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Effect of different modes of pollination on seed set of mustard (*Brassica juncea* L.) sown on different sowing dates

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Abstract

The present study was conducted to determine the effect of different modes of pollination on seed set of mustard (*Brassica juncea* L.) in three different sowing dates. The studies were conducted in mustard crop by inducing the plant to flower early or late through different sowing dates. Open mode of pollination was superior to hand pollination and pollinators exclusion. Higher seed set percentage was observed in open pollination (81.89 %) as compared to hand pollination (58.61 %) and pollinator's exclusion (45.96 %). This shows an increase of 35.93 and 12.56 per cent seed set under open pollination and hand pollination modes over pollinators exclusion. Delayed sowing of mustard resulted into reduction in the seed set. Highest seed siliqua⁻¹ and 1000-seed weight was obtained in open pollination followed by hand pollination. The minimum seed/ siliqua and 1000 seed weight was observed in case of pollinator's exclusion. The mean number of seed siliqua⁻¹ and 1000-seed weight did not vary significantly in different sowing dates during both the year of investigations.

Keywords: modes of pollination, seed set, mustard, sowing date

Introduction

Pollination is an important process in maintaining healthy and bio diverse ecosystems. Many ecosystems, including agro ecosystem depend on pollinator diversity to maintain overall biological diversity. Pollination also benefits society by increasing food security and improving livelihoods [1]. Among the various pollinating agents, insects played a major role. The global annual economic value of insect pollination is estimated to be 153 billion [2]. 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 [3] due to their suitable body size, hairiness, thoroughness, steadfastness, floral constancy and manageable populations. The role of pollinators in cross pollination of important agro-horticultural crops is well recognized. Insect pollination results in a uniform crop and improves the quality of fruit. The important insect pollinators include honey bees, solitary bees (*Xylocopa*, *Andrena*, *Halictus*), bumble bees, stingless bees (*Trigona*, *Melipona*) and dipterans flies (*Syrphus*, *Bombilius*). The major pollinator dependent crops are fruit and vegetable crops, spices and plantation crops and pulses and oilseed crops. India is one of the largest mustard growing country in the world occupying the first position in area and second position in production after China [4]. *Brassica* is an excellent research crop to study patterns of variation in pollinator behaviour because it is mostly pollinated by insects and has a rapid life cycle, does not self pollinate and require insects for cross pollination [5]. 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 [6]. So far, honeybees alone are considered as significant pollinators on *Brassica* crop, however a number of other insects also visit on this crop during flowering period as reported by various workers from different parts of the country [7; 8]. Time of sowing is very important for mustard production [9]. Sowing dates is an important factor that determines the length of growing season and hence yields [10]. Delayed in planting, unfavourable weather conditions during flowering period, fertilization and pod formation can cause a decrease in duration of maturity period, the number of pods per plant, the number and weight of grains, and finally can lead to decrease in grain yield [11]. Hence, the objective of our experiment was to study the effect of different modes of pollination on seed set of mustard (*Brassica juncea* L.) in three sowing dates.

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Materials and Methods

The investigations were carried out at Baghor farm, Department of Entomology, Dr. Y. S. Parmar University of Horticulture and Forestry Nauni, Solan (Himachal Pradesh) situated at 33.3° N latitude, 70.70° E longitude and 1256 m amsl. Experiment was conducted in mustard crop by inducing the plant to flower early or late through different sowing dates during 2015 i.e. 6th October (D₁), 23rd October (D₂) and 12th November (D₃) and 2016 i.e. 1st October (D₁), 17th October (D₂) and 3rd November (D₃). The experiment was laid out in a Randomized Block Design (RBD) with three replications each with three sets of plots. Per cent seed set was calculated out for different modes of pollination:

1. Open pollination: Observations on seed set were recorded in mustard flowers exposed to all insect pollinators under open condition (Fig.1). Seed set was recorded on the flower basis. Hundred flower buds were marked at balloon stage for recording data on seed set. The observations on seed set were recorded after petal fall. Per cent seed set was calculated from the number of flowers counted.

2. Hand pollination: Hundred flowers at balloon stage were enclosed in the selfing bags. Dehisced pollen was applied on the stigma at the time of anthesis (Fig.3). The stigma receptivity was examined by magnifying hand lens and stigma showing greenish yellow to yellowish colour with droplets of secreted fluid was considered to be receptive. After application of pollen, flowers were bagged to avoid any contamination after pollination. The observations on seed set were recorded.

3. Pollinator's exclusion: Flowers at balloon stage were caged by insect proof nylon net to exclude all the pollinators (Fig.2). The cages were assembled five days before flowering and were disassembled at the end of flowering period to allow complete plant development. The seed set was recorded at harvest in each mode of pollination for comparison.

Per cent seed set: Seed set percentage for different modes of pollination was calculated as:

$$\text{Seed set (\%)} = \frac{\text{Number of pods}}{\text{Total numbers of flowers}} \times 100$$



Fig 1: Open pollination



Fig 2: Pollinator's exclusion

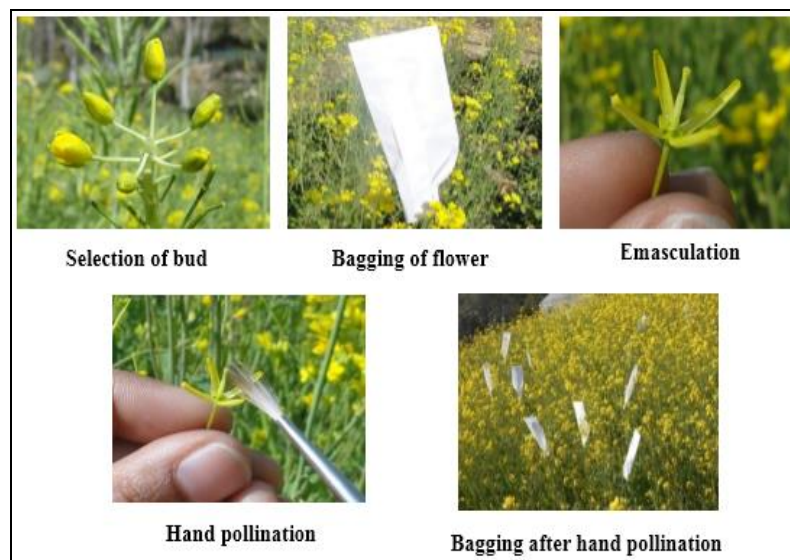


Fig 3: Procedure for hand pollination

Effect of different modes of pollination on seed quality parameter

1. Number of seed/pod: The number of seeds from randomly selected pods from each of the selected plant for each mode of pollination (open pollination, hand pollination and pollinator's exclusion) was counted and

the mean number was worked out.

2. Thousand seed weight: From every treatment (open pollination, hand pollination and pollinator's exclusion), seeds from the plant in a given replication were mixed and weight of 1000 seeds was recorded with the help of weighing balance.

Results & Discussion

Studies on the modes of pollination on per cent seed set in mustard crop

The per cent seed set was higher in open pollination (78.44 %) followed by hand pollination (59.43%) and pollinator's exclusion (46.12 %) during 2015. Similarly the seed set was more (85.33 %) in open pollination followed by hand pollination (57.79 %) and pollinator's exclusion (45.80 %) during 2016.

Maximum seed set was recorded in open pollinated crop ranged from 76.80 to 81.60 per cent in different sowing dates during 2015. The seed set obtained by hand pollination was significantly low than in open pollinated crop in crop sown on D₁ (58.50 %), D₂ (61.40%) and D₃ (58.40%). The lowest seed set was observed under pollinator's exclusion during 2015

(Table 1). During 2016 the per cent seed set in open pollination was recorded 85.73, 85.35 and 84.93 and in hand pollination it was 60.79, 56.85 and 55.74 whereas, in pollinator's exclusion it ranged from 43.88 to 47.47 in mustard crop sown on D₁, D₂ and D₃ (Table 1).

Pooled data (2015 and 2016) irrespective of modes of pollination indicated that sowing date did not have significant effect on seed set percentage. The pooled data (irrespective of sowing date) further revealed significant higher seed set in open pollination (81.89 %) as compared to hand pollination (58.61%) which is statistically at par with pollinator's exclusion (45.96 %) (Table 1). This shows an increase of 35.93 and 12.56 per cent seed set under open pollination and hand pollination modes over Pollinators exclusion.

Table 1: Effect of different mode of pollination on seed set of mustard

Sowing date	Seed set (%)											
	2015				2016				Pooled			
	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
Open Pollination (OP)	76.91 (61.38)*	81.60 (66.03)	76.80 (61.34)	78.44 (62.92)	85.73 (68.21)	85.35 (68.20)	84.93 (68.32)	85.33 (68.24)	81.32 (64.80)	83.48 (67.12)	80.86 (64.83)	81.89 (65.58)
Hand Pollination (HP)	58.50 (49.95)	61.40 (51.59)	58.40 (49.89)	59.43 (50.48)	60.79 (51.28)	56.85 (48.95)	55.74 (48.29)	57.79 (49.50)	59.64 (50.61)	59.13 (50.27)	57.07 (49.09)	58.61 (49.99)
Pollinator's exclusion (PE)	45.64 (42.46)	47.40 (43.48)	45.31 (42.27)	46.12 (42.74)	47.47 (43.51)	46.05 (42.67)	43.88 (41.40)	45.80 (42.53)	46.56 (42.98)	46.73 (43.08)	44.60 (41.84)	45.96 (47.64)
Mean	60.35 (51.27)	63.47 (53.70)	60.17 (51.17)	61.33 (52.05)	64.66 (54.33)	62.75 (53.27)	61.52 (52.67)	62.98 (53.42)	62.50 (52.79)	63.11 (53.49)	60.84 (51.92)	62.16 (52.74)

CD_(0.05) Year (NS), Modes of pollination (2.96), Year x Modes of pollination (NS), Sowing date (NS), Year x Sowing date (NS), Modes of pollination x Sowing date (NS), Year x modes of pollination x sowing date (NS)

* Figures in the parentheses are angular transformed values

Sowing date: 2015:D₁: 6th October, D₂:23rd October, D₃:12th November

2016:D₁: 1st October, D₂:17th October, D₃:3rd November

The present findings on higher seed set percentage in open pollination are in conformity with the already recorded observations of Chand and Singh, 1995^[12] on *Brassica juncea* and Mishra *et al.* 1988^[13] on *B. campestris* var. sarson. They also documented higher seed set in open pollinated flowers as compared to pollinator's exclusion. Goswami and Khan, 2014^[14] reported highest per cent seed set in open pollinated (83.42%) plots followed by bee pollinated (75.41%) and pollinator's exclusion (62.80%). Many workers^[15, 16, 17] have also reported highest yield of *Brassica* in open pollinated plots, followed by the plots caged with honeybees, whereas the pollinator's excluding plot yielded the lowest. Other workers^[18, 15, 19] have also documented higher seed set in open pollinated plot as compared to pollinator's exclusion.

Effect of different modes of pollination on different quality parameters

Seed Siliqua⁻¹

Highest mean number of seed siliqua⁻¹ was produced in open pollinated crop (15.50 seed siliqua⁻¹) which was significantly more with those produced in hand pollinated (14.12 seed siliqua⁻¹) and pollinator's exclusion (12.13 seed siliqua⁻¹) during 2015. Similarly during 2016, The mean number of

seed siliqua⁻¹ was 15.58, 14.23 and 12.06 seed siliqua⁻¹, respectively in open pollination, hand pollination and pollinator exclusion.

Irrespective of modes of pollination, highest number of seed siliqua⁻¹ was obtained in D₂ (13.97 seed siliqua⁻¹) followed by D₁ (13.96 seed siliqua⁻¹) and reduced in the late sowing D₃ (13.82 seed siliqua⁻¹) during 2015 (difference, non-significant). Similarly during 2016, data irrespective of modes of pollination, highest mean number of seed siliqua⁻¹ was recorded in D₁ (14.10 seed siliqua⁻¹) which was statistically similar to D₂ (13.97 seed siliqua⁻¹) and D₃ (13.80 seed siliqua⁻¹) (Table 2). The highest number of seed siliqua⁻¹ was (15.60 seed siliqua⁻¹) in open pollination (D₁). The lowest number of seed siliqua⁻¹ was 12.01 in pollinator exclusion (D₃) during 2015. The highest seed siliqua⁻¹ was 15.59 in open pollination (D₂) and lowest seed siliqua⁻¹ was 11.72 in pollinator's exclusion (D₃) during 2016. From the pooled data (2015 and 2016), it is evident that among different modes of pollination, significantly maximum seed siliqua⁻¹ (15.54) was recorded with open pollination as compared to hand pollination (14.18 seed siliqua⁻¹) and pollinator's exclusion (12.09 seed siliqua⁻¹). The seed siliqua⁻¹ did not vary significantly with different sowing dates it was 14.03, 13.97 and 13.81 seed siliqua⁻¹, respectively on D₁, D₂ and D₃ (Table 2).

Table 2: Effect of different modes of pollination on seed siliqua⁻¹

Sowing date	Seed siliqua ⁻¹ (number)											
	2015				2016				Pooled			
	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
Open Pollination (OP)	15.60	15.49	15.42	15.50	15.66	15.59	15.48	15.58	15.63	15.54	15.45	15.54
Hand Pollination (HP)	14.07	14.25	14.04	14.12	14.33	14.18	14.19	14.23	14.20	14.22	14.11	14.18
Pollinator's exclusion (PE)	12.22	12.16	12.01	12.13	12.32	12.14	11.72	12.06	12.27	12.15	11.86	12.09

Mean	13.96	13.97	13.82	13.92	14.10	13.97	13.80	13.96	14.03	13.97	13.81	13.94
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CD (0.05) Year (NS), Modes of pollination (0.77), Year x Modes of pollination (NS), Sowing dates (NS), Year x Sowing dates (NS), Modes of pollination x Sowing dates (NS), Year x Modes of pollination x Sowing dates (NS)

Sowing date; 2015: D₁: 6th October, D₂: 23rd October, D₃: 12th November

2016: D₁: 1st October, D₂: 17th October, D₃: 3rd November

1000-seed weight

Irrespective of sowing date, highest mean 1000–seed weight (3.08 g) was recorded in open pollinated crop which was statistically similar to those produced in hand pollinated crop (2.97 g) during 2015. The crop grown under pollinator's exclusion was produced the lowest 1000 weight (2.36 g). Similar trends were observed during 2016. The data further showed that the advancement and delayed date of sowing.

Irrespective of modes of pollination, highest mean 1000- seed weight was obtained in D₁ (2.87g) followed by D₂ (2.81g) and reduced in the late sowing D₃ (2.78 g) during 2015 (difference, non-significant) (Table 3). Similarly during 2016, highest mean 1000- seed was recorded in D₁ (2.83 g) which

was statistically similar to D₂ (2.82g) and D₃ (2.76g).

The highest 1000-seed weight was 3.07 g in open pollination (D₂). The lowest 1000 –seed weight was 2.34g in pollinator's exclusion (D₃) during 2015 (Table 3). Similarly during 2016, highest 1000-seed weight was 3.13g in open pollination (D₁) and lowest 1000–seed weight was 2.35 in pollinator's exclusion (D₁ and D₂).

Irrespective of years (pooled 2015 and 2016), among different modes of pollination significantly highest 1000-seed weigh of 3.09 g was recorded in open pollination as compared to hand pollination (2.95 g) and pollinator's exclusion (2.35 g). The advancement and delayed date of sowing had no significant effect on 1000–seed weight (Table 3).

Table 3: Effect of different mode of pollination on 1000-seed weight

Sowing date	1000-seed weight (g)											
	2015				2016				Pooled			
	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
Open Pollination (OP)	3.07	3.11	3.06	3.08	3.13	3.12	3.09	3.11	3.10	3.11	3.07	3.09
Hand Pollination (HP)	3.01	2.95	2.95	2.97	3.00	2.98	2.83	2.94	3.00	2.96	2.89	2.95
Pollinator's exclusion (PE)	2.37	2.36	2.34	2.36	2.35	2.36	2.35	2.35	2.36	2.36	2.34	2.35
Mean	2.87	2.81	2.78	2.80	2.83	2.82	2.76	2.80	2.82	2.81	2.77	2.80

CD (0.05) Year (NS), Modes of pollination (0.07), Year x Modes of pollination (NS), Sowing dates (NS), Year x Sowing dates (NS), Modes of pollination x Sowing dates (NS), Year x Modes of pollination x Sowing dates (NS)

Sowing date; 2015:D₁: 6th October, D₂: 23rd October, D₃: 12th November

2016:D₁: 1st October, D₂: 17th October, D₃: 3rd November

In the present investigations, highest seed siliqua⁻¹ and 1000-seed weight was obtained in open pollination followed by hand pollination. The minimum seed/ siliqua and 1000 seed weight was observed in case of pollinator's exclusion. The present findings are in line with the findings of Kumari *et al.*, 2013^[20], who reported maximum number of pods per plant in *B. juncea* under open pollinated plots than pollinator's exclusion. Similarly Singh and Singh, 1992^[21] reported that bee pollinated *B. campestris* L. var. toria plants produced 11 times more pods per plant than self- pollinated plants.

The mean number of seed siliqua⁻¹ and 1000-seed weight did not vary significantly in different sowing dates during both the year of investigations. Siadat and Hemayati, 2009^[22] have also reported negligible effects of planting dates on seed per pod and 1000 seed weight.

Conclusion

Open mode of pollination was superior to hand pollination and pollinators exclusion. Higher seed set percentage was observed in open pollination as compared to hand pollination and pollinator's exclusion during both the year. Maximum seeds siliqua⁻¹, 1000–seed weight were recorded in open pollination as compared to hand pollination and pollinator's exclusion.

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