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Effect of pollination modes on yield components in Indian mustard (*Brassica juncea* L.)

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Abstract

Effect of different modes of pollination on yield parameters of Indian mustard showed that the maximum number of pods/plant, pod length, pod setting (%), number of seeds/pod, thousand seed weight, seed yield/ plot, seed germination (%), seed vigour and oil content (508.72 pods/plant, 5.69 cm, 86.32%, 15.66 seeds/pod, 6.87 g, 17.63 q/ha, 89.20%, 628.12 and 39.42%, respectively) were in open pollination followed by that in bee pollination (404.56 pods/plant, 4.92 cm, 78.33%, 14.26 seeds/pod, 6.39 g, 15.57 q/ha, 85.20%, 542.54 and 38.36%, respectively) and pollinators' exclusion (287.56 pods/plant, 3.89 cm, 65.87%, 12.24 seeds/pod, 5.30 g, 13.01 q/ha, 78.40%, 385.54 and 37.04%, respectively). Seed yield increased by 35.50 and 19.66 per cent in open pollinated and *Apis mellifera* pollinated plots, respectively as compared to pollinators' exclusion.

***Key words**: Apis mellifera, Brassica, Indian mustard, pollination, seed germination, seed yield*

Introduction

Among the various pollinating agents, insects played a major role. The global annual economic value of insect pollination is estimated to be € 153 billion (Gallai *et al*., 2009). Of the total pollination activities, over 80 per cent is performed by insects and bees contribute nearly 80 per cent of the total insect pollination, and are considered the best pollinators (Robinson and Morse, 1989) due to their suitable body size, hairiness, thoroughness, steadfastness, floral constancy, and manageable populations. Among rapeseed-mustard, Indian mustard [*Brassica juncea* (L.) Czern & Coss.] is predominantly cultivated in Haryana and adjoining states. It is known as *rai, raya* or *laha* in vernacular language. It is grown extensively for its seeds which yield an essential oil and condiment. Rapeseed-mustard oil is considered the best quality oil for human consumption as compared to other edible oils because of the lowest amount of harmful saturated fatty acids and adequate amount of two essential fatty acids i.e. linoleic and linolenic acid, (Porter and Crompton, 2008). Although India is the largest cultivator of oilseeds at the global level, but to feed the growing population, more than 40 per cent of vegetable oil is still imported in the country. Furthermore, per capita consumption of edible oil is likely to reach 23.1 kg by 2030 from the present level of 13.4 kg (Singh, 2014). Therefore, to achieve this target, there is a need to increase the rapeseed mustard production. But, increase in production of rapeseed mustard is possible either by increasing area under this crop or through increase in crop yield. As increase in area is possible only at the cost of other crops, hence there is scope for increasing the yield by pollination. Planned crop pollination is considered to be the most important input as all other inputs will be just useless if pollination does not occur. Because of yield optimizing benefits, bee pollination can play an important role in maintaining a sustainable and profitable agriculture with minimum environmental disruptions.

The inflorescence of *B. juncea* is an elongated corymbose raceme, borne terminally on the main stem and branches, carrying bright yellow flower (Langer and Hill, 1991 and Pua and Douglas, 2004).

Indian mustard (*B. juncea*) is a naturally autogamous species, yet in this crop frequent out-crossing occurs which varies from 5 to 30 per cent depending upon the environmental conditions and random variation of pollinating insects (Kumar *et al*., 2013). The bowl shaped flower of mustard is a suitable place for the landing of insect pollinators, especially honey bees (Roubik, 1989). The introduction of hives of honey bees for controlled pollination reported to increase 31.90 per cent of seeds per plant under autogamy conditions (Mussury and Fernandes, 2000). The honey bee pollination increased the pod set by 74.30 per cent and number of seeds by 4.07 per pod as compared to the other insects' pollination on mustard bloom (Verma and Joshi, 1983). According to Free (1993), *A. mellifera* is of great economic importance in terms of increased yield and quality of commercially grown insect pollinated crops and also assists self pollinated crops. Singh and Choudhary (2005) observed that the increase in mean yield in mustard crop, *B. juncea* L. due to honeybee pollination was 61.71 per cent. Kumari (2014) reported increased seed yield per plot in *B. juncea* cv. RLC-1 by 98.24 and 48.77 per cent, respectively in open pollination and plots caged with *A. mellifera* colony over plots caged without the honey bee colony. Therefore, the present study was planned to study the effect of different pollination modes on yield components in Indian mustard (*Brassica juncea* L.)

Materials and Methods

The experiment was carried out on Indian mustard variety RH 0749 (recently developed and recommended by CCS HAU, Hisar) during 2015-2016 at Research Area of Oilseeds Section, Department of Genetics and Plant Breeding and Apiculture Laboratory of the Department of Entomology, CCS Haryana Agricultural University, Hisar, Haryana. The sowing of the crop was done in 1st week of October, 2015 with five replications. All the normal package of practices was followed for raising a healthy crop. There were three treatments with five replications each under Randomized Block Design (RBD). The plot size was 10×10 m and the cage size was 10×10×15m

The effect of different modes of pollination on *B. juncea* yield (both quantitative and qualitative) was investigated using following three modes (Plate 1):

OP: Open pollination (flowers were left open i.e. without any caging and to be pollinated by all means)

BP: Bee pollination (plants growing in a plot were caged by netting cloth. One colony of 5 frame bee strength having 4 brood frames strength was kept inside the crop)

PE: Pollinators' exclusion (plot was caged by netting cloth to exclude all the pollinators)

The following observations were recorded at harvest for comparison of different treatments:

Number of pods per plant: From each of the replicated plot, the mean number of pods was counted from each of the five tagged plants.

Pod length (cm): Twenty pods were chosen at random from each of the five randomly selected plants from each of the replicated plots. The length of these randomly selected pods was measured with scale. The mean pod length was then worked out for each of the replicated plot.

Per cent pod setting: Pod-set percentage (PSP) for each plant was calculated by number of pods/ total flowers×100.

Number of seeds per pod: The number of seeds per 20 randomly selected pods from each of the plants under each of the replications was counted and the mean number (per 20 pods) was worked out for every replication.

Seed yield per plot: The seed yield (kg) per unit area covered by the cage (10×10 m) or equivalent to this in the case of the treatments where cages were not used (open pollination treatment), was recorded from all the replications of the various treatments and were converted into quintal/hectare.

Per cent seed germination: The germination percentage was studied using wet paper method. There were three treatments with five replications each. Five plants from each replication of the respective treatment were taken randomly to bulk

A. Open pollination (OP)

B. Bee pollination (BP)

C. Pollinators' exclusion (PE)

Plate 1: Different (A, B, C,) modes of pollination of flowers in *Brassica juncea*

the seeds. From this bulk sample, fifty seeds were taken at random and placed on germination paper in petri plates. The samples were incubated at 25° C and 80 per cent relative humidity. The germination count was made seven days after incubation. Mean germination percentages for every treatment were worked out.

Seed vigour: After seven days of germination of the seeds for each of the replications of the respective treatment, 20 seedlings were selected at random and their length was measured. Mean seed vigour was then worked out using the following formula:

Seed vigour = Mean seedling length × mean germination percentage

Oil content: Ten gram seed each was taken from every replication of the various treatments for *B. juncea*. The oil from the samples was extracted using Soxhlet Extraction Apparatus.

The data recorded on the entire above said yield parameters was analyzed using ANOVA for Randomized Block Design. The differences among the various treatment means were compared using LSD at five per cent level of significance.

Results and Discussion

The results for pre-defined parameters were recorded and presented in Table 1 under the following subheadings:

Number of pods per plant

The mean number of pods per plant of *B. juncea* was significantly the highest in open pollination (508.7 pods/plant) followed by that in bee pollination (404.6 pods/plant) and pollinators' exclusion (287.6 pods/plant). The above results are strongly supported by the findings of Atmowidi *et al*. (2007) who reported that number of pods increased by three times in insect pollinated plots of mustard (*B. rapa*). Singh and Singh (1992) also reported that bee pollinated *B. campestris* L. var. Toria plants produced 11 times more pods per plant than self-pollinated plants. The present findings are also in line with the findings of Kumari *et al.* (2013) who reported that the maximum number of pods per plant in *B. juncea* (cv. RLC-1) was observed in open pollinated plots (1137.2 pods) which was significantly higher than that in *A. mellifera* pollinated plots (506.2 pods) and significantly the lowest were observed in pollinators' exclusion (222.3 pods).

Pod length

The mean pod length of *B. juncea* was significantly the highest in open pollination (5.7 cm) followed by that in bee pollination (4.9 cm) and pollinators' exclusion (3.9 cm). The results of the present investigation are in corroboration with the results of Sihag (1986) who reported that the pod length was significantly higher in open pollinated plots of *B. juncea* var. Prakash (6.5±0.9 cm, 581±26.4 and 14.37±1.1, respectively) at Hisar. Kumari *et al*. (2013) also reported the highest pod length in *B. juncea* (cv. RLC-1) in open pollinated plots (4.93 cm) which was significantly higher than that in *A. mellifera* pollinated plots (4.2 cm) and significantly the lowest were observed in pollinators' exclusion (3.8 cm). Similar results were also recorded by Bhowmik *et al.* (2014) who determined that the length of siliqua in *B. juncea* increased by 47.2 per cent in the open pollinated plants than controlled plants where insect pollinators were excluded.

Per cent pod setting

The per cent mean pod setting of *B. juncea* was significantly the highest in open pollinated plots (86.3%) followed by that in plots caged with *A. mellifera* colony (78.3%) and pollinators' exclusion (65.9%). The present findings are strongly supported by the findings of Verma and Joshi (1983) who compared the honey bee pollination with other insects' pollination on mustard bloom and found that the honey bee pollination increased the pod set by 74.3 per cent. Similar results were recorded by Mishra *et al.* (1988) who reported that per cent pod setting in *B. campestris* var. sarson was significantly higher in open- pollinated flowers than in net caged and muslin- bagged ones. The present findings are also in line with the findings of Mahindru *et al*. (1998) who reported that zero, one, two and five bee visits per flower by *A. mellifera* resulted in 57.4, 65.5, 82.5 and 88.4 per cent pod setting, respectively in *B. juncea*. Similar results were recorded by Bhowmik *et al.* (2014) who observed significant increase in percent fruit set in *B. juncea* in open

Table 1: Influence of different modes of pollination on *Brassica juncea* flowers on seed yield and quality parameters during the year 2015-2016 at Hisar

Treatments	Mean number of pods per plant	Mean pod length (cm)	Mean number of seeds per pod	Mean thousand seed weight (g)	Mean seed yield (q/ha)	Seed yield (% increase)	Pod setting (%)	Mean seed germination (%)	Mean oil content (%)	Mean seed vigour index
Bee Pollination (BP)	404.56±4.47 (20.14)*	4.92±0.02	14.26±0.091 (3.91)*	6.39±0.19	15.57±0.22	19.656	78.33±0.95 (62.25)**	85.20±1.36 (67.44)**	38.36±0.09 (38.25)**	542.54±9.34
Open pollination (OP)	508.72±14.50 (22.57)	5.69±0.06	15.66±0.109 (4.08)	6.87±0.19	17.63±0.28	35.500	86.32±1.54 (68.38)	89.20±1.86 (71.05)	39.42±0.12 (38.88)	628.12±17.92
Pollinators' exclusion (PE)	287.56±15.30 (16.96)	3.89±0.02	12.24±0.039 (3.64)	5.30±0.15	13.01±0.35	-	65.87±3.71 (54.33)	78.40±1.33 (62.32)	37.04±0.08 (37.47)	385.54±8.69
CD	1.11	0.13	0.038	0.51	1.04	-	5.60	5.08	0.18	48.65
SE(m)	0.34	0.04	0.012	0.16	0.31	-	1.69	1.53	0.05	14.69

* Figures in parentheses are the means of "n+1 transformation

** Figures in parentheses are the means of angular transformation

pollinated plants by 6.4 per cent as compared to the controlled plants where insect pollinators were excluded.

Number of seeds per pod

The mean number of seeds per pod of *B. juncea* was significantly the maximum in open pollinated plots (15.7 seeds/pod), followed by that in plots caged with *A. mellifera* colony (14.3 seeds/pod) and pollinators' exclusion (12.2 seeds/pod). The above results are strongly supported by the findings of Sihag (1986) who recorded that at Hisar, the number of seeds per pod in *B. juncea* was significantly higher in open pollinated plants (17.20±4.5 seeds) as compared to selfed plants (14.4±1.1 seeds). Similar results were recorded by Atmowidi *et al.* (2007) who reported that insect pollination increased the number of seeds per pod by 98.2 per cent in *B. juncea*. The present findings are also in line with the findings of Kumari *et al.* (2013) who reported the maximum number of seeds per pod in *B. juncea* (cv. RLC-1) in open pollinated plots (14.0 seeds/pod) which was significantly higher than that in *A. mellifera* pollinated plots (12.4 seeds/pod) and significantly the lowest were observed in pollinators' exclusion (10.0 seeds/pod). Similar results were also recorded by Bhowmik *et al.* (2014) who observed significant increase in number of seeds per siliqua in open pollinated plants of *B. juncea* by 52.8 per cent as compared to the controlled plants where insect pollinators were excluded.

Thousand seed weight

The mean thousand seed weight of *B. juncea* was significantly the highest in open pollinated plots (6.9 g) followed by that in plots caged with *A. mellifera* colony (6.4 g). Significantly the lowest mean thousand seed weight (5.3 g) was recorded in plots caged to exclude all pollinators. The results of the present investigation corroborate the observations made by Singh and Singh (1992) who reported that bee pollinated plots produced three times heavier seeds than self-pollinated plants in *B. campestris* var. toria. Similar observations were recorded by Kumari *et al.* (2013) who observed the maximum thousand seed weight in *B. juncea* (cv. RLC-1) in open pollinated plots (4.6 g) which was significantly higher than that in *A. mellifera* pollinated plots (4.0

g) and significantly the lowest were observed in pollinators' exclusion (3.8 g). Bhowmik *et al.* (2014) also observed significant increase in mean weight of 100 seeds in open pollinated plants of *B. juncea* by 240 per cent as compared to the controlled plants where insect pollinators were excluded. The present findings are also corroborated by the results of Kamel *et al.* (2015) who observed that the weight of 1000 seeds was higher in open pollinated plants (3.1 g) than those of caged plants (2.4 g) in *B. napus*. In contrary to the above findings, Latif *et al*. (1960) reported that seed produced in cages with honey bees was heavier than the seeds from open plots of *B. juncea*.

Seed yield per plot

Mean seed yield per plot of *B. juncea* was significantly the highest in open pollination (17.6 q/ha) followed by that in bee pollination (15.6 q/ha) and pollinators' exclusion (13.0 q/ha). Significant increase in seed yield by 35.5 per cent was observed in open pollinated plots of *B. juncea* and by 19.7 per cent in *A. mellifera* pollinated plots as compared to the controlled plots where insect pollinators were excluded. These findings are in conformity with the findings of Sihag (1986) who reported that the seed yield was significantly higher in open pollinated plots (14.0±3.2 q/ha) than the caged plots (7.7±1.2 q/ha) of *B. juncea* at Hisar. The present findings are also in line with the findings of Chand and Singh (1995) who reported an increase in seed yield of mustard to the extent of 67.7 and 28.1 per cent in open pollinated and caged crop with honeybees, respectively over the control (pollinators' excluded plots).

Singh and Choudhary (2005) also observed that the increase in mean yield in mustard crop, *B. juncea* L. due to honeybee pollination was 61.7 per cent. Similar observations were recorded by Kumari *et al.* (2013) that the maximum seed yield per plot was in open pollinated plots (9127.8 kg/ha) compared to crop pollinated by *A. mellifera* (7066.66 kg/ha) and the least in pollinators' exclusion (5066.7 kg/ha) in *B. juncea* (cv. RLC-1). Blochtein *et al.* (2014) also reported that the free visitation of insects increased productivity by 17% in the Hyola 420 cultivar and by approximately 30% in the Hyola 61 cultivar of *B. napus*. The present findings are also in corroboration with the observations made by Kamel *et al.* (2015) who observed that yield per plant and yield per feddan (1 fed = 0.42 ha) were higher in open pollinated plants (32.0 g seeds and 677.6 kg seeds, respectively) than those of caged plants (18.9 g seeds and 248.6 kg seeds, respectively) in *B. napus*.

Per cent seed germination

In the present study, mean per cent seed germination of *B. juncea* was highest in open pollinated plots (89.2%), followed by plots caged with *A. mellifera* colony (85.2%) and pollinators' exclusion (78.4%). The above results are strongly supported by the findings of Prasad *et al*. (1989) who found maximum germination per cent in *B. juncea* in uncaged plants (98.0%) followed by the plants caged with bees (93.3%) and plants caged to exclude the pollinators (73.0%). The present findings are also corroborated by the findings of Mahindru *et al*. (1998) who reported that intensive pollination of *B. juncea* by *A. mellifera* increased seed germination by 7.2 per cent over natural pollination, which decreased by 0.23 per cent upon pollinators' exclusion over natural pollination. Kumari *et al.* (2013) also reported that the highest germination percentage was recorded in open pollinated plots (90.8%) compared to crop pollinated by *A. mellifera* (87.3%) and the least in pollinators' exclusion (80.0%) in *B. juncea* (cv. RLC-1). Similar results were recorded by Bhowmik *et al.* (2014) who observed that pollination increases the germinability of the resulting seeds of *B. juncea* to 36±3 per cent as germination percentage in open pollinated seeds was 96±3.2 per cent where as in control only 60±5.6 per cent seeds germinated.

Seed vigour

The mean seed vigour of *B. juncea* was significantly the highest in open pollinated plots (628.1) followed by that in plots caged with *A. mellifera* colony (542.5) and pollinators' exclusion (385.5). The results of the present investigation are strongly supported by the findings of Jakhar *et al.* (2014) who reported that the seed vigour-I and seed vigour-II was significantly higher under open pollination (3462.7 and 11.5, respectively) as compared to under without insect pollination (1378.1 and 5.9, respectively) in radish.

Oil content

The data recorded on mean oil content of *B. juncea* revealed that the highest oil content was observed significant in open pollinated plots (39.4%) followed by that in plots caged with *A. mellifera* colony (38.4%). Significantly the lowest mean oil content (37.0%) was recorded in plots caged to exclude all pollinators. These findings corroborate the findings of Prasad *et al*. (1989) who found maximum oil content in *B. juncea* in uncaged plants (32.1%) followed by the plants caged with bees (31.8%) and plants caged to exclude the pollinators (26.3%). Similarly, Mahindru *et al.* (1998) reported that intensive pollination of the crop by *A. mellifera* increased oil content by 8.3 per cent over natural pollination and it resulted in decrease of this parameter by 2.4 per cent when the visit of *A. mellifera* was excluded. The present results are also in line with the findings of Kumari *et al.* (2013) who reported that in *B. juncea* (cv. RLC-1), the highest oil content was in open pollination (30.1%) compared to crop pollinated by *A. mellifera* (25.9%) and the least in pollinators' exclusion (22.8%). This study concluded that number of pods/plant, pod length, pod setting (%), number of seeds/pod, thousand seed weight, seed yield/plot, seed germination (%), seed vigour and oil content significantly increased under open pollination and bee pollination treatments than compared to pollinators' exclusion. Thus augmentation of hive bees and wild bees as part of crop management should be adopted by farmers for increasing the yield of Indian mustard.

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