

## Review Article

### Utilization of bumblebee in crop pollination

#### ABSTRACT

Bumblebees play a vital role in pollination of plants due to ~~being their~~ large size, and very hairy hairiness and ~~so thus are~~ ideal for picking up and transferring pollen. ~~Bumble bees~~ They have ability to ~~can~~ vibrate ('buzz') flowers and have no communication system. ~~Bumblebees but can work better efficiently in tunnels as they have a better sense of direction. They are 400 times more efficient than honeybees at any pollination chore, and are capable of visiting 30 to 50 flowers per minute. Bumblebees~~ They are non-swarming and less aggressive than honeybees. ~~Bumblebees work better in tunnels as they have a better sense of direction. They are 400 times more efficient than honeybees at any pollination chore, capable of visiting 30 to 50 flowers per minute.~~ Bumblebee generally forages during ~~the~~ early morning (0530-0800h) and evening (1700-1900h) time. Bumblebees are better pollinators than honeybees in greenhouses and glass houses and ~~it they~~ have a great ~~potentiality-potential~~ to serve as a supplemental ~~pollinator-pollinators~~ in ~~the~~ cultivation of crops such as tomato, eggplant, cucumber, melon, strawberry, pumpkin, cherry, sweet pepper, etc. It ~~increases-improves the~~ yield and quality parameters of the fruits and number of fruit and seed, fruit diameter, fruit length, fruit weight as well as improves the quality of the fruit. In India, efforts are being made at Solan to mass rear bumble ~~bee-bees~~ and ~~utilized-utilize~~ them in pollination. ~~Some-A few~~ private companies ~~are trying~~ have attempted to ~~introduce-introduce~~ newer species of bumblebees in India. ~~In a-the present era.~~ The global population of bumblebees is ~~decline-declining~~ at ~~global level~~ due to injudicious use of pesticides, loss of natural colony and ~~mechanization in agriculture~~ and climatic changes.

**Keywords:** Bumblebees, pollinator and foraging behavior

#### INTRODUCTION

Bumblebees are social insects, belonging to order Hymenoptera, tribe Bombini and genus *Bombus* in the family Apidae. There are over 250 known species of bumblebees in the world, ~~existing~~ primarily existing in the Northern Hemisphere although they ~~also~~ occur in South America ~~also~~. They have been introduced to New Zealand and the Australian state of Tasmania. ~~There are about~~ Of the 400 species of bumblebees worldwide (Heinrich, 1979). ~~There are~~ the six species of bumblebee found commonly found are, viz., Buff-tailed bumblebee, *Bombus terrestris*; White-tailed Bumblebee, *Bombus lucorum*; Garden

Formatted: Highlight

Comment [GN1]: No mention about these two aspects ( mass rearing at Solan, introduction of bumblebees in India) can be seen

Formatted: Highlight

Comment [GN2]: There is no discussion about these aspects in the text. Kindly include.

Formatted: Highlight

Formatted: Highlight

~~Bumblebee, *Bombus hortorum*; Red-tailed Bumblebee, *Bombus lapidaries*; Early Bumblebee, *Bombus pratorum* and Common Carder Bee, *Bombus pascuorum*. In India, *Bombus haemorrhoidalis* is reported by Chauhan *et al.*, (2013)<sup>b</sup> at Solan.~~

Comment [GN3]: Please quote a reference.

~~In India, *Bombus haemorrhoidalis* is reported from Solan.~~ Bumblebees live in organized colonies in nests typically built in a small hole in the ground or under a clump of grass. The three castes of bumblebees are the queen, female workers and males. Bumblebees have an annual life cycle; Bumblebees pass through four stages (egg, larva, pupa and adult) during their life span. Bumblebee colonies infested by pests and diseases like mite, moth, conopid flies, nematode and *Nosema* spp. They are robust, hairy and black with yellow bands and make a buzzing sound while flying. However, some species have orange or red bands on their bodies or may be entirely black. A rarity, the bumblebee is a warm-blooded insect, by “shivering” her massive flight muscles; she can create heat in her thorax. Then, by contracting her muscles, she circulates the warmth into her abdomen. Bumblebees require pollen as a protein source for feeding their larvae and nectar as a sugar (carbohydrate) source - a fuel for the adults’ flight and to produce wax to build for their nest building. ~~There are about 400 species of bumblebees worldwide (Heinrich, 1979). There are six species of bumblebee found commonly viz., Buff tailed bumblebee, *Bombus terrestris*; White tailed Bumblebee, *Bombus lucorum*; Garden Bumblebee, *Bombus hortorum*; Red tailed Bumblebee, *Bombus lapidaries*; Early Bumblebee, *Bombus pratorum* and Common Carder Bee, *Bombus pascuorum*. In India, *Bombus haemorrhoidalis* is reported by Chauhan *et al.*, (2013)<sup>b</sup> at Solan.~~

Formatted: Highlight

Comment [GN4]: Please delete. The same line is repeated in the paragraph below.

Formatted: Highlight

Bumblebees live in organized colonies in nests typically built in a small holes in the ground or under a clumps of grass. The size of queen cells are is 16.56-20.57 mm in length and 12.55-15.20 mm width, the size of worker cells are is 13.16- 14.24 13.16-14.24 mm in length and 10.01-10.95 mm in width. Honey pots are 15.31-20.35 mm in length and 12.91-16.32 mm in width. The three castes of bumblebees are the queen, female workers, and males. The body length of the queen is 20-25 mm, the worker is 18-25 mm and that of the male is 14 -16 mm. Bumblebees have an annual life cycle; Bumblebees and pass through four stages (egg, larva, pupa, and adult) during their life span. The queen lays eggs in batches of 5-20 on the ball of pollen in the pots, seals this it with wax, and incubates the eggs to keep them warm. Eggs hatched in 2.6 days (mean) after laying and the larval period are is 17.2 days while the average pupal stage period remained for was 8.6 days. The average total period from egg to adult

is 28.4 days. Bumblebee colonies are infested by pests and diseases like mites, moths, conopid flies, nematodes, and *Nosema* spp. Bumblebee forages on all kinds of flowers and covers about 8-12 flowers in one minute and it spends 4-8 sec/flower for the collection of pollen and nectar on a single flower (Chauhan *et al.*, 2013<sup>a</sup>).

#### Role of Bumblebee as a Pollinator:

Bumblebees play a vital role in pollination of plants due to being large, very hairy and so are ideal for picking up and transferring pollen. Bumblebees are active at temperatures near 5°C and as well as on cloudy, foggy and rainy days. It will fly in winds of up to 40 mph (70 km/hr). The bumblebees can vibrate ('buzz') flowers and have no communication system. Bumblebees are non-swarming and less aggressive than honeybees. Bumblebees work better in tunnels as they have a better sense of direction. They are 400 times more efficient than honeybees at any pollination chore, capable of visiting 30 to 50 flowers per minute. Bumblebee generally forages during early morning (0530-0800h) and evening (1700-1900h) time (Chauhan *et al.*, 2013<sup>b</sup>). Bumblebees are better pollinators than honeybees in greenhouses and poly house and are of great economic importance in greenhouse cultivation of such as tomato, brinjal, strawberry, cucumber, melon, sweet pepper, cherry and pumpkin.

#### Bumblebee in crop pollination:

Abak *et al.* (1995) observed that the bumblebee pollinated plants of eggplant and tomato recorded significantly higher fruit yield (23% in eggplant and 17% in tomato), number of fruits per m<sup>2</sup> and number of seeds per fruit. However, there was no significant differences observed in fruit quality parameters like total soluble solids content, pH of fruit juice, titratable acidity, fruit diameter and fruit length in both crops as compared to control. In case of pepper, Abak *et al.* (1997) reported that average yield, weight of fruit, diameter of fruit and the numbers of seeds increased by 4.0%, 10.0%, 6.0% and 12.5%, respectively in the bumblebee pollination as compared to control in greenhouse.

~~Dogterom *et al.* (1998) reported that the tomato~~ Tomato flowers pollinated by *B. vosnesenskii* produced larger fruit than manually pollinated flowers as evidenced by significant increases ( $P < 0.05$ ) in fruit weight, height, diameter and seed count. Overall, bumblebee treatments (bumblebees and bumblebees plus manual) resulted in significantly greater ( $P < 0.05$ ) fruit weight, seed count, fruit diameter and fruit height compared with non-bee treatments (manual and no-pollination). In contrast, fruit roundness did not differ between treatments (Dogterom *et al.*, 1998) ( $P < 0.05$ ).

In cucumber and watermelon, Stanghellini *et al.* (1998) stated that bumblebee the flowers visited by bumblebees visited flowers recorded had significantly lower abortion rates and higher seed sets in the cucumber and watermelon than those visited by honeybees visited flowers (Stanghellini *et al.*, 1998).

Bumblebee pollination in eggplant Eggplants pollinated by bumblebees yielded higher (25%) than those that had vibration treatment with bigger Fruit sizes (14% in weight and 7% in length) and

Formatted: Highlight

Formatted: Highlight

Comment [GN5]: It is copied from that paper verbatim: Please paraphrase/rewrite as " Bumblebees forage on different kinds of flowers visiting about 8-12 flowers per minute. To collect pollen and nectar from a single flower it spends 4-8 seconds"

Formatted: Highlight

Comment [GN6]: Repeat of first line in the Abstract. Kindly delete or paraphrase.

Formatted: Highlight

Formatted: Highlight

Formatted: Highlight

Formatted: Highlight

Comment [GN8]: In the previous paragraph, it is mentioned as 8-12 flowers/min and here, it is 30-50 flowers/min. The reference cited are the same author a and b. Please clarify. If both are true, combine the data as 8-50. Or if the conditions are different, please mention that.

Comment [GN9]: Repeat of abstract. Please rephrase.

Formatted: Highlight

Comment [GN10]:

Comment [GN11]: Repeat of the abstract. Kindly rephrase.

four times higher number of seeds per fruit were higher (4 times) in bumblebee pollinated fruits than vibration treatments (Abaket *et al.*, 2000).

Dasgan *et al.* (2004) reported significantly higher tomato yield (4.12 kg m<sup>-2</sup>) in bumblebee pollinated plants ( $P < 0.01$ ) with an increased yield of 89.9% and 60.9% over vibration treatment and growth regulator application respectively was observed. ( $P > 0.05$ ) and also significantly improve the quality of tomato like numbers of fruit, number of seeds per fruit, volume of fruits and number of carpels were also significantly higher (Dasgan *et al.*, 2004).

Formatted: Norwegian, Bokmål (Norway)

Serrano and Jose (2006) studied the sweet pepper flowers visited by bumblebee and noticed that similarly, the bumblebee visited flower visits by bumblebees produced larger and heavier fruits then and higher yields of non-visited flower sweet pepper and significantly produced higher yield as compared to self-pollination (Serrano and Jose, 2006) control (self-pollination).

Dimou *et al.* (2008) found that in strawberries, the pollination done by bumblebees had a significant impact on the number and weight of marketable fruits produced. The fruit yields were higher in comparison to the control group. In control group, 30% of the fruits produced were deformed due to insufficient pollination (Dimou *et al.*, 2008) the total number of the marketable fruit as well as its total weight was significantly higher in the row that was pollinated by the bumblebees compared to the control and fruit produced in the control row 30% was deformed because of ineffective pollination in strawberry.

Formatted: English (United States)

Nault *et al.* (2011) recorded that Bumblebee supplementation led to higher pumpkin yields :16.5 lbs/plant compared to 15.2 lbs/plant with honey bee supplementation and 13.1 lbs/plant in non-supplemented fields in New York (Nault *et al.* (2011) bumblebee supplemented fields produced higher yield (16.5 lbs/plant), followed by honey bee supplemented fields (15.2 lbs/plant) and then non-supplemented fields (13.1 lbs/plant) of pumpkin in New York.

Vergara and Buendia (2012) observed The tomato plants pollinated by bumblebees produced fruits with greater the number of seeds per fruit was higher in bumblebee pollinated compared to those tomato plants as compared to plants pollinated mechanically or not pollinated at all. Maturation time was significantly longer and sugar content, fresh weight and seed count were significantly higher in bumblebee pollinated flowers than in flowers those pollinated manually or with no supplemental pollination, but did not differ with flowers pollinated mechanically (Vergara and Buendia, 2012).

The positive impact of the bumblebees in bell pepper was found through the 3.77% increase in the number of fruits per plant and 24.6% higher fruit weight as well as 13.51% and 21.52% increases in fruit length and fruit breadth respectively. An increase of 23.84% in the number of healthy fruits, 113.64% more seed number and 5.44% increase in 1000 seed weight and 89.42% higher fruit yields per m<sup>2</sup> over control plots (Thakur, 2018).

### **Impact of pesticides on bumblebee population**

According to a study colonies treated with neonicotinoid (imidacloprid) suffered a significantly reduced growth rate and an 85% decline in production of new queens as compared to control colonies. It was suggested that the negative impact of these chemicals was considerable on wild bumblebee populations across the developed world (Whitehorn *et al.*, 2012).

**Comment [GN12]:** In the abstract, effect of mechanization and climate changes are mentioned. Please discuss with references.

**Comment [GN13]:** Kindly include more work and references.

### **Conclusion:**

Pollination is one of the most important ecological processes on the planet. Among pollinators, bumblebees have gained importance as an efficient pollinator due to its large size and very hairy makes them more ideal for picking up and transferring pollen of many commercial crops grown under greenhouse, glasshouse, poly houses and open field. Bumblebees are better pollinators than honeybees in greenhouses and glass house and it have a great potentiality to serve as a supplemental pollinator in cultivation of crops such as tomato, eggplant, cucumber, melon, strawberry, pumpkin, cherry, sweet pepper *etc.* Pollination by bumblebees lead to higher yield and increase the number of fruit and seed, fruit diameter, fruit length, fruit weight and also improve the quality of the fruit in crops such as ----- and thus can render farming more profitable. Pesticides including ----- have been proven to the cause of bumblebee population decline and may be avoided in zones with crops that require pollination by bumblebees.

**Comment [GN14]:** Please rephrase as the sentence gets often repeated.

**Comment [GN15]:** Please edit as the sentence is repeated .

**Comment [GN16]:** Kindly fill-in

**Formatted:** English (United States)

Whitehorn *et al.* (2012) reported that the neonicotinoid (imidacloprid) treated colonies had a significantly reduced growth rate and suffered an 85% reduction in production of new queens as compared to control colonies and they suggest that they may be having a considerable negative impact on wild bumblebee populations across the developed world.

Thakur (2018) noted that the bumblebees increase the number of fruits per plant (3.77%), fruit weight (g) (24.60%), fruit length (cm) (13.51%), fruit breadth (cm) (21.52%), healthy fruits (23.84%), seed number (113.64%), 1000 seed weight (g) (5.44%) and fruit yield per m<sup>2</sup> (kg) (89.42%) in bell pepper over control.

### **Conclusion:**

Pollination is one of the most important ecological processes on the planet. Among pollinators, bumblebees has gained importance as an efficient pollinator due to its large size and very hairy makes them more ideal for picking up and transferring pollen of many commercial crops grown under greenhouse, glasshouse, poly houses and open field. Bumblebees are better pollinators than honeybees in greenhouses and glass house and it have a great potentiality to serve as a supplemental pollinator in cultivation of crops such as tomato, eggplant, cucumber, melon, strawberry, pumpkin, cherry, sweet

pepper etc. It give higher yield and increase the number of fruit and seed, fruit diameter, fruit length, fruit weight and also improve the quality of the fruit.

#### References:

- Abak, K., Dasgan, H. Y., Ikiz, O., Uygun, N., Sayalan, M., Kaftanoglu, O. and Yeninar, H. (1997). Pollen production and quality of pepper grown in unheated greenhouses during winter and the effects of bumblebees (*Bombus terrestris*) pollination on fruit yield and quality. *Acta Horticulture*. 437: Proc. Int'l symp. on pollination. Pp. 303-308.
- Abak, K., Ozdogan, A. O., Dasgan, H. Y., Derin, K. and Kaftanoglu, O. (2000). Effectiveness of bumble bees as pollinators for eggplants grown in unheated greenhouses. *Acta Horticulture*, 514: Proc. XXV IHC- part 4. Pp. 197-203.
- Abak, K., Sari, N., Paksoy, M., Kaftanoglu, O. and Yeninar, H. (1995). Efficiency of bumble bees on the yield and quality of eggplant and tomato grown in unheated glasshouses. *Acta Hort.*, 412: I Int'l symp. on Solanacea for Fresh Market. Pp. 268-274.
- Chauhan, A., Katna, S. and Rana, B. S. (2013<sup>a</sup>). Ethological studies on bumble bees under subtropical conditions in India. *Journal of Medical Science And Clinical Research*, 1 (3) : 125-129.
- Chauhan, A., Katna, S., Rana, B. S. and Sharma, H. K. (2013<sup>b</sup>). Studies on pests and diseases of bumble bee (*Bombus haemorrhoidalis* Smith) in India. *Journal of Medical Science And Clinical Research*, 1 (2) : 93-98.
- Dasgan, H. Y., Ozdogan, A. O., Kaftanoglu, O. and Abak, K. (2004). Effectiveness of bumblebee pollination in anti-frost heated tomato greenhouses in the Mediterranean basin. *Turkish Journal of Agriculture and Forestry*, 28 : 73-82.
- Dimou, M., Taraza, S., Thrasyvoulou, A. and Vasilakakis, M. (2008). Effect of bumble bee pollination on greenhouse strawberry production. *Journal of Apicultural Research. Bee World*. 47 (2) : 99-101.
- Dogterom, M. H., Matteoni, J. A. and Plowright, R. C. (1998). Pollination of greenhouse tomatoes by the North American *Bombus vosnesenskii* (Hymenoptera: Apidae), *Journal of Economic Entomology*, 91 (1) : 71-75.
- Heinrich, B. (1979). Majoring and minoring by foraging bumblebees *Bombus Vagans*. *Ecology*. P 245-255
- Nault, B. A., Artz, D. R. and Petersen, J. D. (2011). Proc. of the New England vegetable and fruit conf., Pp.45-47.
- Serrano, A. R. and Jose, G. M. (2006). Quality Fruit Improvement in Sweet Pepper Culture by Bumblebee Pollination. *Scientia Horticulturae*, 110 : 160-166.

Stanghellini, M. S., Ambrose, J. T. and Schultheis, J. R. (1998). Using commercial bumble bee colonies as backup pollinators for honey bees to produce cucumbers and watermelons. *HortTechnology*, **8** (4) : 590-594.

Thakur, S. Studies on bumblebees (*Bombus haemorrhoidalis* Smith) pollination in *Capsicum annuum* L. under protected cultivation. M.Sc. Thesis, Department of Entomology, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India, 2018.

Vergara, C. H. and Buendia, P. F. (2012). Pollination of greenhouse tomatoes by the Mexican bumblebee *Bombus ephippiatus* (Hymenoptera: Apidae). *Journal of Pollination Ecology*, **7** (4) : 27-30.

Whitehorn, P. R., Stephanie, C., Wackers, F. L. and Dave, G. (2012). Neonicotinoid pesticide reduces bumble bee colony growth and queen production, *Science express*. 29 March : 351-352.

UNDER PEER REVIEW