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Review Article

ROLE OF *APIS MELLIFERA* IN MUSTARD SEED PRODUCTION

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Abstract: Indian mustard (*Brassica juncea* L.) is mainly self-pollinated crop, although 20-30% of cross pollination also occurred. Major pollinator for mustard seemed to be bees due to heavy and sticky nature of its pollen. Being a pollination service provider, bees contribute efficiently in enhancing mustard productivity through efficient pollination in an inconspicuous and silent manner. Among different honeybees, *Apis mellifera* plays an important role in enhancing mustard productivity quantitatively and qualitatively. As its foraging activity positively correlated with temperature and bright sunshine and observed maximum at peak flowering period indicated *Apis mellifera* as best performer of pollination. This phenomenon enhances the yield of mustard in terms of no. of pods per plant, pod length, no. of seeds per pod, 1000 seed weight, seed yield per plot, pod setting (%), seed germination (%), seed vigour index, and oil content (%). This study showed that mustard seed yield significantly higher in crop caged with *A. mellifera* as compared to pollination in absence of pollinators.

Keywords: *Mustard, Apis mellifera, Pollination, Floral biology, Foraging behaviour, Qualitative parameters, Quantitative parameters*

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Introduction

Indian mustard (*Brassica juncea* L.) belongs to the plant family Brassicaceae. It is the most extensively grown oilseed crop in India. India is third largest rapeseed/mustard seed producer (7.92 MT), yet its productivity is quite low (1319.5 kg/ha), compared to world's productivity (2172.2 kg/ha). Out of six cultivated oilseed species of genus Brassica more than 80% of total area occupied by Indian mustard (*Brassica juncea*) alone. So, there is an urgent need to increase mustard productivity in India. But increase in mustard production is possible either by increasing mustard crop area or by increasing crop yield. So, increase in mustard crop area will cost decrease in other crop area as well and development of varieties that have significantly high yield will take several years to release [1-6]. *B. juncea* is naturally autogamous species, yet in the crop frequent out- crossing occurs which varies from 5 to 30 per cent depending upon the environmental conditions and random variation of pollinating insects [7]. The mustard crop has 10-20% dependency on bees for pollination, which leads to the creation of new seed sets. Pollination is an ecological service, a role an organism plays in its ecosystem for sustaining the human life. It is a process of transferring the pollen from male anther of one flower to female stigma of same or another flower. Due to lack of proper pollination, failure of seed setting occurs that is one of the major factors for low production of mustard crops. Pollination not only enhance the yield of the crop, but it also contributes to uniform and early pod setting [8].

Floral Biology

Floral Biology refers to the understanding the structure, sexual system and morphological adaptations of the flowers in relation to the pollination ecology. Studies in floral biology can have application, since pollination and seed set are the key factors that affect the yield of the crops. Flowers of mustard are perfect, have four sepals and four petals arranged in cross formation pattern. It consists of tetradynamous stamen in which four long stamens arranged in inner whorl and two short stamens in outer whorl.

After initiation of flower bud, it passes through several morphological changes, which takes 10-15 days in reaching the anthesis stage. A single flower remains open for approximately 3-7 days. Devi *et al.* (2017) [9] recorded rate of anthesis from 08.00 to 18.00 hrs at an interval of 2 hours and observed that maximum percentage of anthesis took place between 10.00 to 12.00 hrs thereafter it decreased. They also studied the receptivity of stigma by visual observation in mustard that was 9 to 45.87 % three days prior to anthesis. The receptivity on the day of anthesis was 100 %. This is because of the higher activity of peroxidase enzyme on the stigmatic surface that facilitates communication between pollen and pistil by loosening the cell wall contents of stigmatic surface and allowing the entry of pollen tubes to fertilize the ovule.

Pollinators

A pollinator is anything that helps to carry pollen from the male part of the flower (stamen) to the female part of the same or another flower (stigma). Abiotic and Biotic pollinators contribute 20% and 80% of the pollination occur worldwide respectively.

Insect Pollinators

Insect pollinators plays an important role in today's agriculture. It includes Bees, Wasps, Moths, Butterflies, Beetles, Weevils, Flies, Midges, *etc.* Out of all these insect pollinators, bees performed 80% pollinations and considered as best pollinators because of their hairiness, thoroughness, steadfastness, floral constancy and manageable populations. Bees include bumble bees, solitary bees, stingless bees and honey bees. Further, honeybees include *Apis mellifera, Apis cerana indica, Apis florea, Apis dorsata*. India is very much destined to have all the kinds of honeybees. Of the 100 crops that provide 90% of the world's food, 71% are bee pollinated, and honey bees (*A. mellifera*) are the managed pollinator conscripted to provide the necessary pollination services for most of the crops [10].

Pollinators are attracted towards mustard flowers

The structure of Brassica flowers is well adapted to generalist insect pollinators; it has colourful petals, large amounts of pollen, scent production and nectar production during the whole flowering period, which attracts insects to feed [11]. Bowl shaped flower of mustard provides suitable place for landing of insect pollinators. Nectar concentration in nectar is high enough to attract insect pollinators, reaching a maximum of 52%. Das & Jha (2018) [12] observed insect pollinators on flowers by using hand net, sweeping was done from 7 hrs in the morning to 5 hrs in the evening at an interval of 2 hrs once in a week starting from 10% of the flowering throughout the blooming period. They reported that total 13 insect visitor belonging to order Hymenoptera, Diptera & Lepidoptera observed on mustard blossom. Out of these 3 orders, Hymenopteran were the dominant floral visitors which consists of six species from two families Apidae and Halictidae. The former family was the most abundant comprising five species namely *A. dorsata, A. mellifera, A. cerana indica, A. florea* and *Ceratina* sp. than the later one which containing only single species namely *Halictus* sp.

Goswami & Khan (2014) reported the relative abundance of different insect visitors on flowers of mustard during different hours of the day. They observed that the abundance (percentage of insect/m^2/2min.) of Hymenopterans were maximum (79.97 %) followed by the Dipterans (16.15 %) and others (3.73 %). They also stated that Italian honey bee (*Apis mellifera*) was maximum (31.56 %) followed by *Apis dorsata* (10.56 %), *Apis cerana* indica (10.52 %), *Apis florea* (5.16 %), the stingless bee (7.16 %), *Halictus* sp. (6.09 %), *Anthophora* sp. (5.05 %), Alkali bee (1.66 %), *Campsomeriella collaris* (1.35 %), and *Xylocopa iridipennis* (1.10 %). Das & Jha (2018) observed that, *A. mellifera* was the most predominant species with an average population of 0.83 bees/m^2 representing 35.18 % of total insect visitors during the entire blooming period. It was further observed that, the pollinator population increased with flowering and after reaching a peak period gradually declined.

Characteristics of *Apis mellifera*

Apis mellifera commonly known as European and Italian bee, as it was originated from Italy. It was introduced in India during 1962-64. Now, it is well established in India and slowly replacing Indian bee colonies in domestication of bee colonies. One of the major characteristics is its domestic nature, by which it can be easily reared and safely migrated from one place to other place for pollination and honey production [13]. Swarming tendency is less in *A. mellifera* and Absconding tendency is not observed as well. They are good honey gatherer, as it produces 20-40kg of honey/colony/year. They have a prolific queen, which means they have high fecundity even under adverse weather conditions, and that's why they are rapidly recovered after dearth period [14].

Interaction Between Bees and Brassica

As we know, bees body covered with feathery hairs and have another anatomical modification that helps to carry pollen from one flower to another. As bees dip her head into flower for sipping the nectar, which is seated deep inside the flower, its body rubs against the anther holding pollen. When she flies to another flower, the pollen from her body drops down into stigma and thereby affecting pollination.

Anatomical modifications of bee

As worker bees hover momentarily over flowers by using her highly adapted legs that we called as foragial legs. The pollen brush present on foreleg used for collecting pollen from anterior parts of body. The pollen brush present on middle leg collect pollen from middle parts of the body which is raked off by pollen comb on to the pollen press of hindlegs. Pollen press is a deep notch located at joint just below the pollen basket. By flexing the leg, bees pack her pollen into pollen basket, which enables the bee to carry pollen from field to hive.

Foraging Behaviour

It refers to field visit of honeybees for the collection of pollen, nectar, propolis and water. This behaviour is closely linked to honeybee colony and ambient environment. This behaviour is actually performed by worker honeybees from the age of 21 days onwards. The parameters to evaluate pollination efficiency which are favoured for mustard crop productivity are Foraging intensity (no. of bees/m^2/min), Foraging rate (no. of flower visited/min), Foraging speed (time spent/flower).

Foraging intensity (no. of bees/m^2/min)

Kunjwal *et al*. (2014) [15] studied the foraging intensity of *A. mellifera* in different varieties/lines of *B. juncea* under caged pollination. They observed that the average abundance of *A. mellifera* was maximum (5.04 bees/m^2/2min) at 2.00 pm and minimum (2.19 bees/m^2/2min) at 10.00 am. This was due to the fact that *A. mellifera* are positively correlated with temperature and sunshine hours. Kumari (2014) [16] reported the foraging intensity of *A. mellifera* at mustard bloom stage ranged from 0.7 to 4.3 bees/m^2 during different weeks of flowering period. They observed that foraging intensity was maximum on 4th week of flowering while minimum on 1st week of flowering.

Foraging rate (no. of flower visited/min)

Kunjwal *et al*. (2014) studied the foraging rate of *A. mellifera* in different varieties/lines of *B. juncea* under caged pollination. They observed that the highest no. of flower visited per min by *A. mellifera* was 8.54 at 12.00 pm while it was minimum 2.79 flowers/min at 10.00 am. Kumari (2014) reported the foraging rate of *A. mellifera* at mustard bloom stage ranged from 8.4 to 13.7 bees/m^2 during different weeks of flowering period. They observed that foraging rate was maximum on 4th week of flowering (8.9) while minimum on 1st week of flowering (4.5).

Foraging speed (time spent/flower)

Kunjwal *et al*. (2014) studied the foraging speed of *A. mellifera* in different varieties/lines of *B. juncea* under caged pollination. They observed that average time of foraging speed 2.31 s was recorded highest at 12.00 pm and lowest 1.22s at 10.00 am. Kumari (2014) reported the pollen gatherers of *A. mellifera* at mustard bloom stage ranged from 10 to 40 during different weeks of flowering period. They observed that pollen gatherers (%) was maximum on 1st week of flowering (25.8%) while minimum on 4th week of flowering (24.2%).

Factors Affecting Efficiency of Bee Colony

A. Number of colonies

Chaand *et al*., (2017) [17] recommended to place three colonies/ha in single walled Langstroth hives in mustard field in order to build up the colony strength *viz*., brood, and pollen reserves.

Abrol (2007) suggested to place three to five colonies of *A. mellifera* per hectare of crop during flowering period.

B. Strength of colony

Abrol (2007) reported that larger and stronger colonies are five times better than the smaller and weaker ones. Saini *et al*., 2018 [18] observed that out of 5, 10 and 15 frame strength/ colony, stronger colony (15 frames) were superior in brood rearing and pollen reserves. Chaand *et al*., (2017) reported the influence of colony strength on foraging activity of *A. mellifera* at different time intervals. They observed that as the colony strength increases, the no. of outgoing bees and no. of incoming bees with pollen also increases. So here, out of 6, 8 and 10 frame strength colony, no. of outgoing bees and incoming bees was observed maximum in 10 bee frame strength colony.

C. Time and placement of colonies

Abrol, (2007) suggested to introduce colonies when 5–10% of the mustard crop is in bloom and placing the hive entrance towards East is the best way to get the most work done by the bees. As they see the sun early, they will start the work earlier. Nagpal *et al*., (2019) [19] found that colony placed at 10 % flowering of mustard crop were found more efficient in pollination.

Treatments for assessment of seed yield

For pollination studies and what are the impact on yield due to bees or any other pollinators, different treatments are generally utilized for comparison.

On this basis, we can decide what actually the role of bee pollination on yield parameters or seed production. So here, three different treatments were taken to understand the impact of bee pollination on yield parameters *viz*., Open pollination: In Open pollination, flowers were left open, which are free access to all pollinators. Bee pollination: In Bee pollination, plots are caged with muslin cloth with only bee colony. Pollinator's exclusion: In this case, plants are caged with muslin cloth, and excluded all pollinators. Hossain *et al*., (2020) [20] reported the flowering period (days) of mustard at different treatments and observed higher flowering period when mustard field were netted without any bee pollinators *i.e*., 56 days and lowest flowering period observed when netted with bees *i.e*., 45 days. This is because of the pollination pressure which causes well fertilization of flowers, and after fertilization flower petals shed early that reduces the flowering period in bee pollinated treatments.

Parameters of Seed Yield

Quantitative parameters include No. of pods per plant, Pod length, No. of seeds per pod, 1000 seed weight, Seed yield per plot. Qualitative parameters include Pod setting (%), Seed germination (%), Seed vigour index, Oil content (%).

Quantitative parameters

Sekhon *et al*., (2020) [21] reported the impact of *A. mellifera* on quantitative parameters of mustard. They observed that in case of planned pollination with *A. mellifera*, no. of pods per plant, no. of seeds per pod, pod length (cm), and 1000 seed weight were getting maximum followed by open pollination and pollination without any pollinators. Hossain *et al*., (2020) observed that no. of pods per plant, no. of seeds per pod, mean seed yield per plant and mean seed yield per plot was maximum when mustard field netted with bees (*A. mellifera*) and lowest in case of pollination without any pollinators. Patidar *et al*. (2017) [22] reported the role of *A. mellifera* in enhancing the yield attributing characters of mustard that no. of siliqua per plant, no. of seed/siliqua showed maximum 186.44 and 13.82 respectively in plots having free access to all the pollinators (OP) followed by 154.82 and 12.75 in BP and lowest was recorded in PE.

Nagpal *et al*., (2017) [23] reported the influence of *A. mellifera* on seed yield of *B. juncea* that the maximum number of pods/plant, pod length, number of seeds/pod, thousand seed weight, and seed yield/ plot, (508.72 pods/plant, 5.69 cm, 15.66 seeds/pod, 6.87 g, 17.63 q/ha, respectively) were in open pollination followed by that in bee pollination (404.56 pods/plant, 4.92 cm, 14.26 seeds/pod, 6.39 g, 15.57 q/ha, respectively) and pollinators' exclusion (287.56 pods/plant, 3.89 cm, 12.24 seeds/pod, 5.30 g, 13.01 q/ha, respectively) Kumari (2014) reported the influence of number of *A. mellifera* visits on seed yield parameters of mustard. They noticed that no. of seeds per pod, weight per seed (mg), Seed weight per pod (mg) all these parameters were maximum in those blooms in which *A. mellifera* visited 8 times, and lowest was found in those blooms in which *A. mellifera* not visited. Kumari (2014) reported the effect of distance of *B. juncea* from *A. mellifera* colony on quantitative parameters. They observed that no. of pods per plant, pod length (cm), number of seeds per plot, 1000 seed weight (g), and seed yield per plot (q/ha) were observed maximum at 0 m distance which decreases significantly as distance increases by every 20 m and reached to significantly low level when 220 m away from *A. mellifera* colony. This is because, bees prefer to visits the crop which are located nearer to the colony and thereby efficient pollination occurred. Devkota *et al*., (2016) [24] reported the effect of *A. mellifera* pollination on yield of mustard. They observed maximum seed yield *i.e*., 7.79 q/ha in bee pollination treatment and lowest seed yield *i.e*., 5.39 q/ha were observed in excluded pollinators field.

Qualitative Parameters

Nagpal *et al*., (2017) reported the influence of *A. mellifera* on qualitative parameters of mustard. They observed that in case of bee pollination, pod setting (%), seed gemination (%), oil content (%), and seed vigour index were observed maximum compared to pollination without any pollinators. In case of bee pollination, there was 100% pollination by *A. mellifera*. Kumari (2014) reported the influence of *A. mellifera* visitation on *B. juncea* bloom with respect of qualitative parameters. They observed that seed germination (%), oil content (%), and seed vigour index were maximum in case of bee pollination followed by pollination without any pollinators. Kumari (2014) reported the effect of distance of *B. juncea* from *A. mellifera* colony on qualitative parameters. They observed that seed germination (%), seed vigour index, oil content (%) were observed maximum at 0 m distance which decreases significantly as distance increases by every 20 m and reached to significantly low level when 220 m away from *A. mellifera* colony.

Conclusion

Mustard is rich source of pollen and nectar and a cross pollinated crop by bees. Among different honeybees, *A. mellifera* plays an important role in enhancing mustard productivity quantitatively and qualitatively. Pollination efficiency of *A. mellifera* are correlated with floral biology and foraging behaviour, resulted in increased no. of pod per plant, no. of seed per pod, length of pod, seed yield per plant, yield per plot, seed germination, oil content, and seed vigour. It is recommended to place 3 colonies/ha at 5-10% of flowering.

Future Thrust

Need to integrate both protective application of pesticides and use of bees in a manner to boost oilseeds production. It is required to develop usage of pollinators friendly practices in agricultural management as well as identify pesticide which are less toxic to honeybee (*A. mellifera*). There should necessity to create awareness among farmers about the utility of *A. mellifera*, in increasing crop yields through pollination.

Application of research: Supplemental pollination with *A. mellifera* in mustard is recommended as it will help farmers in obtaining higher quantity and quality of produce and thereby doubling the farmers income.

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