

## OBSERVATIONS ON THE FORAGING BEHAVIOR OF COMMERCIAL *BOMBUS TERRESTRIS* L. AND *APIS MELLIFERA* L. COLONIES ON SOME CULTIVARS OF *CARTHAMUS TINCTORIUS* L. IN CAGED CONDITIONS

CIGDEM OZENIRLER, KADRIYE SORKUN

**ABSTRACT.** *Carthamus tinctorius* L. (Safflower) has been cultivated especially for its seed. Pollination success of safflower can affect the seed yield and pollination rates can be influenced by temperature, humidity and pollinating insect abundance. Within this context, foraging activities of commercial *Bombus terrestris* L. and *Apis mellifera* L. colonies were investigated on four different cultivars (Balçı, Dincer, Linans and Remzibey-05) of safflower. The visitation rates and the abundance of the bees, evaluated with the temperature and relative humidity. Three 90 m<sup>2</sup> fields were prepared and every field was divided into four parcels. Before the blooming period of the plant starts, the fields were caged with teflon net. In the first and second cages, there was only one commercial *B. terrestris* and *A. mellifera* colony respectively. In the third cage there were both *B. terrestris* and *A. mellifera* colonies. The highest numbers of bees recorded at about 09:00 a.m. and it was found that the abundance of the bees decreased dramatically after this peak. The competition between two managed bees caused declines in the visitation rates of both species. Among the four cultivars, Dincer was the most preferred one while Linans was the least.

### 1. INTRODUCTION

*Carthamus tinctorius* L. or safflower is an annual or biennial herbal plant in the family of Asteraceae and represented by 16 species in the world [1]. *C. tinctorius* is the only cultivated taxon [2]. It is widely farmed in India, the USA, China and Mexico, Spain, Ethiopia, Turkey [3]. Safflower has a growth potential under water-stress [4] and that is for it is classified as a promising crop in agro-ecosystems in arid areas [5]. Safflower seed oil content can vary between 25-35% [6-10].

Insect pollination is essential for crop production by enabling or increasing seed and fruit set in many crops [11]. Even safflower is basically self-pollinated, pollinator insects are generally necessary for optimum fertilization and maximum yield [12]. *C. tinctorius* is a huge nectar or/and pollen source for many insect groups, such as Hymenoptera, Lepidoptera, Diptera, Coleoptera and Odonata [12, 13]. 95% of the insect visitors were recorded as Hymenoptera [14]. Bee pollinators enhance the probability of both self- and cross-fertilisation and consequent seed set by tripping the flower [15].

The potentials of the different bee species have been recognized in many studies [16-18] but the diversity of the species has not yet played an important role in the design of agricultural systems [19]. Honeybees and bumblebees are the majority of insect visitors of cultivated entomophilus plants [20, 21].

Given the evidence that pollination by bees increases safflower yield and has a positive effect in seed production, it is essential to understand how commercial *Bombus terrestris* and *Apis mellifera* are performing in terms of bee species-specific foraging behavior and pollination efficiency. In this study, we investigate daily foraging performance of managed honeybees and bumblebees on four different cultivars of safflower in caged conditions.

## 2. MATERIALS AND METHODS

### 2.1 Study field

The study field was located at 39° 52'05.93" N; 032°43'47.94" E, 1042 mt. Three 90 m<sup>2</sup> fields were divided equally into four parcels to sow four different safflower cultivars. Seeds were provided by the Directorate of Trakya Agricultural Research Institute, Republic of Turkey Ministry of Food Agriculture and Livestock. Cultivation was conducted at 25-28 March 2014. Before the blooming period of the plant starts, the 90 m<sup>2</sup> fields were caged with teflon net and ~270 m<sup>3</sup> cages were prepared. The net allows water, air and sunlight to pass while preventing (the other) insect pollination except managed bees in cages.

The air temperature and relative humidity were recorded with "DS1923 temperature/humidity logger iButton R". The readings taken at intervals of 60 minutes (3600 seconds). Data loggers were placed inside plastic tubes

that having holes and hanged with rope to the top of the cages. After the blooming period the data loggers were collected and the data set was exported to an Excel sheet to evaluate.

## 2.2 Pollinator abundance and foraging behavior

*Apis mellifera* colonies were provided by Development Foundation of Turkey which is one of the official colony breeding companies in Turkey founded in 1978. The small honey bee colonies contained about 150 workers, brood and a queen. *Bombus terrestris* commercial colonies were provided by Koppert Biological Systems-Turkey. The bumble bee colonies contained about 80 workers, brood and a queen.

The abundance and foraging behavior of bees at the safflower plants were recorded with standardized transect walks from outside the cages. The blooming period had started on 08.07.2014 and finished on 20.07.2014. Starting from 07:00, 09:00, 11:00, 14:00, 16:00, 18:00, foraging activity of the bees was investigated six times a day between 09.07.2014 and 18.07.2014. At the beginning of the trial, sunrise time was 05:25 a.m. and sunset time was 20:23 p.m.

## 3. RESULTS AND DISCUSSION

As a result of our study, when the activities of *Apis mellifera* and *Bombus terrestris* on *Carthamus tinctorius* were examined, it was observed that pollen collection behavior started one hour after sunrise and then reached to maximum level around 09:00. After 11:00, it has been determined that it has a decreasing tendency (Figure 1). The line graph showing the densities of active bees observed during the 10-day observation period of bees in pollination cages according to the observed hours (07: 00,09: 00, 11: 00,14: 00,16: 00,18: 00) were plotted in Excel.

The anthers of the safflower plant usually bloom in the early morning [22]. In a study conducted in India, they determined that the bee activities on the safflower plant started early in the day and new flowers were more preferred [23]. In Canada, honey bees began to search for nutrients at around 07:00 in the morning and bee activity in the range of hours between 09.00 and 11.00

hours reached the highest level reported [14]. During these two hours, the amount of nectar and pollen in the flowers is gradually decreasing and it has been determined that almost all of the resources have been consumed at 12.00. It was reported that pollen and nectar were not re-secreted after 12.00, and in this context, it was expected that bee activity would decrease parallel to the decrease of resources after 12.00.

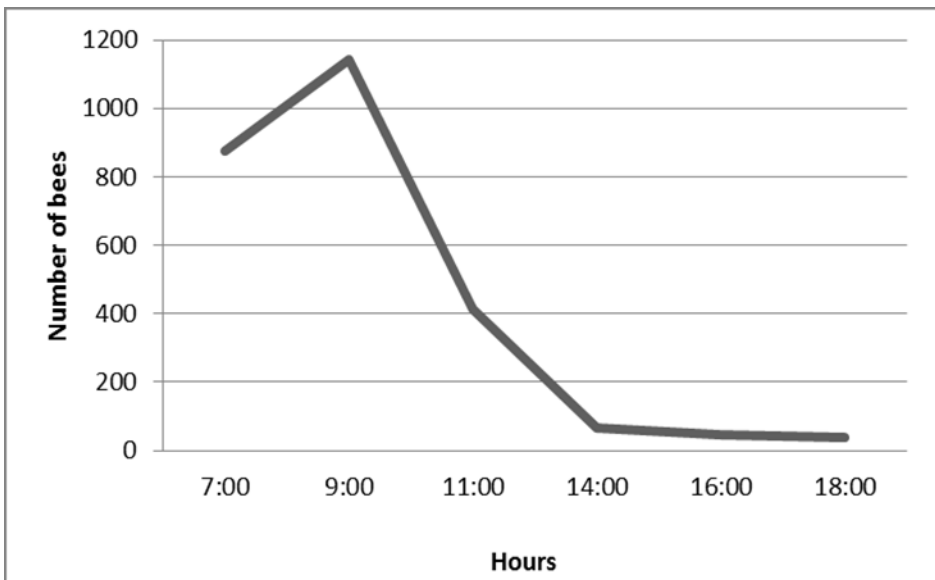


FIGURE 1. Daily abundance of the foraging bees. x axis is representing the number of bees; y axis is representing the hours of observations.

In parallel with the increase in temperature and the decrease of moisture, it was observed that the bees increased their activity on the flowers and the activity was more intense in the period of 07: 00-11: 00, when the temperature was 26-33 °C [24]. When previous studies on this subject were evaluated, our findings were consistent with the literature. In the figure 2., abundance of the foraging bees was given with the air temperature and humidity.

Active bee numbers are expressed as primary axis and temperature and humidity values are expressed on secondary axis. When the daily activities are evaluated, the interval of bee activity at the highest level is 08: 00-10: 00.

Rubis et al. (1966) and Levin and Butler (1966) reached equivalent results in Arizona; Unlike Langridge and Goodman (1980), they determined that bees were active in Australia about one hour before pollen scattering [25-27]. It was also observed that pollen collection was terminated earlier in the day than nectar collection. Boch (1961) and Eckert (1962) reported that many bees had pollen load, and Levin and Butler (1966) reported that bees collecting nectar were more numerous than pollen collecting bees [14, 27, 28].

Pollen collection per capitulum was 24 seconds for *Apis cerana*, 17 seconds for *A. dorsata*, 32 seconds for *A. florea* [29]. As a result of our study, 5 capitulum / minute for *Apis mellifera* and 5,5 capitulum per minute for *Bombus terrestris* were found to vary on different cultivars (Figure 3.).

On Balcı, Dinçer, Linas and Remzibey-05 lines, the honeybees were determined as 5.5, 7, 0, 4 capitulum / min, and bumblebees respectively 4.5, 5, 4.5 and 5 capitulum / min, respectively. Among the four cultivars, Dinçer was the most preferred one while Linans was the least.

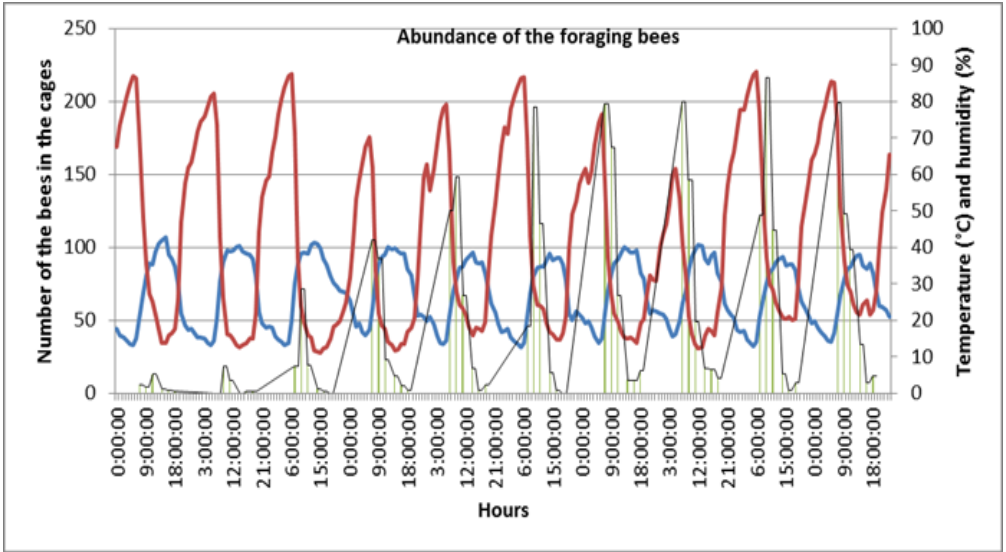


FIGURE 2. Abundance of the foraging bees; red line: humidity, blue line: temperature, green bars: total number of the foraging bees.

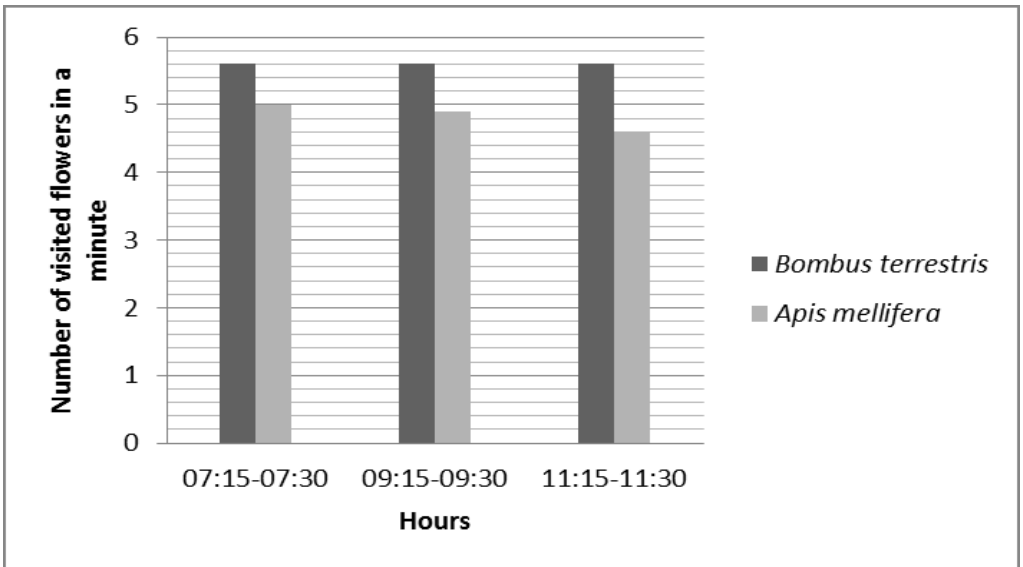


FIGURE 3. x axis is the number of visited flowers in a minute, y axis is the observation hours.

#### 4. CONCLUSION

Our studies showed that the number of foraging bees decreasing while the two managed pollinator species were in the same cage. Although the expectations towards to that increasing number of pollinator species can cause much more effective pollination rates, in our study we found that in caged conditions, the competition between honeybees and bumblebees occurred because of the niche overlap.

**Acknowledgements.** This study is a part of Cigdem Ozenirler's PhD thesis and supported by Hacettepe University Research Foundation Project No:014B0460100.

#### REFERENCES

- [1] X. Hu, S.Yin, Z. Huang, A. Elomri and Y. Lu, A new phenylpropanoid derivative isolated from *Carthamus tinctorius* L.. *Records of Natural Products*, 10(1), (2016) 17-21.
- [2] X. Zhou, L.Tang, Y. Xu, G. Zhou, and Z. Wang, Towards a better understanding of medicinal uses of *Carthamus tinctorius* L. In traditional chinese medicine: A phytochemical and pharmacological review. *Journal of ethnopharmacology*, 151(1),(2014) 27-43.
- [3] R. R. Al-Samaraae, A. E. Atabani, G.Uguz, G. Kumar, O. Arpa, A. Ayanoglu, M. N. Mohammed and H. Farouk, Perspective of safflower (*Carthamus tinctorius*) as a potential biodiesel feedstock in Turkey: Characterization, engine performance and emissions analyses of butanol–biodiesel–diesel blends. *Biofuels*, (2017) 1-17.
- [4] A. Rashid, A. A. Attary, A. Beg, S. Pourdad, H. Ketata, N. Ali and K. A. Dejaz, Oilseed crops for the highlands of cwana. *ICARDA Caravan (ICARDA)*, 16, (2002) 27-29.
- [5] I. Mihoub, F. W. Badeck, F. Aid, M.Lamothe-Sibold and J. Ghashghaie, Relationship between taproot morphological traits, carbon isotope composition and grain yield in safflower. *Arid Land Research and Management*, (2018) 1-16.
- [6] E.Ashrafi and K. Razmjoo, Effect of irrigation regimes on oil content and composition of safflower (*Carthamus tinctorius* L.) cultivars. *Journal of the American Oil Chemists' Society*, 87(5), (2010) 499-506.

- [7] B. Arslan, The determination of oil content and fatty acid compositions of domestic and exotic safflower (*Carthamus tinctorius* L.) genotypes and their interactions. *Journal of Agronomy*, 6(3), (2007) 415-420.
- [8] N.Camas, A.K. Ayan and C. Cırak, Relationships between seed yield and some characters of safflower (*Carthamus tinctorius* L.) cultivars grown in the middle black sea conditions. Proceedings of the VIth International Safflower Conference, Istanbul-Turkey, 6-10 June, 2005. SAFFLOWER: a unique crop for oil spices and health consequently, a better life for you., Engin Maatbacilik Ltd. SSti, (2005) 193-198.
- [9] R. Baroncelli, S. Sarrocco, A. Zapparata, S. Tavarini, L. G. Angelini and G.Vannacci, Characterization and epidemiology of colletotrichum acutatum sensu lato (c. Chrysanthemi) causing carthamus tinctorius anthracnose. *Plant Pathology*, 64(2),(2015) 375-384.
- [10] U. Gecgel, M. Demirci, E. Esendal and M.Tasan, Effects of sowing dates on some physical, chemical and oxidative properties of different varieties of safflower (*Carthamus tinctorius* L.). Proceedings of the VIth International Safflower Conference, Istanbul-Turkey, 6-10 June, 2005. Safflower: a unique crop for oil spices and health consequently, a better life for you., *Engin Maatbacilik Ltd. Şti*, (2005) 139-146.
- [11] S.G. Potts, P. Neumann, B.Vaissière and N.J.Vereecken, Robotic bees for crop pollination: Why drones cannot replace biodiversity. *Science of the total environment*, 642, (2018) 665-667.
- [12] A.K. Pandey and A. Kumari, Pollination ecology of safflower (*Carthamus tinctorius* linn), Seventh International Safflower Conference, Waaga Wagga Australia, (2007) 1-10.
- [13] J. F. Shao, Q. M. Quan, W. G. Cai, L. L. Guan and W. Wu, The effect of floral morphology on seed set in *Carthamus tinctorius* Linnaeus (Asteraceae) clones of Sichuan province in China. *Plant systematics and evolution*, 298(1), (2012) 59-68.
- [14] R. Boch, Honeybee activity on safflower (*Carthamus tinctorius* L.). *Canadian Journal of Plant Science*, 41(3), (1961) 559-562.
- [15] B. Marzinzig, L. Brunjes, S. Biagioni, H. Behling, W. Link and C.Westphal, Bee pollinators of faba bean (*Vicia faba* L.) differ in their foraging behaviour and pollination efficiency. *Agriculture, Ecosystems & Environment*, 264, (2018) 24-33.
- [16] J. Free, Insect pollination of crops. Acad, Press, London-New York, (1993) 172-180.
- [17] Y. Guler and F. Dikmen, Potential bee pollinators of sweet cherry in inclement weather conditions. *Journal of the Entomological Research Society*, 15(3), (2013) 9-19.



- [18] A.J. Campbell, A. Wilby, P. Sutton and F.L. Wäckers, Do sown flower strips boost wild pollinator abundance and pollination services in a spring-flowering crop? A case study from UK cider apple orchards. *Agriculture, Ecosystems & Environment*, 239, (2017) 20-29.
- [19] H.H. Velthuis and A. Van Doorn, A century of advances in bumblebee domestication and the economic and environmental aspects of its commercialization for pollination. *Apidologie*, 37(4), (2006) 421-451.
- [20] K.S. Delaplane, D.R. Mayer and D.F. Mayer, Crop pollination by bees. *Cabi.*, (2000).
- [21] I. Kucukbasmacı and T. Ceter, Investigation of pollinator species of order Hymenoptera in Kastamonu University Campus, *Mellifera*, 16(2), (2016) 25-37.
- [22] D. Abrol and U. Shankar, Pollination in oil crops: Recent advances and future strategies, in Technological innovations in major world oil crops. *Springer*, 2, (2012) 221-267.
- [23] A. Howard, Studies in Indian oil-seeds. I. Safflower and mustard. *Mem. Agric. India. bot.*, 7, (1916) 237-272.
- [24] A. Bukero, A. G. Lanjar, G. A. Thebo, S. A. Nahyoon and N. A. Waraich, Floral activity time period of pollinators on safflower *Carthamus tinctorius* L.. *Science International*, 27(1), (2015) 347-348.
- [25] D. Rubis, M. Levin and S. McGregor, Effects of honey bee activity and cages on attributes of thin-hull and normal safflower lines. *Crop Science*, 6(1), (1966) 11-14.
- [26] D. Langridge and R. Goodman, A study of pollination of safflower (*Carthamus tinctorius*) cv. Gila. *Animal Production Science*, 20(102), (1980) 105-107.
- [27] M.D. Levin and G. d Butler, Bees associated with safflower in south central Arizona. *Journal of Economic Entomology*, 59(3), (1966) 654-657.
- [28] J. Eckert, The relation of honey bees to safflower. *American Bee Journal*, 102, (1962) 349-350.
- [29] A. Deshmukh, G.M. Rao and A. Karve, Studies on the effect of honey bee pollination on the yield of safflower. *Indian Bee Journal*, 47, (1985) 1-2.

Current address: CIGDEM OZENIRLER: Hacettepe University, Science Faculty, Department of Biology; Hacettepe University Bee and Bee Products Applied and Research Center, Beytepe, 06800, Ankara-Turkey.

*E-mail* : [cozenir@hacettepe.edu.tr](mailto:cozenir@hacettepe.edu.tr)

*ORCID*: <https://orcid.org/0000-0003-0390-2416>

Current address: KADRIYE SORKUN: Hacettepe University, Science Faculty, Department of Biology; Hacettepe University Bee and Bee Products Applied and Research Center, Beytepe, 06800, Ankara-Turkey.

*E-mail* : [kadriye@hacettepe.edu.tr](mailto:kadriye@hacettepe.edu.tr)

*ORCID*: <https://orcid.org/0000-0003-3224-7748>