BIBLIOGRAPHY

DELLIAS, ERIC C. APRIL 2007. Documentation on Bumblebees (*Bombus terristris* Linnaeus) as Pollinator of Tomato under Greenhouse Condition in Israel. Benguet State University, La Trinidad, Benguet.

Adviser: Lita M. Colting, PhD

ABSTRACT

The study was conducted at Kibbutz Sde Elyahu, Beit Shean Valley, Israel from January to July 2006 to observe how bumblebees are used as pollinator of tomatoes under greenhouses.

Fifteen (15) bumblebee colonies were situated to pollinate tomatoes inside 1.5 hectares.

The bumblebee colonies were maintained inside the greenhouse from the time the tomato flowers bloom up to the last bloom.

The increased in yield was estimated to be 25% as a result of bumble pollination.

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INTRODUCTION

Rationale

Israel is one of the countries that developed appropriate technologies in agriculture, such that despite its barren land it is one of the top ranking exporters of fresh produce to Europe and western countries. Israeli agriculturists, scientists and researchers continue to explore to geared on improving the quality and quantity of the products, to satisfy the consumers, and to meet the needs of the farmers. One of the technologies that they promote is the use of natural pollinators to increase and improve the quality and the quantity of products. They also practice environment-friendly pest management allowing pollinators to thrive in greenhouses. They grow agricultural crops in greenhouses and employ drip fertigation to optimize the use of water which is a very limited resource in the country.

The bumblebee is an ideal natural pollinator for protected crops such as greenhouse tomato, bell pepper, strawberry, and an important backup for outdoor crops during marginal seasons. Unlike honeybees – also important pollinators of crops, bumblebee adapts well to confined greenhouse conditions as stated by Aviel (2006). It has been shown that the use of bumblebees in tomato greenhouse has increased the yield of export – quality tomatoes by 25% compared to manual pollination.

Before, Israel farmers usually pollinate greenhouse crops with artificial method and manual pollination. Farmers tried to use honeybees in greenhouse but it was not successful for honeybees prefer open field condition, hence alternative pollinator with the use of bumblebees has been looked into (Aviel, 2006).

The tomato (*Lycopersicon esculentum*, Mill) flower is self-fertile or self-pollinating, containing both stamens and pistil. The flower has six yellow petals and six stamens that unite at the tip of the anthers to form a cone surrounding the pistil. In order for the flower to be pollinated, the flower needs to be vibrated to let the pollen fall into the cone of stamens and land on the stigma at the tip of the style. When the style is shorter than the surrounding cone, normal contact can occur between the pollen and the stigma, however, when the style protrudes out of the cone it is difficult for the pollen to meet the stigma.

Statement of the Problem

Unlike in open areas, condition inside the greenhouse do not favor self pollination of tomato flower for the relative humidity is high and there is low air movement so the flowers are not shaken enough to allow self pollination. The artificial shaking of the flower can be optimally achieved by the introduction of bumblebees. Bumblebee is capable of vibrating the tomato flower using its unique buzz pollination mechanism which is claimed to be far superior to any manual or artificial pollinators such as electric bee, pulse air or hormones (Aviel, 2006).

Research was perform on the natural pollinator (the bumblebees) and was documented. There is a need, therefore, to answer the following questions:

1. What are the practices involved in planting tomatoes in Israel?
2. What are the processes in mass producing bumblebees?
3. How and when are the bumblebee colonies set inside the greenhouse?
4. How the bumblebees pollinate tomatoes?
5. What makes bumblebees an efficient pollinator of tomatoes?

Objectives of the Study

1. To identify the practices involved in planting tomatoes?
2. To discuss how bumblebees are reared.
3. To describe the characteristics of bumblebee in pollinating tomatoes.
4. To discuss how the bumblebee colonies are set inside the greenhouse.
5. To show the bumblebee as pollinators are far better than other means.

Importance of the Study

The study will be a point of reference for further research and will serve as a guide when adaptation of the technology will be considered.

Also, it will give information on bumblebees adapted as a natural pollinator that boost the greenhouse products of Israel that leads as one of the exporter of fresh produce in the Middle East.

Scope and Limitation of the Study

Data gathering for the study was conducted on January to July 2006. This was conducted at Beit She'an Valley, Israel.

The study was limited to the ocular observations of the researcher and personal interview with Shaul Aviel a field service advisor who gave lectures, demonstrations, and data regards to the study.

REVIEW OF LITERATURE

The Bumblebees

Bumblebees are similar to their close relatives, the honey bees, and that their colonies are headed by a queen, which is the main egg-layer, and many workers, which are the daughters of the queen, and the drones (males) which are being produced during the mating season. However, the colonies of bumblebees, unlike those of honey bees, only survive during the warm season; new queens hibernate alone to begin another colony the following spring. In addition, there is usually lesser number in a bumblebee colony than in a honeybee colony and bumblebees do not use a dance to communicate the location of food to other members of the colony, as honey bees do. They do not also store large amount of honey as honeybees do. The biology of bumblebees has been well studied, and is shown in Figure 1 (Aviel, 2006).

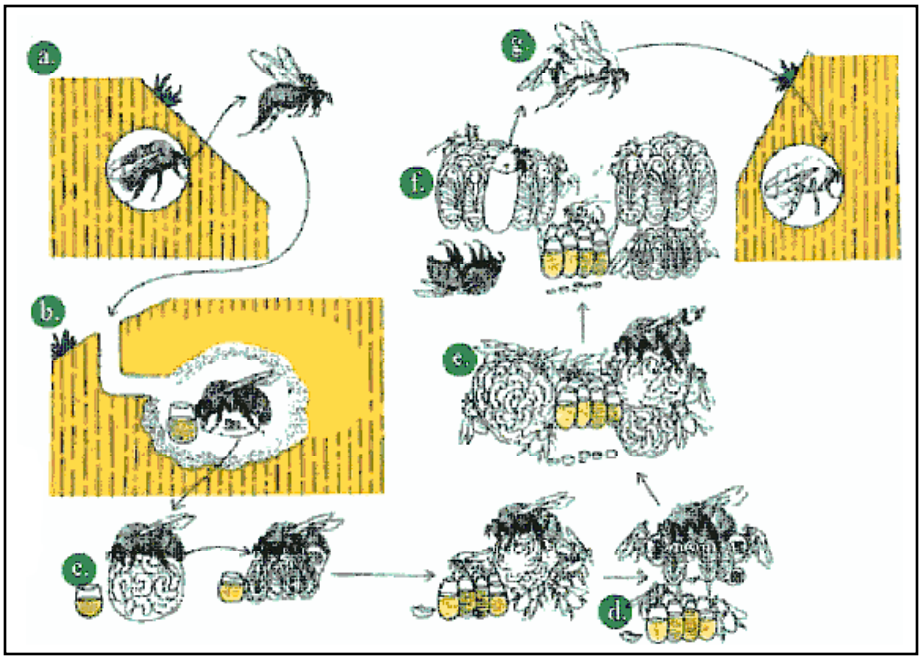

Figure 1. An illustration of the life cycle of bumblebee

Bumblebees are important pollinators of many plants like tomato, avocado, eggplant, cherry, courgette and bell pepper. Both queens and workers collect pollen and transport it back to the colony in the pollen baskets on their hind legs. Workers are small if born early in the year, and large if born later. Also, some species of bumblebees are larger than others. Differences in body size, and especially in tongue length, are important in determining which flower species a bumblebee will visit for nectar and may determine which flowers it can pollinate (Sugden, 1997).

Sugden (1997) further mentioned that bumblebee is also recognized as vital to the production of certain seed crops. Bee scientists have developed a means to cause queens to skip their winter hibernation and produce colonies year-round. Enabling bumblebees to be reared in hive boxes, available for use in pollinating crops anytime of the year and in various places.

Also, bumblebees are increasingly cultured for agricultural use as pollinators because they can pollinate plant species that other pollinators cannot by using a technique known as buzz pollination. For example, bumblebee colonies are often placed in tomato production inside the greenhouse because the frequency of buzzing that a bumblebee exhibits effectively pollinates tomatoes (McDonald et al., 2006).

Bumblebee Compared to Honeybees

Compared to the honeybees, the bumblebee is capable of vibrating the flower using the unique buzz pollination mechanism for the tomato flower needs vibration for proper pollination and fruit set, under greenhouse conditions. Unlike the honeybee, the bumblebee is less affected by adverse weather conditions. Temperatures below 15 degrees centigrade, rain or cloudiness above 70 degrees centigrade will keep the

honeybees in their hives but not the bumblebees which will continue functioning without interference. This characteristic makes the bumblebees excellent pollinators of winter crops. Unlike the honeybee, the bumblebee is better adapted to perform under confined greenhouse conditions. The bumblebee is less inclined to look for alternative sources of pollen and nectar outside the greenhouse. Therefore the bumblebees will stay inside the greenhouse even if it is opened for ventilation purposes. Also, bumblebees are vulnerable to pesticides. It is desirable to use non-chemical alternative as possible to control pests in crops. Since bumblebees were introduced into greenhouse tomatoes in Israel, there has been a 50% reduction in the overall chemical input in crops. Their application in the greenhouse requires a friendlier pest control regime (Aviel, 2006).

METHODOLOGY

Locale and Time of the Study

The study was conducted at a farm of Beit She'an Valley (Figure 2), Israel from January to July 2006. It is located in a valley wider that La Trinidad valley in Benguet where the main campus of Benguet State University is established. The temperature was 32° C during the conduct of the study.

The place was chosen as the study area for it is where the kibbutz that started the mass rearing of bumblebees for local and for export market was located. Map of the study area was shown in Figure 3.

Figure 2. Greenhouses in Beit Shean Valley

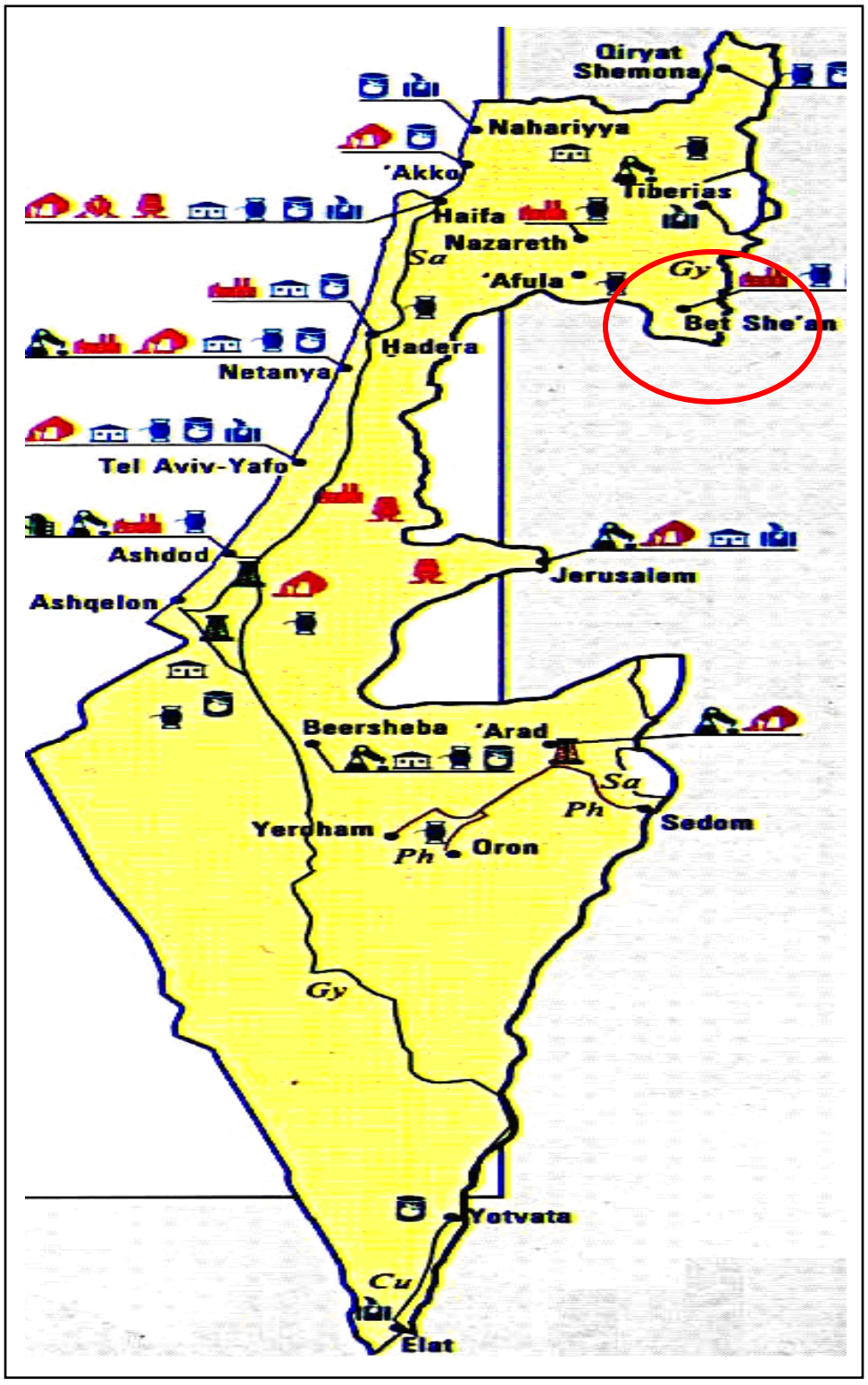

Figure 3. Map of Israel showing Beit Shean Valley

Respondents of the Study

The study was dependent on the ocular observations of the researcher and an interview with Shaul Aviel. (Field Service Advisor) who gave the lectures, information and demonstrations on bumblebees this shown in Figure 4.

Figure 4. An interview with Shaul Aviel

Data Collection

A personal interview with Shaul Aviel (Field Service Advisor), visits to greenhouses, ocular observations and photo taking were done.

Data Gathered

The data gathered were the different practices involved in planting tomatoes; the rearing of bumblebees; characteristics of bumblebee as pollinator of tomatoes; bumblebee colonies set inside the greenhouse and the efficiency of bumblebees as pollinators.

Data Analysis

The data gathered were consolidated and presented in narrative form with photo documented.

RESULTS AND DISCUSSION

Tomato Production in Israel

Tomato productions in Israel are done under polyethylene greenhouse or glasshouses because of adverse weather conditions such as rainy-winter, excessive heat during summer and frequent changes of air temperature. The dimension of the greenhouse was 125 x 120 meters. The tomatos were planted on soil and/or artificial medium like coconut husk with plastic covering. The distance between plants is 50 cm and the distance between plots is 100 cm. The tomatoes while young were provided with supporting trails with the use of nylon strings, but as they become taller the lower stems were laid in the ground. This was done to lower the height of the tomato to easily reach the fruits during the harvest. The tomatoes can reach a maximum height of 10 m.

In terms of irrigation and fertilizer application, the water and fertilizers were mixed in big tanks that were connected to pressurized water pumps and to allow equal distribution of water and fertilizer. A main pipe was connected to the water pump, where secondary pipes or the pipes with drippers were connected. The drippers were laid near or parallel the tomato plants where the liquid will form circular-form until each will meet. The process is called fertigation. Before fertigation, the nutrition needed by the plant is first analyzed.

Bumblebee Industry

Bumblebee has become a commodity in Israel because of the efficiency as pollinator of thousands of hectares of greenhouses tomatoes. The economy Bio-Bee located at Sde, Eliyahu, Beit Shean Valley, Israel has been mass producing bumblebee as

pollinators since 1990. In Israel, Bio-Bee Company supply pollination services to more than 500 hectares and over 1000 clients. Also, bumblebee hives are exported to Europe, Japan, Africa, and South America.

Tomato growers in Beit Shean Valley preferred to use bumblebee as natural pollinator for their crops. Results shown in Table 1.

Table 1. The number of farmers using bumblebees as pollinator of tomato crops in each Kibbutz of Beit Shean Valley

KIBBUZT	TOTAL NO. OF FARMERS	NO. OF BUMBLEBEE USERS
Shluckot	6	6
Lofan	5	5
Kfar Ruppin	8	8
Yardenit	5	5
Sde Eliyahu	6	6
TOTAL		30

Rearing of Bumblebees

The bumblebees (*Bombus terristris* Linnaeus) or the large earth bumblebees are reared in dark rooms or naturally, they dig and build their colony under the ground.

Kibbutz Sde Elyahu the pioneer of mass production has especial rooms in rearing bumblebees. The rooms should be dark and were highly monitored to avoid the entry of diseases that can cause damage to the starting colonies. Red lights are being used for

monitoring and checking the colonies, for bumblebees can not visualize red lights. Unfortunately, the rearing house was not visited as it is restricted to visitors.

The Bumblebee Hive

Figure 5 shows the white and clean plastic box where the bumblebees from the rearing house are placed for field distribution. The box has been especially designed to provide maximum ventilation with the provision of numerous slits at the bottom of the box, sidewalls and lids to allow airflow that helps the bumblebees quickly and efficient remove dirt to keep the hive clean. Clean hives lengthen lifespan of the bees.

The bumblebees are provided with artificial food with the provision of a bag of sugar-water with drinking apparatus in a separate unit within a cardboard covering beneath the bee colony (Figure 6). The bumblebees obtain their food through a wick, which transports the liquid from the bag into the brood compartment. Between the plastic inner housing colony box and the food unit there is a thick layer of styrofoam (about 2 cm) with a cotton wool covering the brood from above to provide maximum insulation for the bumblebees.

Figure 7 shows the addition of dry pollen to the hive as a natural dietary supplement. These are put at the center of the square part of the plastic inner lid with slightly raised borders where the pollen eventually falls and become accessible to the bees.

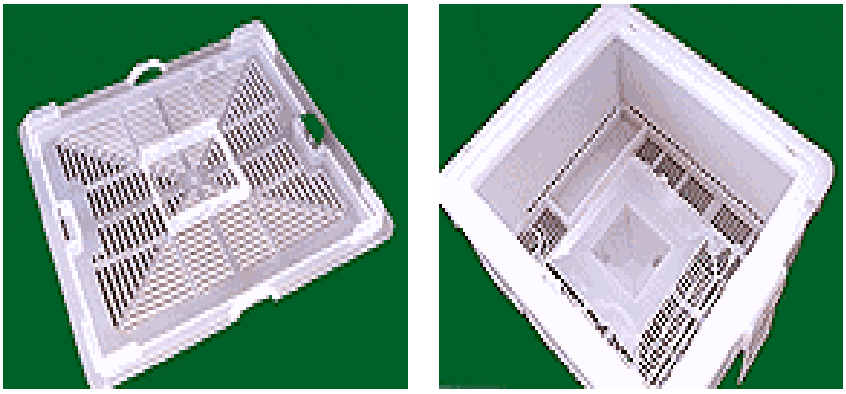

Figure 5. The white box where the bumblebee colony are placed for field use after they have been reared in dark room

Figure 6. Bag of water-sugar (food) and the drinking apparatus

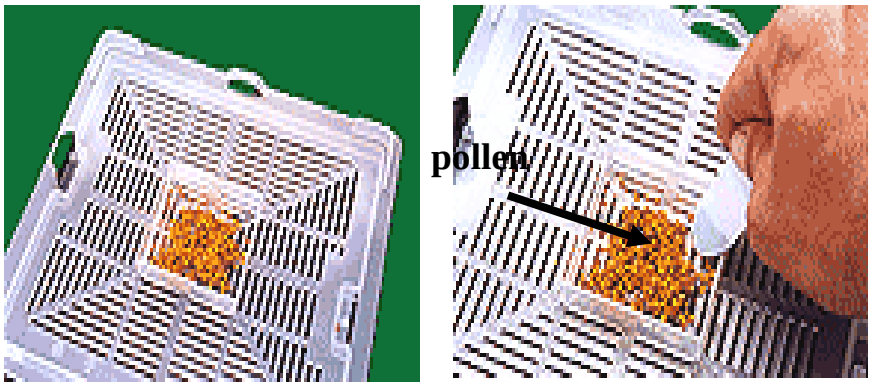

Figure 7. Dry pollen is added to the hive as a dietary supplement

Arrangement of the Bumblebee hive

For final transport to the fields, the plastic hives are put inside a cartoon box (Figures 8 and 9), provided with two openings that will serve as passage for the bees when these are settled in the greenhouses. These openings are provided with shutter (Figures 10 and 11).

Figure 8. The top view with the water-sugar, food court and food wick

Figure 9. The top view, food covered with styrofoam

Figure 10. The bee colony in polyethylene put through the cartoon box

Figure 11. The top and side view of the bumblebee hive

Figures 12 to 14 show the full lowering of the plastic shutter to block totally both the flight-holes during transport. If the colony is transferred to another plantation, one of the holes will be kept open. This flight-hole allows the bees to enter and will not able to exit. If the colony is used for pollination the plastic shutter is opened to the maximum to expose the two flight-holes. These allow the bees to enter and exit in front of the hive.

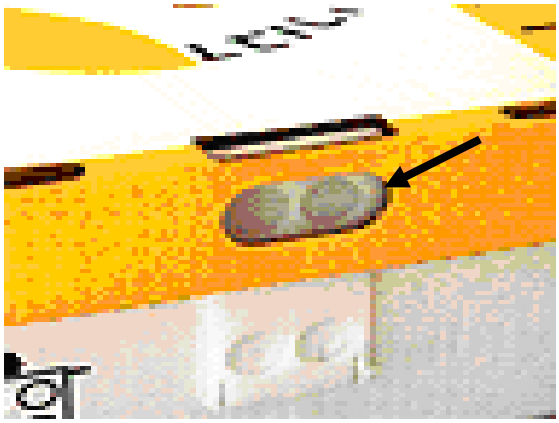

Figure 12. The flight-holes are closed

Figure 13. One flight-hole is opened

Figure 14. The two flight-holes are fully opened

Transport of Bumblebee hive

Figure 15 shows sets of bumblebee colonies inside the packing house ready for transport to various farms within Israel or for export. Bumblebee colonies are being transported by close van truck with controlled temperature 28 ° C. During the transport all the colony is closed and sealed.

Figure 15. Bumblebee colonies in cartoon hive box ready for market

Bumblebee Colonies Inside the Greenhouse

Fifteen (15) colonies of bumblebees are put inside a 1.5 hectares greenhouse when the tomato flowers are about to bloom until the flowering stage will end. The colonies are set up at least two (2) ft. from the ground with the provision of stands either made of wood or metal materials (Figures 16 to 17). The colonies are set in the corner of the greenhouse near the entrance and about three (3) ft. apart. The setting up of colonies is done 9 o'clock in the morning. After the colonies are set up, the plastic shutter is lifted to open the flight-holes so that the bees can enter in and exit from the hive respectively.

Figure 16. A bumblebee colony set on top of a table

Figure 17. The researcher showing a colony set on metal stand

Behavioral Characteristics of Bumblebee

Bumblebees are efficient pollinator of tomatoes for they are able to open the tomato flower in order to be pollinated. They have a heavy body that upon clinging on the flower, the latter bends allowing the flower-cone to open and also the falling of the pollens. Apart from this the bumblebee vibrates its wings while bending its body causing the shaking of the tomato flower. This activity enhances the falling of the pollen grains to the stigma resulting to pollination. This kind of pollination system is called buzz pollination.

The following photos (Figures 18 to 20) show a tomato flower before and after bumblebee visitation. A flower with scars caused by bumblebees eventually fruit set, while flowers that has no scars, pictures that there was no visitation happened.

Figure 18. Unpollinated tomato flower

Figure 19. Bumblebee visiting a tomato flower

Figure 20. A tomato flower with scars indicating successful pollination

Efficiency of Bumblebee Pollinator

Figures 21 to 22 show two tomato plantations grown in various media that were pollinated by bumblebees. The crop in-charge claims that the use of bumblebees in tomato production under greenhouses has increased the yield of export quality tomatoes by 25% compared to manual pollination.

Figure 21. Tomatoes pollinated by bumblebees grown in soil medium

Figure 22. Tomatoes pollinated by bumblebees grown in artificial medium

SUMMARY, CONCLUSION AND RECOMMENDATION

Summary

The study was conducted at Kibbutz Sde Elyahu, Beit Shean Valley, Israel from January 2006 to July 2006 to observed tomato plantations inside the greenhouse, to observed the behavioral characteristics of bumblebees that makes it efficient as pollinator of tomatoes and to observed how colony is prepared and set in tomato plantations.

The tomatoes are planted in soil or artificial medium. The distance between plants is 50 cm. and between plots is 1 m. The tomato is provided with supporting trails but the lower stems are laid in the ground as they mature. Water and fertilizers are applied through fertigation.

Bumblebees are attracted to the yellow flowers. They visit fully bloomed flowers and as they cling to the petals that cover the pistil and it bends allowing the flower-cone to open. The wings of the bumblebees continue vibrate causing the tomato flower to shake and the falling of pollen grains into the pistil.

The bumblebee colony covered of white plastic box with ventilation, encased of cartoon boxes provided with food. The colonies were transported in closed van truck. The colonies were set near the entrance of the greenhouse with stand.

Conclusion

Bumblebee colonies are introduced as pollinators in tomatoes under greenhouse condition in Israel. The bumblebees increased yield and improved fruit quality.

Recommendation

Based on the results and observations the researcher recommend that the use of natural pollinators should be adopted in the country especially in promoting organic farming and upholding the use of biological control.

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