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Bumblebees in Greenhouses: The Secret Pollination Weapon for Thriving Crops

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Abstract

Protected cultivation is the foremost method, helping growers overcome climate challenges and attain the utmost yield. However, pollination continues to be a constraining factor in greenhouse cultivation. Bumblebee pollination is crucial and effective for greenhouse conditions. Bumblebees, with their efficient pollination techniques and adaptability to greenhouse conditions, play a pivotal role in enhancing crop yields and quality. However, it also has some drawbacks to achieve sustainable pollination.

1. Introduction

Bumblebees are sturdy and sizeable insects that sport black and yellow hues. Their hairy black or yellow abdomen sets them apart from carpenter bees. When gathering food, bumblebees carry sizable pollen baskets on their hind legs, which they often fill to the brim. Queen bumblebees are usually twice the size of workers or males. Bumblebees are found wherever flowering plants are located and contribute immeasurably as pollinators of wildflowers and crops. These bees belong to a crucial insect group for the pollination of vegetables, fruits, oilseeds, legumes, and fodder crops and pollinate over 25 crops worldwide, including blueberries, strawberries, peppers, zucchinis, melons, cranberries, and tomatoes, as well as alfalfa, red clover, cotton, and sunflower. They are used for pollination both in greenhouses and outdoors. Honey bees are the most commonly used species for pollinating field crops. However, it's worth noting that bumblebees and honeybees are not always interchangeable as pollinators for some plant species. Bumblebees are a great alternative to manual pollination. They are effective pollinators for greenhouse-grown tomatoes, sweet peppers, and strawberries. Their longer tongues and wing-vibrating tendencies make them more effective pollinators for certain plant species. They are also more capable of foraging than bees in cool and adverse conditions. During spring, bees start foraging earlier and remain

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active even in cloudy weather to find nectar and pollen.

Figure 1: Pollination of a. Tomato, b. strawberry, c. oilseed rape flowers by bumblebee

Figure 2: A Potential pollinator

2. Bumblebees as a Potential Pollinator in Greenhouses: A Comparison with Honeybees

Bumblebees are recommended for greenhouse pollination due to their ability to achieve higher rates of cross-pollination. They visit a greater number of flowers per minute, with a flying capacity of 64 km/h. They also exhibit less swarming behavior and are less aggressive which are considered safe parameters for use compared to honeybees. Bumblebees employ a technique known as 'buzz-pollination' to pollinate flowers, enabling them to accomplish pollination in a single visit. In contrast, a honeybee typically requires 7-10 visits to a flower before achieving full pollination. Bumblebees, are characterized by their larger bodies and primarily focus on foraging for pollen rather than nectar. Hence, these bees are proven to be more reliable pollinators, especially in protected environments, ensuring both the quantity and quality of tomatoes produced. On the other hand, the efficiency of honeybee pollination in tomato greenhouses often fails to meet the required commercial production levels (Bispo et al., 2009) due to their limited foraging activity and due to their inherent dislike of the floral scent of tomatoes and fruitless attempts to gather food (Zhang et al., 2020).

Bumblebees exhibit activity at significantly lower temperatures, approximately 5°C, compared to honeybees, which typically become active at temperatures ranging from 15 to 18°C. This difference allows bumblebees to engage in pollination over a more extended period during each season. Ensuring the presence of flowering plants throughout the season becomes crucial, particularly during colder periods, to support and sustain these pollinators. Bumblebees demonstrate increased activity on cloudy, foggy, and rainy days, in contrast to honeybees, which tend to remain within the hive and avoid flying during such weather conditions. Thus, bumblebees engage in pollination for a more extended duration in each day compared to other pollinators which leads to an approximately 20-25% increase in their daily pollination period. Moreover, these bees possess longer "proboscises" than honeybees, allowing them to efficiently collect pollen from flowers with narrow corolla tubes, such as those found in bell peppers, tomatoes, blueberry plants, and other similar species. Bumblebees exhibit a superior sense of direction, making them particularly valuable in protected or semi-protected greenhouses. In contrast, honeybees struggle with orientation, often getting lost as they collide with the glass surfaces. The absence of an advanced communication system decreases the probability of bumblebees abandoning crops in favor of more attractive flowers.

3. Pollination Mechanism

Certain plant families, including Solanaceous crops, feature "perfect" flowers where both male and female reproductive parts are present on the same flower, enabling self-pollination. In the case of solanaceous crops, which are characterized by downward-facing tubular flowers, relying solely on natural wind-induced pollination may not be efficient. In this case, mechanical vibration helps to enhance pollination. Bumblebees, through a technique known as "sonication," excel at this process by gripping the flower tube and using their flight muscles to create vibrations that release pollen from the male part onto the female part.

4. Advantages of Bumblebee Pollination in Protected Cultivation

Bumblebees demonstrate a considerably greater pollen-carrying capacity, depositing approximately 2.7 times

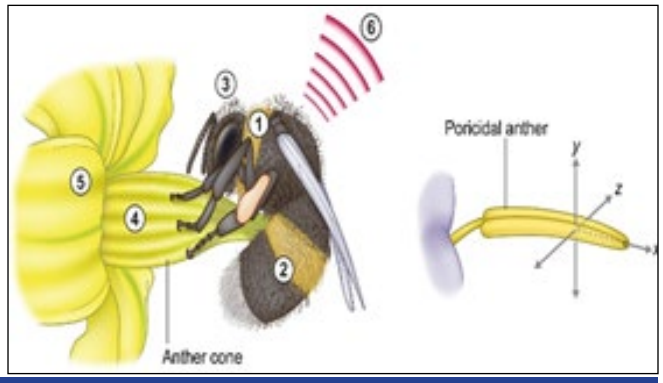

Figure 3: Buzz Pollination; Left-hand panel: Bee vibrating the anther cone of a Solanum flower with poricidal anthers. Right-hand panel: Single poricidal anther with three axes of vibration (x, y, z). The indirect flight muscles cause cyclical deformation of the bee's thorax that results in vibrations (1). These vibrations are transmitted to the anther cone (4) by direct contact with the thorax, head, abdomen, and, to a lesser extent, the legs (1–3). Vibrations are also transmitted to other parts of the flower including the petals and sepals (5). The vibrating bee also transfers energy to the surrounding air results in an audible component (6)
Source: Mario Vallejo-Marin, 2019

more pollen per flower. This substantial pollen abundance plays a crucial role in robust pollination, leading to the production of more uniform and larger fruits and vegetables, resulting in enhanced yields. In greenhouses, tomatoes often face insufficient pollination without human intervention, requiring growers to manually pollinate using handheld electric vibrators, which is time-consuming. Utilization of bumblebees proves to be a cost-effective substitute for manual pollination which lowers production costs and also reduces labour requirements (Velthuis and Van Doorn, 2006). Fruit flavor is becoming more and more important to producers in addition to yield and quality issues. Previous studies have pointed out that tomatoes pollinated by bumblebees reported a more appealing taste compared to those treated with vibrators (Hogendoorn et al., 2010). Consequently, consumers exhibit a higher willingness to pay for tomatoes that have undergone bumblebee pollination. It also results in the formation of better fruit and faster ripening. It is a sustainable and eco-friendly approach that contributes to the preservation of biodiversity and the overall health of ecosystems.

Commercial bumblebees (*Bombus* spp.) are the primary pollinators used inside which structure in Europe and North America. These bees have much smaller colonies, which makes them easier to transport. Companies such as Koppert Biological Systems and Biobest have developed methods to rear them continuously throughout the winter season in greenhouse environments for seasonal production needs across the continent. They have also designed special packaging that allows them to be shipped with a food source through the mail.

Bumblebees are effective pollinators for certain fruits (berries), vegetables (tomatoes, peppers, and eggplants), and seed crops (cabbage, carrots, and cucumbers). Bumblebees are less hostile than honeybees and are better adapted to low UV conditions (Dyer and Chittka, 2004). They are good pollinators of the vine and solanaceous crops inside and outside growth structures. However, their colonies are short-lived, lasting only about 8 to 12 weeks. For indoor pollination of vegetable crops, it is recommended to have one to three colonies per quarter acre of enclosed space. If you have a greenhouse of 30 x 48 feet or 30 x 192 feet, one bumblebee colony should be sufficient to pollinate the crops *viz*., tomato, pepper, or vine crop.

5. Drawbacks

Producing commercial bumblebee colonies is a costly and complicated task. The main challenge is to make mature colonies available throughout the year, which is difficult and expensive. Additionally, colonies do not have a shelf-life, and the demand of growers could not be unpredictable. Another issue in the commercial production of bumblebees is to ensure that colonies are of standard quality and strength that can act as good pollinating units. To overcome these challenges, queens are artificially overwintered by exposing them to carbon dioxide, which allows for the continuous production of bumblebees. Young queen bees are placed with honey bees to encourage early oviposition. One of the main issues with using bumblebees in greenhouses is that people are often scared of working around stinging insects, particularly large bees. However, this fear is usually overcome quickly after working around the gentle bumblebee species that have been intentionally bred by beekeepers.

6. Conclusion

Introducing bumblebee colonies into greenhouses fosters sustainable and beneficial pollination practices, addressing modern agricultural challenges. This

intentional introduction ensures crops receive vital attention during flowering stages, exemplifying harmony between technology and nature. Collaborating with these diligent pollinators not only boosts yields but also promotes resilience and environmental consciousness in greenhouse agriculture.

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