MELLIFERA RESEARCH ARTICLE

Using Commercial Bumblebees in The Pollination of Field Grown Tomatoes A Case Study: "Caged Tomatoes in Open Fields"

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ABSTRACT

There are many disquisitions that points out the efficiency of bumblebees in the production of *Solanum lycopersicum* L. (tomato). Tomato flowers do not produce nectar and also releasing pollen from the poricidal anthers can be possible if only the bees use buzzing behavior. Although the plant is not an attractive source for the bees, thanks to greenhouse technologies, we can use bumblebees to pollinate tomatoes. In this study, our aim was to create a simple pollination cage for field grown tomatoes and evaluate foraging behaviors of commercial bumblebees in this cage. Within this scope, the pollen storages of the hive were evaluated. The weather conditions in the microhabitats (inside the hive, inside the cage, outside of the cage and 15 meters far from field) were compared to see if the cage material changes temperature and/or humidity. Yield analyses were applied both in open field and caged tomatoes. *Solanum lycopersicum* L. plant is preferred by bumble bees unless there is a more attractive plant around. The temperature values were found significantly different whereas humidity values were not. As a result of the study, total tomato production and the numbers of seeds were increased with the pollination of bees. We can claim that pollination cages are also usable for the entomophilous plants production and can be alternative systems for non-heating green houses.

Keywords: *Solanum lycopersicum* L., bumblebees, pollination, open field, cage, pollen analysis

Introduction

Pollinators have gained the key importance as they perform the task of pollination in many crops [1]. Pollination by wild animals is a key ecosystem service [2]. Among these animals, bees are the main pollinators of nearly 70% of world's crops [2]. The estimated value that pollination by bees brings to production exceeds millions of dollars and euros every year [3].

Diversity of the wild bees, which are foraging for pollen, is one of the most important points in pollination services (both for agricultural practices and natural habitats). Beside this, manageable bees are the insurance of the entomophilous crops' production. Honey bees (*Apis sp.*), bumblebees (*Bombus* sp.), *Osmia* spp., *Megachile rotundata* and *Nomia melanderi* are the most important bee taxa using commercially in agricultural production [4]. Which pollinator is preferable depends on

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the local costs and climatic conditions [1] as well as the pollinators' foraging behavior.

For example, buzz-pollinated crops, which include species from 65 families and comprise tomatoes and potatoes, cannot be pollinated by honey bees and rely on certain wild bee species with the ability to use vibration to extract pollen from the anthers [5].

Tomato flowers do not produce nectar and also releasing pollen from the poricidal anthers can be possible if only the bees use buzzing behavior [6]. Although the plant is not an attractive source for the bees, thanks to greenhouse technologies, we can use bumblebees to pollinate tomatoes [7]. Commercial *Bombus terrestris* colonies have been used in greenhouses since 1987 [8].

In modern world, one of the most produced vegetable is tomato and Turkey ranks 4th in tomato production [9]. Turkey has produced 12.615.000 tons of tomatoes in 2016 and 3.614.472 tons of tomatoes were produced in greenhouses [10]. This statistic shows that 73% of tomato was produced in open fields.

Health and environmental issues are the two main approaches concerning agricultural practices [11]. In addition to these, food taste and quality have become important for consumers recently. Lower production costs, increasing yields, stimulating growers to use biocontrol methods for crop protection and improving quality of the vegetable, fruit and seed are the advantages of using bumblebees in agricultural practices [1].

Within this scope, our aim in this study was to create a simple pollination cage for field grown tomatoes and to evaluate foraging behaviors of commercial bumblebees in this cage.

Materials and Methods

Treatment field and planting structure

The treatment field was located in Yenikent Zir Valley, Ankara / Turkey (39.981693, 32.500793). 100 tomato seedlings were planted on 23rd of May 2016. 50 of them were inside the cage; 50 of them were outside the cage. The cage was ~32,5 m^3. The net material is alluminium and allows water, air and sunlight to pass while preventing (the other) insect pollination except bumble bees in cage (cage size was 2.5 m × 2.5 m × 5.2 m and screen mesh size 0,1 × 0,1 mm.).

Temperature and humidity

During the flowering season of tomatoes, temperature and humidity data were recorded with four data loggers (DS1923

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temperature / humidity logger iButton R). These devices were programmed so that the data could be collected in 60 minutes periods. Data recorder devices were placed in plastic tubes with holes in them and one of them is suspended in the cage with rope from the highest point of the cage. A data logger device was hung on a pole just outside the cage, one of the devices was hung on a pole 15 meters far from the research field and the last device was inside the hive to record the temperature and humidity. The results were analyzed with one-way analysis of variance (ANOVA) with Excel.

Management of the bees

Commercial *Bombus terrestris* colony was provided by Koppert Biological Systems-Turkey. The bumblebee colony contained about 50 workers, brood and a queen.

Pollen analysis

At the end of the trials, the hive was taken to the laboratory. It was kept in the -18 °C for 5 days. Then it was opened and pollen pots were investigated. Pollen grains were picked up with a needle. Samples were prepared according to the Wodehouse method [12]. Identifications were carried out with Nikon Eclipse E400 microscope by using several taxonomic keys [13-16]. Pollen slides were photographed with Olympus BX7 microscope.

Harvest and yield analysis

Harvest was done by T. Dabak. At the end of the season, total harvested material was calculated as kilogram unit. Seed amount was evaluated for these two groups with randomly chosen samples.

Results and Discussion

Temperature and humidity

One way ANOVA was conducted among three groups (cage, outside and control). According to the temperature values (Table 1), it was found that there was a statistically significant difference between groups as determined by one-way ANOVA (p = 0,9.6E-08). But there were no statistically significant differences between group means as determined (p = 0,1).

Table 1. Temperature and humidity data. The data were given as mean±std..

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	Temperature (°C)	Humidity (%)
Hive	22,7±3,3	55,8±6,7
Cage	25,5±1,9	49,6±7,1
Outside	31,7±2,8	43,9±6,5
Control	26,7±2	46,4±6,4

Pollen analysis

The results of the palynological investigations show that *Solanum lycopersicum* L. is the only foraging plant for this bumblebee colony. Inside of the nest with pollen pots (Fig.1) and pollen photos (Fig. 2) are given.

Figure 1. Pollen pots seen inside the nest

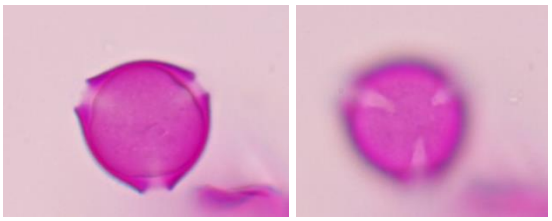

Figure 2. Pollen photos of *Solanum lycopersicum* L. found in the nest

Foraging activities

S. lycopersicum lacks of nectar [17] and because of this there wasn't any pollinator visiting the plants outside. Therefore the wild bees were only visiting other plant families around, such as Asteraceae and Fabaceae.

Harvest and yield analysis

As a consequence of green-housing using bumble bees, the emergence of qualificational features such as width, length, weight and seed amount increase an undeniable amount of marketable crops [11, 12]. This situation not only increases the rise of yield, but also the quality of the product which leads to a positive effect on producers' income.

Many studies have been made on bumble bees and their effective in greenhouse tomato production [18-20]. According to a

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study carried out especially on tomatoes showed that, while compared to that of vibration and shaking, the rise of efficiency caused by bumble bees is 90%, and compared to that of the of hormones it is 61%. Compared to the vibration technique, the increase of the average weight of tomatoes caused by bumble bee usage is 41 % and compared to that of hormones it is 9% [13].

At the end of the season, we harvested totally 335 kg of tomatoes (open field: 140 kg; caged field: 195 kg). Moreover, the seed count inside of the cage significantly increased (61%) with respect to the outside. The seed averages 152 per tomato inside the cage whereas the seeds harvested outside of the cage averages 94 per tomato.

Conclusion

Good agricultural practices are based on sustainable agriculture to continuously improve farming systems by means of integrated pest management and integrated crop management. For avoiding the usage of pesticides or other agricultural inputs and incorrect usage of chemicals, we urgently need to help, educate and encourage farmers towards good agricultural practices. This is very crucial for both internal market import and external exports. This will increase and ensure the production of more safe and healthy goods.

In the commercial production of tomatoes, there are several studies that using bumblebees in greenhouses, increasing the quality. But also it was found out that *Solanum lycopersicum* L. is not an attractive plant for the bees if there are melliferous plants around them. That is for in the production process of open field tomatoes, bumblebees usually do not forage on tomato flowers. The cages helping the tomato producers to using bumblebees in the real production season: summer.

With the results of our study, we can claim that pollination cages are also usable for the entomophilous plants production. They can be alternative systems for non-heating green houses.

Acknowledgements

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AÇIK ALANLARDA YETİŞTİRİLEN DOMATESLERİN TOZLAŞMASINDA TİCARİ BOMBUS KOLONİLERİNİN KULLANIMI ÖRNEK BİR ÇALIŞMA: AÇIK

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ALANLARDA KAFES İÇİNDE DOMATES ÜRETİMİ

Öz: Bombus arılarının, *Solanum lycopersicum* L. (domates) üretimine olan etkisini gösteren birçok araştırma vardır. Domates çiçekleri nektar üretmez ve gözenekli anterlerindeki polenlerin aktarımı ancak silkeleme davranışı ile polen toplayan arılar tarafından gerçekleştirilebilir. Bu bitki, arılar için her ne kadar çekici olmasa da, seralarda kullanılan teknolojik yöntemler sayesinde bombus arıları ile tozlaştırılabilir hale gelmiştir. Bu çalışmadaki amacımız, açık alanda yetişen domatesler için basit tozlaşma kafesleri oluşturarak kafes içerisine yerleştirilen bombusların beslenme davranışlarını değerlendirmektir. Çalışma kapsamında, kovanın polen depoları değerlendirilmiştir. Kafesin ısı ve/veya nem koşullarını etkileyip etkilemediğini görmek için mikrohabitatların (kovan içi, kafes içi, kafes dışı ve kontrol amaçlı 15 metre uzaklıktaki bir nokta) ısı ve nem koşulları karşılaştırılmıştır. Verim analizleri açık ve kafes içi koşullar için gerçekleştirilmiştir. *Solanum lycopersicum* L. bitkisi, etrafta daha cazip bir bitki olmadığı sürece bombus arıları tarafından tercih edilmektedir. Sıcaklık değerleri arasında anlamlı bir farklılık tespit edilirken, nem değerleri arasında edilmemiştir. Toplam domates üretimi ve domateslerdeki çekirdek sayısı arı ile tozlaşma sonucunda artış göstermiştir. Tozlaşma kafeslerinin de entomofil bitki üretimi için kullanılabileceğini ve ısıtmasız sera sistemleri yerine alternatif sistemler olabileceği düşünülmektedir.

Anahtar Kelimeler: *Solanum lycopersicum* L., bombus arısı, polinasyon, açık alan, kafes,

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