stated that honeybee visits were denser between

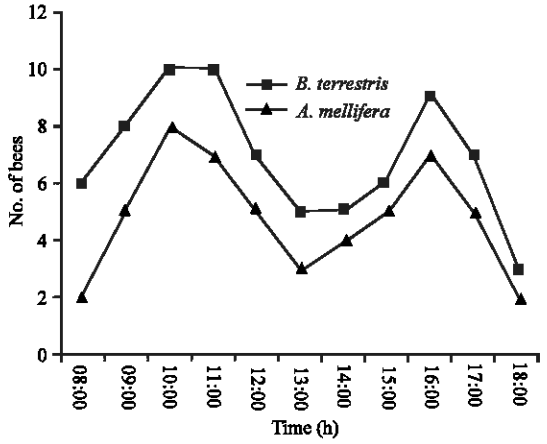

Fig. 1: The working hours of hooneybees and bumblebees in the (a) cage

10:00 am to 12:00 pm and between 15:00-18:00 pm, Satyanarayana and Seetharam (1982) determined that bee activities were denser at 10:30 am and at 16:30 pm and Parker (1981) recorded that bee visits were more dense at 9:00 am.

After studying the efficiency of the different treatments on a total number of seeds (No. head^{-1}), seed yields (g head^{-1}), seed setting efficiency (%), 1000 seeds weight (g), seed oil contents (%) and head diameters (cm) the statistical differences of the treatments were acknowledged ($p<0.005$) (Table 2). Statistically no differences were found between the M1 and M4 treatments, which had the lowest full seed number. In this study, the highest full seed number was obtained from the M3 treatment followed by M2. The highest seed yield was obtained from the M3 treatment, followed by M2 and M3. It was determined that the M4 treatment had the lowest seed yield. Statistical differences weren't found between the M1 and M2 treatments on seed setting efficiency. It was presumed that there were statistical differences amongst these two treatments and the M3 and M4 treatments. As M3 had the highest seed setting efficiency ratio, M1 and M2 treatments followed and the lowest seed setting efficiency ratio was obtained from the M4 treatment ($p<0.005$) (Table 2).

The efficiency of the different applications on 1000 seed weight was observed. There, where no differences statistically between M3 and M2 treatments and these practices had the highest 1000 seed weight. It was also observed that the M1 treatment had the lowest

Table 2: Effectiveness of honey bees and bumblebees as pollinators on sunflower

Labels	Total seed (No. head^{-1})	Seed yield (g head^{-1})	***Seed setting efficiency (%)	1000-Seed weight (g)	***Seed oil content (%)	Head diameter (cm)
M1	219.7±25c	18.8±1.8c	31.6±0.7b	73.3±5b	27.7±0.8b	16±1a
M2	251.7±19.6b	23.7±1.1b	45.5±7.2b	98.1±8.7a	30.7±1.3a	17.4±2.9a
M3	479.7±60.3a	37.1±6.4a	75.2±4.5a	97.3±4.3a	33.0±0.5a	13.7±0.5a
M4	152±38.8c	18.65±3.5d	15.8±2.7c	89±2.4ab	31.0±0.5a	18.5±0.6a
F-values	36.28*	26.58*	30.61*	4.33**	5.97**	1.54 ns

(M1 = Prevent from visiting bees, M2 = Honey bee, M3 = Bumble bee, M4 = Tulle bags were placed over heads), Means within a column with the same letter are not significantly different (LSD test at 5% level). One-way ANOVA was applied for data, *: Significant at the 1%, **: Significant at the 5%, ***: Percentage data were subjected to Arcsin transformation before further analysis

mean value. Therefore, M4 application displayed similarities not only with the lowest but also the highest ratios. The efficiency of the different applications on oil ratio was noticed and statistical differences were figured out among the applications ($p<0.005$). According to the results of the treatments, M2, M3 and M4 treatments had the highest oil ratio and the M1 treatment had the lowest oil ratio. In the case of head diameter, although the highest average value was obtained from M4 (the trays put into mesh bags) treatment and the lowest average value was obtained from the M3 (practice with Bumble bee) treatment, no statistical differences were found amongst these four treatments ($p>0.005$) (Table 2).

After the results obtained from the application of bumblebees were checked, they displayed statistical differences from other treatments on a total number of seeds (479.7 No. head^{-1}), seed yield (37.1 g head^{-1}), seed setting efficiency (75.2%) and 1000-seeds weight (97.3 g). It was observed that treatment with bumblebee was more effective on sunflower pollination than honeybees (Table 2). Following the assessment of the results obtained from the application of honeybees 1000 seeds weight was (98.1 g) and the oil ratio (30.7%) were found at a higher ratio. However, no statistical differences were found with the application of bumblebees. After the total number of seeds (251.7 No. head^{-1}), seed yield (23.7 g head^{-1}), seed setting efficiency (45.5%), was checked, this treatment was followed with application of bumblebees (Table 2). These results clearly indicated that bumblebees and honey bees affected the fertility and fertility factors. Similar to the results, Hoffman and Wittman (1987) determined that bee pollination increased seed component by 52% on plants caged with bees and without bees, Meynie and Bernard (1997) pointed out that seed component ratio was 88% on *A. mellifera* Calmasur and Obek *et al*. (1999) determined that they obtained the highest full seed number and weight, full seed component ratio and oil content from the sunflowers pollinated in open air and then honeybee pollination took place afterwards.

In the case of the head diameter, which was one of the parameters examined in the experiment, there were no statistical differences observed amongst the treatments with bumblebee (13.7), honey bee (17.4), caged heads (16) and the heads put in to bags (18.5 cm).

It was observed that bumblebees began to perform immediately and was far more active after it was placed into the cage. It was concluded that the reason for this was that bumblebees were better in adapting to covered areas than honey bees in average. Similar, studies were reported by Meynie (1995), Meynie and Bernard (1997) *B. terrestris*, whom were very effective pollinators and Aslan (2003) also pointed out that bumblebees had an important role on sunflower pollination.

CONCLUSION

In this study, it was concluded that bee pollination was important on sunflower cultivars, especially on the confection sunflowers produced in our region. It was assumed not to be limited to sunflower pollination only with honey bees, but also to support and protect the use of other wild bees on pollination, will improve the yield and quality of agricultural products.

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