

## FORAGING BEHAVIOUR OF HONEYBEES IN SEED PRODUCTION OF *BRASSICA OLERACEA* VAR. *ITALICA* PLENCK.

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### Abstract

Work on ascertaining the diversity and foraging behaviour of pollinators and their impact on seed yield in broccoli was carried out. The blooming crop of the broccoli was visited by 17 species of insects belonging to 6 orders and 11 families of class insects. Hymenopterans were the most dominant visitors constituting 98.18 per cent of the insect visitors, followed by others (1.82%). Among the hymenopteran species, *Apis dorsata* F. was highest in number (47.88%) among the visitors of broccoli flower, followed by *Apis mellifera* L. (30.65%), *Apis cerana* F. (16.31%), *Apis florea* F. (3.32%) and others (1.82%). The mean foraging rate irrespective of different dates and times was the highest for *A. dorsata* ( $5.35 \pm 0.33$  flowers/min) followed by that of *A. mellifera* ( $4.87 \pm 0.34$  flowers/min), *A. cerana* ( $1.75 \pm 0.23$  flowers/min) and *A. florea* ( $0.11 \pm 0.09$  flowers/min). The number of flower visit per minute at different time interval was highest in case of *A. dorsata*, followed by *A. mellifera*, *A. cerana* and *A. florea*. The studies on diurnal foraging speed (time spent by bees in seconds) by honeybees at different times and dates indicated that *A. dorsata* had the highest foraging speed across different dates and times followed by *A. mellifera*, *A. cerana* and *A. florea*. Mean time spent irrespective of different dates and times was the highest for *A. dorsata* ( $5.20 \pm 0.520$  sec) followed by that of *A. mellifera* ( $3.87 \pm 0.22$  sec), *A. cerana* ( $1.72 \pm 0.23$  sec) and *A. florea* ( $1.05 \pm 0.58$  sec). The foraging speed was the highest in case of *A. dorsata* followed by *A. mellifera*, *A. cerana* and *A. florea* on broccoli blooms. Results on the quantitative parameters of yield such as numbers of siliqua per plant, number of seeds per siliqua, seed weight and seed yield showed significant differences under different mode of pollination in the broccoli seed crop.

### Introduction

Brassica vegetable, broccoli is grown in the Jammu region during cropping season and also in off seasons under protected/polyhouse conditions. Low seed yield due to inadequate pollination is often faced as a major problem of *Brassica* seed production. Inadequate pollination is caused by several factors and the most important of which includes the lack of adequate number and diversity of pollinators. Thus, there is a need to ensure pollination by conserving the pollinators and attracting them towards the crop land. This can be achieved only through planned honeybee pollination, owing to the fact that honeybees are the only pollinators which we can managed. Pollination by insects is inevitable for *Brassica*, since they are generally incompatible (Sihag 2001) and the pollen is heavier and sticky, which is unable to be easily wind borne. Even though, the bees are reported as marvelously coevolved pollen transferring devices for *Brassicaceae*, the pollination potential and economic importance of the effect of honeybees on these vegetables is still need to be established (Neupane *et al.* 2006). Therefore, keeping in view the economic importance of the crop, the present study was conducted to study the pollinator diversity and their foraging behaviour and to evaluate the role of insect pollinators on seed crop production.

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### Materials and Methods

The experimental trial was laid at University Farm SKUAST-Jammu, Main Campus Chatha, Jammu, during Rabi 2014-2015. Observations of flower-visiting insects were conducted from the start of flowering until approximate 95% of the flower faded. The relative abundance of pollinators (number of flowers visited by pollinators) were studied randomly on selected five plants during different times of the day (09.00 - 1100, 1200 - 1400, 1500 - 1600 hrs) at weekly interval during the blooming period were counted. The observations on foraging behaviour viz. initiation and cessation time of pollinators activity on bloom, number of flowers (No. of pollinators/m<sup>2</sup>/min ) visited by insect pollinators at different hours of the day, foraging rate of honeybees (Mean number of flowers visited/min) and foraging speed (Time spent by different insect pollinators in seconds) were recorded.

To evaluate the role of honeybees for enhancing the seed production *A. mellifera* (6 frame strength) were used. The treatments comprised of caged plant (without *A. mellifera*), caged plants (with one colony of *A. mellifera*) and completely open pollinated plants. The experiment was laid out in a RBD and each treatment was replicated three times. The data on effect of mode of pollination on quantitative yield parameters viz. number of siliqua per plant, siliqua length, seeds per siliqua, 1000-seed weight (g) and seed yield (q/ha) were also recorded.

### Results and Discussion

The blooming crop of the broccoli was visited by 17 species of insects belonging to 6 orders and 11 families of class insecta. Hymenopterans were the most dominant visitors constituting 98.18 per cent of the insect visitors, followed by others (1.82%). Of all these insects, honeybees *Apis dorsata*, *A. mellifera*, *A. cerana* and *A. florea* were the dominant flower visitors and comprised more than 98.18 per cent of the total flower visiting insects (Fig. 1). Considering the abundance of Hymenopteran species, *A. dorsata* was highest in number (47.88%) among the visitors of broccoli flower, followed by *A. mellifera* (30.65%), *A. cerana* (16.31%), *A. florea* (3.32%) and others (1.82%). The other important insects frequenting broccoli flowers were *Eristalis* spp., *Metasyrphus corollae*, *Episyrphus balteatus* and *Musca domestica*; the latter group of insects mostly collected nectar and frequented at interrupted hours and were not considered as dependable pollinators. The rest species of the orders Diptera, Coleoptera, Neuroptera, Lepidoptera and Hemiptera were found as casual visitors of the broccoli flowers. The results are in conformity with the earlier studies made by various workers (Verma and Poghat 1994, Tara and Sharma, 2010, Sharma and Kumar 2014) who reported Apoidea as the most prominent flower visitors of *Brassica* species.

The composition of different insects belonging to different orders presented in Fig. 2 revealed that activity of honeybees varied with the variation in the abiotic factors. The *A. mellifera* started foraging on the broccoli blooms in the 45th standard week of 2014 The maximum population of *A. mellifera* ( $4.33 \pm 0.88$ ) while the lowest foragers population ( $1.27 \pm 0.66$ ) was recorded on March 12, 2015 and February 25, 2015, respectively. Sushil *et al.* (2013) reported that average number of foraging *A. mellifera*/plant was highest in open pollinated condition than pollinator exclusion condition. The maximum ( $2.00 \pm 0.41$ ) *A. cerana* population was recorded on February 19, 2015 while lowest ( $0.60 \pm 0.11$ ) was recorded on February 25, 2015. The maximum ( $5.67 \pm 0.06$ ) and minimum ( $2.13 \pm 0.24$ ) population of *A. dorsata* was recorded on March 15, 2015 and February 25, 2015, respectively. The maximum population of *A. florea* ( $0.73 \pm 0.17$ ) was recorded February 22, 2015. The *A. mellifera*, *A. dorsata* and *A. cerana* started their activities in considerable number from 10.00 a.m. while and *A. florea* and syrphids started at 10:00 hrs in few numbers. The activity of *A. mellifera* went on increasing from 10.00 - 11.00 a.m. (2.90) to 01.00 - 02.00 p.m. (2.94) and gradually declined thereafter to 04.00 - 05.00 p.m. (2.24). The activity of

*A. cerana* was highest in the morning hours at 10.00 - 11.00 a.m. (1.72) and gradually declined to 1.26 at 01.00 - 02.00 p.m. and increased again in the evening hours 04.00 - 05.00 (1.32). Similarly, *A. dorsata* activity was 4.46, 4.38, 3.78 numbers at 10.00 - 11.00 a.m. 01.00 - 02.00 p.m. and 04.00 - 05.00 p.m., respectively. Similar, trend was observed in *A. florea* activity with 0.34, 0.40, 0.14 numbers at 10.00 - 11.00 a.m., 01.00 - 02.00 p.m. and 04.00 - 05.00 p.m., respectively. The studies are in line with by Maity *et al.* (2014) Reddy *et al.* (2015) who reported that climatic factors play a significant role in influencing the foraging activity and behavior of social insects especially honeybees.

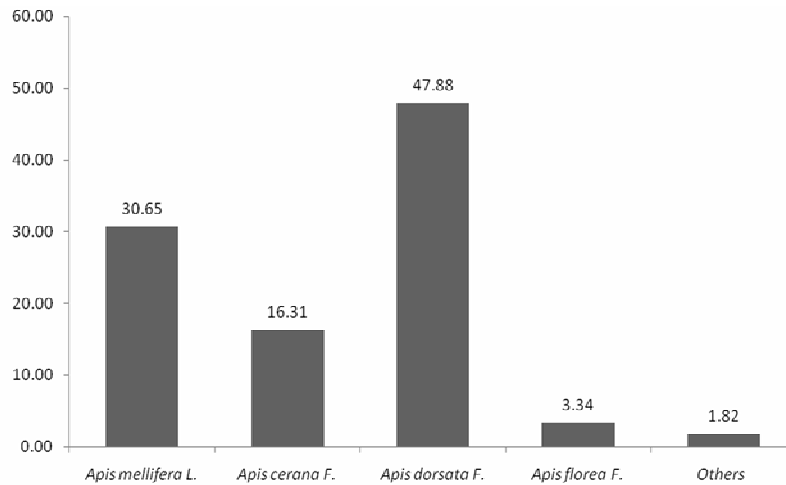


Fig. 1. Relative proportion of pollinators on blooming broccoli.

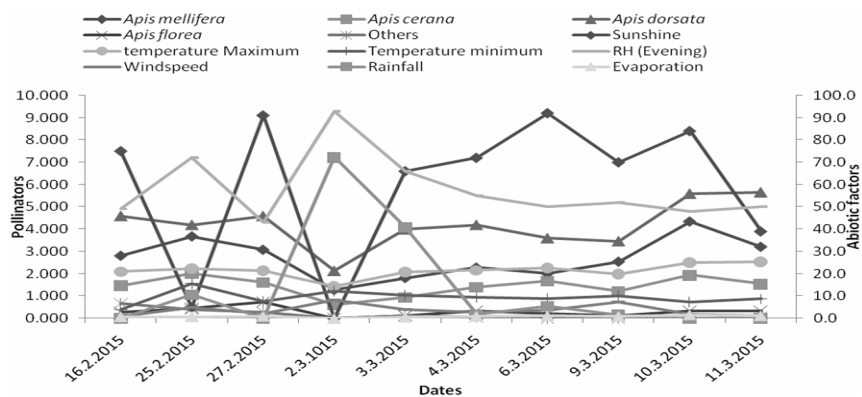


Fig. 2. Relative proportion of pollinators on blooming broccoli in relation to abiotic factors.

The mean foraging rate (Fig. 3) irrespective of different dates and times was the highest for *A. dorsata* ( $5.35 \pm 0.33$  flowers/min) followed by *A. mellifera* ( $4.87 \pm 0.34$  flowers/min), *A. cerana* ( $1.75 \pm 0.23$  flowers/min) and *A. florea* ( $0.11 \pm 0.09$  flowers/min). Kakar (1981) observed the commencement of foraging activity of honeybees on cauliflower at 0800 hr and was highest

between 1200 and 1400 hr of the day. *A. dorsata* foraged most rapidly visiting on an average 9.95 flowers/minute, followed by 8.05 and 7.60 by *A. mellifera* and *A. cerana indica*, respectively. The lowest foraging ( $3.53 \pm 0.48$  flowers/min) of *A. mellifera* was observed on March 06, 2015. The number of flower visit was the highest ( $5.82 \pm 0.74$  flowers/min) at 01.00 - 02.00 p.m. and the lowest ( $4.08 \pm 0.48$  flowers/min) at evening hours 04.00 - 05.00 p.m. The foraging rate of *A. dorsata*, was maximum ( $7.93 \pm 1.37$  flowers/min) on February 22, 2015 in the peak flowering season, while the lowest foraging ( $3.00 \pm 0.61$  flowers/min) was observed on March 12, 2015. The number of flower visit was the highest at 01.00 - 02.00 p.m. ( $5.90 \pm 0.52$  flowers/min) and the lowest ( $4.94 \pm 0.53$  flowers/min) at 04.00 - 05.00 p.m. The foraging rate of *A. cerana* was maximum on February 22, 2015 ( $2.47 \pm 1.30$  flowers/min) while minimum ( $0.93 \pm 0.52$  flowers/min) was observed on February 16, 2015. The number of flower visit was the highest ( $2.74 \pm 0.23$  flowers/min) at 10.00 -11.00 am and the lowest ( $0.88 \pm 0.39$  flowers/min) at evening hours 04.00 -05.00 p.m. The studies are in consonance with Rana *et al.* (1993) and Chand *et al.* (1994) who also reported that the foraging activity of *A. cerna* increased at 1000 hr and reached peak at 1100 hrs on mustard bloom. Similarly, the activity of *A. dorsata* was increased from 1400 hr and reached the peak at 1600 hrs. The number of visits per minute by *A. cerana* was positively

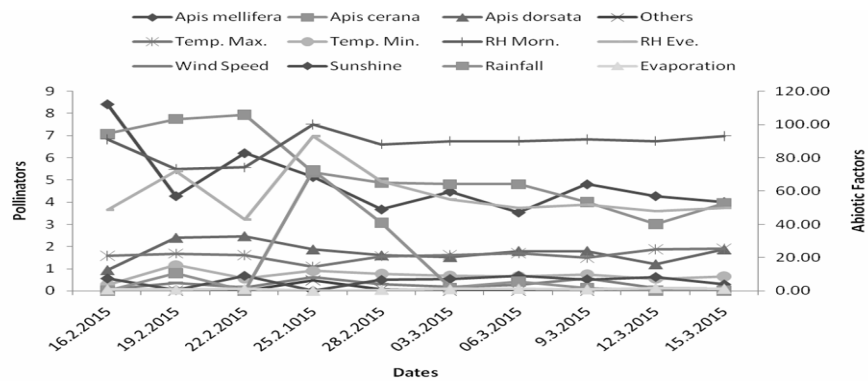


Fig. 3. Foraging behaviour (number of flowers visited/min ) by pollinators on Broccoli

correlated with maximum relative humidity and minimum temperature. Verma and Partap (1994) also reported that the duration of individual foraging trips of *A. cerana* was 26.9 min for cauliflower and 23.9 min for cabbage; visits to individual flowers lasted from 4.3 to 6.7 sec during the day in both crops; bees visited 5 - 8 flowers/min. The foraging activity declined considerably after 05.00 p.m. The decreased activity during late afternoon hours, coinciding with higher day temperatures, could be attributed to two factors. The first being the requirement of more number of bees to maintain the colony temperature, thus the number available for foraging is less. Secondly, the anthesis of a large number of flowers takes place in early morning and hence, pollen availability was sumptuous as compared to hot hours. In addition, nectar solidified with increased temperature, requiring more time and energy to harvest, prompting bees to make maximum use in morning hours. The preferential foraging in morning hours may be an evolutionary adaptation to maximize their resource collection efficiency. It may be concluded that the diurnal foraging pattern of insect visitors on broccoli flower follow the increasing trend from 1000 to 1300 hrs and declined thereafter. This may be due to the fact that the temperature during this period i.e. 1000 to 1300 hrs was more favourable for the activities of the insects as well as for the anthesis of the

crops. Moreover bees communicate by their dance language with their hive mate that depends upon position of the Sun (Free 1993) it may have significant effect on the bee foraging.

The time spent on each head varied among three major insect visitor/pollinator species (Fig. 4). Mean time spent (in sec) irrespective of different dates and times was the highest for *A. dorsata* ( $5.20 \pm 0.520$  sec) followed by that of *A. mellifera* ( $3.87 \pm 0.22$  sec), *A. cerana* ( $1.72 \pm 0.23$  sec) and *A. florea* ( $1.05 \pm 0.58$  sec). The mean time spent per flower by *A. mellifera* varied from ( $2.80 + 0.064$  sec) on March 03, 2015 to maximum of ( $4.90 \pm 0.85$  sec) on February 16, 2015. In case of *A. dorsata*, the mean time spent per flower varied from ( $3.93 \pm 0.60$  sec) on March 15, 2015 to maximum of ( $6.53 \pm 1.23$  sec) on February 16, 2015 and vary significantly over different dates

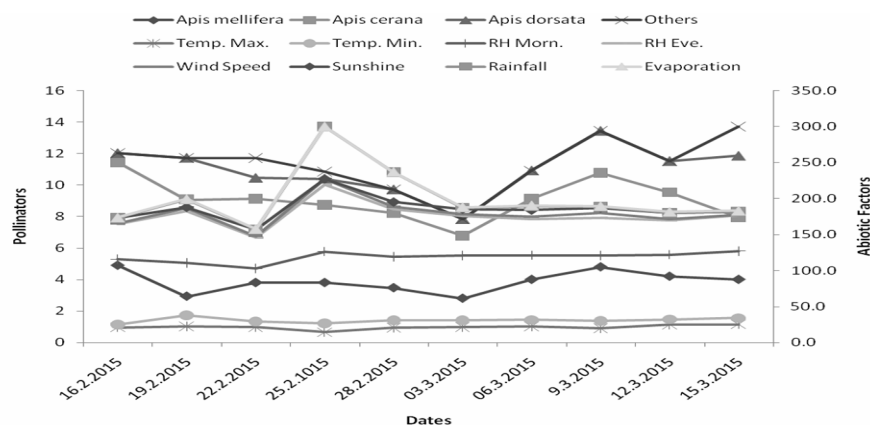


Fig. 4. Time spent (sec) by pollinators on broccoli.

and time. The mean time spent per flower by *A. cerana* varied from ( $0.60 \pm 0.35$  sec) on February 16, 2015 to maximum of ( $3.93 \pm 0.33$  seconds) on March 15, 2015. The mean time spent per flower by *A. florea* varied from ( $0.47 \pm 0.29$  sec) to maximum of ( $1.87 \pm 0.94$  sec). The foraging speed of *A. mellifera* was the highest ( $4.28 \pm 0.25$  sec) at 01.00 - 02.00 p.m. and the lowest ( $3.24 \pm 0.37$  sec) at evening hours 04.00 - 05.00 p.m. In case of *A. dorsata*, the foraging speed was the highest at 01.00 - 02.00 p.m. ( $5.58 \pm 0.25$  sec) and the lowest ( $4.84 \pm 0.50$  seconds) at evening hours 04.00 - 05.00 p.m. The foraging speed of *A. cerana* was the highest ( $2.46 \pm 0.44$  sec) at 10.00 - 11.00 a.m. and the lowest ( $0.96 \pm 0.44$  sec) at evening hours 04.00 - 05.00 p.m. In case of *A. florea*, the foraging was the highest at 01.00 - 02.00 p.m. ( $0.22 \pm 0.15$  flowers/min). The average time spent by *Apis* species are in line with those of Pandey and Tripathi (2003). Joshi and Joshi (2010) reported that at 9.00 hrs *A. cerana* spent  $5.11 \pm 0.9$  sec per apple flower and visited  $10.71 \pm 0.7$  flowers per min. *A. mellifera* spent  $7.43 \pm 0.8$  sec per flower and visited  $8.44 \pm 0.2$  flowers. *A. cerana* visited higher number of flowers than that of *A. mellifera*. Sushil *et al.* (2013) reported that the average time spent by *A. mellifera* per flower was 6.45 sec in broccoli. Maity *et al.* (2014) also reported that time spent by *A. mellifera* per inflorescence ranged from 10.10 - 12.25 sec.

The data presented in Table 1 showed that number of siliqua per plant in broccoli in open pollination ( $474.00 \pm 25.07$  siliqua/plant) and *A. mellifera* ( $355.00 \pm 19.33$  siliqua/plant), were comparatively higher than those formed under caged condition ( $328.00 \pm 43.35$  siliqua/plant) and ( $128.99$  siliqua/plant), respectively. This confirms the findings of number of workers that *Brassica* spp. crops being cross pollinated are greatly benefited by the insect pollination (Singh and Singh

2004, Sushil *et al.* 2013). The silique length was comparatively higher in the plants having open access to insect pollinators ( $5.68 \pm 0.16$  cm) followed by *A. mellifera* pollinated ( $5.32 \pm 0.36$  cm) and under caged conditions ( $5.12 \pm 0.34$ ). Similar results were obtained by investigators (Devtoka 2001, Pudasaini *et al.* 2014). The maximum numbers of seeds per silique ( $14.40 \pm 0.92$ ) was recorded in open pollinated plants followed by *A. mellifera* pollination ( $12.80 \pm 0.58$ ). Caged plants produced  $10.40 \pm 1.53$  seeds/silique. Devtoka (2001) also indicated that both *A. cerana* and *A. mellifera* significantly increased the per cent pollination (silique set). Sushil *et al.* (2013) also reported that broccoli plants under planned honeybee pollination have produced 52.80 pods per

**Table 1. Effect of mode of pollination on quantitative yield parameters of broccoli.**

	Bee pollination	Caged pollination	Open pollination
Silique length (cm)	$5.32 \pm 0.36$	$5.12 \pm 0.34$	$5.68 \pm 0.16$
Silique /plant	$355 \pm 19.33$	$328 \pm 43.35$	$474 \pm 25.07$
Seed/silique	$12.80 \pm 0.58$	$10.40 \pm 1.53$	$14.40 \pm 0.92$
1000 grain weight (g)	$2.56 \pm 0.13$	$2.53 \pm 0.09$	$2.97 \pm 0.15$
yield/ha (kg)	323.12	234.46	563.57
Per cent increase in yield	37.81	-	140.37

panicle as against 46.20 pods in natural pollinated crop, with an increase in pod setting to a tune of 12.50%. The least 1000-seed weight ( $2.53 \pm 0.09$  g) was observed in pollinators excluded plants. The 1000-seed weight in open pollinated plants was ( $2.97 \pm 0.15$  g) followed by *A. mellifera* plants ( $2.56 \pm 0.13$  g) and  $2.53 \pm 0.09$  g (pollinators excluded plants). Significantly highest seed yield was recorded in the treatment *viz.*, open pollinated plots (563.57 kg/ha) followed by *A. mellifera* (323.12 kg/ha) plots and caged pollination (234.46 kg/ha). The per cent increase in seed yield was increased to a tune of 140.37 and 37.81%, respectively in open pollinated and honeybee introduced crop over pollinator excluded crop of broccoli. Similar results have been reported by Pandey and Tripathi (2003), where the increase ranged between 1.84 and 4.04 times higher over selfing.

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