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Effect of different Modes of Pollination on Sesame Yield Parameters

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ABSTRACT: Sesame flowers are often visited by a myriad of insects and they play an important role in crop pollination. Determination of role of insect pollinators on qualitative and quantitative yield parameters is of great importance. Hence the present study was conducted on two selected sesame varieties, HT-1 and HT-2 at the CCS Haryana Agricultural University Research Farm in Hisar during the *kharif* of two consecutive years, 2017 and 2018. The results revealed a significant difference in all the recorded parameters, viz., capsule setting percent, number of capsules, 1000 seed weight, seed yield, germination percent, seed vigour and oil content in the provided treatments. Bee pollinated plots were found to be superior, followed by open pollination, while the plots without insect pollination had shown the lowest improvement in the observed parameters. Among the bee-pollinated treatments, Bee Pollination-8F (*Apis mellifera* F. hive with 8 frame strength) was the best treatment, followed by Bee Pollination-6F (*A. mellifera* hive with 6 frame strength). The maximum seed yield of 821.78 and 864.00 kg ha^{-1} was recorded in Bee Pollination- 8F, while the lowest yield of 466.22 and 484.00 kg ha^{-1} was obtained in HT-1 and HT-2, respectively. In HT-1, the highest percent of seed germination (77.61), vigour index (841.01) and oil content (45.80%) were recorded in the plot received with the Bee pollination-8F treatment. Similar results were also documented in HT-2 with values of 73.85, 830.16 and 47.50 for the observed parameters, respectively. This study reflects the importance of bee pollination in sesame.

Keywords: Sesame, bee pollination, open pollination, seed yield, seed germination, oil content.

INTRODUCTION

Sesame is one of the important, oldest and most traditional oilseed crops. Its seeds are highly valued because of their both nutritional and medicinal properties. They are rich in fat, protein, carbohydrates, fiber, and essential minerals. The seeds contain 44-57 percent oil, 18-25 percent protein, 13-14 percent carbohydrates, 6-8 percent fibre, 5-7 percent ash and 6-7 percent moisture. Oil is famous for its stability due to its resistance to oxidative rancidity after long exposure to air (Borchani *et al*., 2010; Hegde, 2012). It is being cultivated in 73 countries on 12.82 million hectares with 6.55 million tonnes of production. Burkina Faso, China, Ethiopia, India, Myanmar, Nigeria, Sudan and Tanzania are the major producers where they share 78 percent of the world's production. India ranked third where sesame is under cultivation in 14.20 million hectares with 0.69 million tonnes of production. However, the productivity of the crop is still low (485 kg/ha) as compared to the global average (827 kg/ha).

In general, self-pollinated crops are mass-flowering crops, and they produce large amounts of pollen and nectar that can be potential resources for bees and other insects. Sesame is also a self-pollinated plant containing both male and female structures within the same flower. In *Sesamum indicum* L., anthesis occurs early in the morning (6 to 8.30 am) and stigma becomes receptive almost very close to that time (9 to 10:30 am) and senescence occurs after six to twelve hours (Bhowmik *et al*., 2018; Jayraj and Beevy, 2020). Its flowers are visited by many insect visitors which have peak activity from 9 am to 12 pm (Mahfouz *et al*., 2012, Rao, 2019). Some of the insect visitors help in transferring pollen from one flower to another and act as pollinators, benefiting the crop at a critical time window. Sesame exhibits significant variation in out-crossing rates which ranges from less than 10% to 68 percent depending on insect activity and environmental conditions (Free, 1993; Sarker, 2004). A recent study on the pollinator dependence of the sesame crop revealed that pollinator deficiency in the crop may lead to a yield gap between 50 and 87 percent (Stein *et al*., 2017). It is indicating the value of pollinators as one of the prime inputs to increase the yield of sesame. In India, there is a wide gap between the potential achievable yield and the average yield of sesame. Planned bee pollination could be useful for increasing the seed yield, thereby reducing the edible oil shortage to some extent. Considering this fact, the present study was conducted to assess the effect of different modes on qualitative and quantitative yield parameters of sesame.

MATERIALS AND METHODS

The present was conducted at Research Area of Department of Entomology (29°09′06.2″N, 75°41′57.3″E) CCS Haryana Agricultural University, Hisar. Two varieties of sesame, HT-1 and HT-2, which are widely grown in Haryana, were selected and raised during *Kharif* of 2017 and 2018 following recommended crop production practices, excluding the plant protection measures (CCSHAU, 2017). To study the effect of different modes of pollination on yield parameters of sesame, the field was laid out in a randomized block design consisting of four replications and each replication was further subdivided into five treatments, viz. Without Insect Pollination (WIP), Open Pollination (OP), Bee Pollination-4 F (BP-4F) @ 4 frame strength colony, Bee Pollination-6F (BP-6F) @ 6 frame strength colony, Bee Pollination-8F (BP-8F) @ 8 frame strength colony. Each plot size was 10 × 10 m. Nylon nets measuring 10 m × 10 m × 3 m with 2 mm mesh size were used for the experiment. During the onset of flowering, the crop was covered with nylon net except for the open pollination treatment. Inside the nylon net, *A. meliifera* hives were placed according to treatments. The experiment was so designed that the plot under without insect pollination treatment was kept protected from any insect foragers and the open pollination plot was left open for natural pollination. After completion of flowering, hives and the nylon nets were removed. The following observations were recorded following methodologies adopted by Bhagawati and Rahman (2015); Nagpal (2016).

(i) Capsule setting percent: Ten flowers were tagged from each treatment and capsule setting percent was estimated using the following formula.

Capsule setting = (Number of capsules per each treatment/Ten flowers) ×100

(ii) Number of capsules per plant: Ten plants from each treatment were randomly selected and the number of capsules per plant was counted.

(iii) Number of seeds per capsule: Twenty selected capsules were used to count the number of seeds per capsule.

(iv) 1000 seed weight: Weight of 1000-seeds was taken using the electronic weighing balance and expressed in grams.

(v) Seed yield per hectare: A total of 10 plants were selected and yield per plant was calculated. This plant yield data was further converted into a hectare basis by multiplying with the total number of plants and expressed in kilograms per hectare.

(vi) Seed germination percent: For recording the seed germination, fifty seeds per treatment were selected and placed in a Petri dish (15 cm) containing the moistened filter paper. This Petri dish was kept in a seed germinator, maintained at a temperature of 25±1^{o}C and RH of 75 % for 7 days and after that, the germinated seeds were counted and expressed in percentage.

(vii) Seed vigour: After 7 days of seed germination, 20 seedlings were randomly selected and lengths were recorded. The mean seedling vigour was estimated using the following formula

Seed vigour index = Germination % × seedling length (cm)

(viii) Oil content: Ten-gram seeds were taken from all replications of each treatment and the oil content of the seeds was extracted using Soxhlet Extraction Apparatus and expressed in percentage.

Statistical Analysis. The data of recorded yield parameters were analyzed using Randomized Block Design with help of OPSTAT statistical software (Sheoran *et al*., 1998). The differences among the treatment means were compared using LSD at the five percent level of significance. Mean data on the number of capsules per plant and the number of seeds per capsule was subjected to square root transformation, whereas mean percentage data recorded for capsule setting, seed germination and oil content was analyzed after angular transformation.

RESULTS AND DISCUSSION

Studies on the effect of different modes of pollination on various qualitative as well as quantitative parameters of *S. indicum* revealed marked differences among the treatments tested in the two varieties. Pooled data of HT-1 (Table 1) and HT-2 (Table 2) clearly showed that bee-pollinated treatments of different frame strength had resulted in significant improvement in yield parameters in comparison to other treatments. These findings demonstrated the important role of insect pollinators in enhancing the qualitative and quantitative yield parameters of sesame. Effect on each observed parameter is discussed below.

Capsule setting percent was found to vary with the mode of pollination. It was highest in BP-8F (92.00%), followed by BP-6F (88.00%) and BP-4F (86.13%), while WIP had the lowest capsule set (74.50%). Accordingly, in HT-2, the mean capsule setting percent was the highest in BP-8F (92.38), followed by BP-4F (86.50), and the lowest in WIP (77.00). Results are consistent with Bhagawati and Rahman (2015) who documented more than 80 percent capsule set in bee-pollinated plots than open pollination (73.63 %) and pollinator excluded plot (65.63 %). Chaudhary *et al*. (2016) also found similar results in Niger where he noted maximum seed set (78.60%) in the plot caged with honey bees followed by crops open to all insect pollinators (65.40%). They found the lowest percent of (18.20%) seed setting in pollinator excluded plot.

Table 1: Effect of different modes of pollination on yield parameters of *S. indicum* Cv. HT- 1 during 2017 and 2018.

Treatment	Capsule set (%)	No. of capsules per plant	No. of seeds per capsule	1000 seed weight (g)	Seed yield per plant (g)	Seed yield per hectare (kg)	% Yield increase Over		Germination (%)	Vigour index	Oil content (%)
							WIP	OP			
Without insect pollination	74.50	52.50	38.35	2.48	5.25	466.22	-	-	46.03	351.61	42.50
Open pollination	78.25	64.60	41.85	2.63	7.08	629.33	34.99	-	63.94	530.03	44.95
Bee Pollination-4F	86.13	69.55	44.80	2.75	7.91	702.67	50.71	11.65	69.79	652.79	45.35
Bee Pollination-6F	88.00	74.93	49.00	2.95	8.50	755.11	61.96	19.99	76.92	760.72	45.52
Bee Pollination-8F	92.00	77.50	57.05	3.12	9.25	821.78	76.26	30.58	77.61	841.01	45.80
CD (P≤0.05)	1.11	0.14	0.14	0.07	0.26	14.12	-	-	1.50	29.03	1.35
SE(m)	0.36	0.05	0.05	0.02	0.09	4.53	-	-	0.48	9.32	0.43

Bee Pollination -4F refers to bee pollination treatment with 4 frame *A. mellifera* colony; Bee pollination -6F means 6 frame *A. mellifera* colony and bee pollination -8F with 8 frame *A. mellifera* colony

Table 2: Effect of different modes of pollination on yield parameters of *S. indicum* Cv. HT- 2 during 2017 and 2018.

Treatment	Capsule set (%)	No. of capsules per plant	No. of seeds per capsule	1000 seed weight (g)	Seed yield per plant (g)	Seed yield per hectare (kg)	% Yield increase Over		Germination (%)	Vigour index	Oil content (%)
							WIP	OP			
Without insect pollination	77.00	53.23	50.20	2.41	5.45	484.00	-	-	53.85	463.85	43.20
Open pollination	80.88	69.12	52.95	2.76	7.35	653.33	34.99	-	58.88	543.91	45.10
Bee Pollination- 4F	84.38	73.81	54.00	2.82	8.61	764.89	58.03	17.07	64.74	656.33	45.45
Bee Pollination- 6F	86.50	83.87	59.20	3.17	9.19	816.89	68.78	25.03	70.70	751.15	46.05
Bee Pollination- 8F	92.38	86.42	65.60	3.32	9.72	864.00	78.51	32.24	72.85	802.66	47.00
CD (P≤0.05)	1.63	0.13	0.10	0.08	0.33	25.03	-	-	0.99	31.33	1.48
SE(m)	0.52	0.04	0.03	0.03	0.11	8.04	-	-	0.32	10.06	0.47

Insect pollination also played a significant role in determining the number of capsules produced. In HT-1, It was found that BP-8F (77.50) treatment produced the most capsules per plant in comparison with other treatments; it was followed by BP-6F (74.93) and BP-4F (69.55), while WIP produced the fewest capsules (52.50). A similar result was obtained in HT-2, where the best treatments in descending order were BP-8F (86.42), BP-6F (83.87), BP-4F (73.81), OP (69.12) and WIP treatment (53.23). Results are in agreement with Sajjanar and Eswarappa (2015) who recorded a significantly higher number of capsules in the sesame crop plots caged with honeybee colony (40.43) than other treatments *viz*., open pollination (36.43) and without insect pollination plot (29.14). Sandipan *et al*. (2017) study on Niger also found a significant increase in the number of capitulum due to the placement of beehives inside the crop. Each treatment produced a different number of seeds per capsule, just like the capsules per plant. In HT-1, BP- 8F (57.05) had recorded with the highest number of seeds and it was followed by BP- 6F (49.00) and BP-4F (44.80), while the lowest (38.35) was observed in without insect pollination treatment. Similar improvements in HT-2 were noticed, where the highest number *i.e.* 65.60 and 59.20 capsules were recorded in BP- 8F and BP-6F, respectively. These findings are in confirmation with Pasthe and Shylesha (2013) who recorded the significant increase in capsule number from 27.93 to 51.90 when sesame plant exposed to the frequent visits of *A. cerana* foragers. Sattigi *et al*. (2004) observed a similar trend in Niger, where the highest (33.1) and the lowest (17.8) number of seeds per capitulum were observed in the plot caged with bees and those caged without bees, respectively.

Thousand seed weight of both cultivars had varied significantly according to the mode of pollination. With pertaining to data of HT-1, BP- 8F (3.12 g) was the best treatment than other treatments and it was followed by BP- 6F (2.95 g), BP- 4F (2.75 g), while the lowest seed weight (2.48 g) was found in WIP treatment. In HT-2 also, the data followed the similar trend. Results are in favour of Sajjanar and Eswarappa (2015) who observed the highest 1000 seed weight in bee-pollinated sesame plot (3.47 g) when compared to open pollination (3.29 g) and pollinator exclusion plots (2.70 g). Similarly, results are in line with Panda *et al.* (1996) registered that the seeds obtained from sunflower grown under open pollination had the highest seed weight (70.8g/1000 seeds) followed by crop subjected to bee pollination (60.8g) and without insect pollination (34g).

BP-8F was found to be the best treatment with a recorded seed yield of 821.78 and 864 kg in HT-1 and HT-2 respectively. With pertaining to HT-1, there was a clear improvement in seed yield with the increase of frames in the beehive where 11.65, 19.99 and 30.58 percent increase was reported over the open pollination in bee-pollinated treatments *viz.*, BP-4F, BP-6F and BP-8F respectively. In HT-2, the same trend in improvement of yield was observed as HT-1 where about 17.07, 25. 03 and 32.24 percent increase in yield was observed in BP-4F, BP-6F and BP-8F over the open pollination, respectively. Panda *et al*. (1988) also stated that both open and bee pollination treatments were effective to increase the seed yield in sesame by 50-59 percent. Sajjanar and Eswarappa (2015) also observed that yield was maximum with honeybees (6.93 q / ha) compared to open pollination (6.26 q/ha) and untreated check (4.66 q/ha). Mishra (1994) also registered the highest yield in open-pollinated (820 kg h^{-1}) followed by *A. mellifera* pollinated plots (744 kg h^{-1}) than without insect pollination (497 kg h^{-1}) in sesame.

Data of HT-1 showed that the seed germination was found to be maximum in BP- 8F (77.61 %) plot and it was followed by BP-6F (76.92 %) and BP- 4F (69.79 %), while the lowest (46.03 %) was recorded in WIP plot. Similarly, the germination percent of HT-2 was 72.85, 70.70, 64.74, 58.88, 53.85 percent, respectively in BP-8F, BP-6F and BP-4F, OP and WIP treatments, respectively. Similar observations were also reported by Chaudhary *et al*. (2016) who recorded the highest germination percentage in niger crop open to all insect pollinators (84.50 %) followed by crop caged with honeybees (79.0%), whereas the lowest germination percent was found in crop caged without insect pollinators (28.40%).

Seed vigour data of HT-1 and HT-2 showed the highest vigour index in bee pollination plots of different frame strengths than other treatments. In HT-1, the maximum seed vigour index was observed in BP- 8F (841.01) treatment and it was followed by BP- 6F (760.72), while the lowest seed germination (351.61) was noted in WIP. Similar observations were also recorded in HT-2 where bee pollination- 8F (802.66) was superior to others, while the lowest seed vigour index (463.85) was recorded in without insect pollination plot. Nagpal (2016), also recorded the highest seed vigour index in open (628.12) and *A. mellifera* pollinated plots (542.54) in comparison to pollinator exclusion (384.54) in *B. juncea*. Like other parameters, there was also a measurable percent variation in oil content. In HT-1, it was slightly varied from 43.20 to 47.00 percent and it was recorded to be highest in BP- 8F treatment (45.80 %) followed by BP-6F (45.52 %), meanwhile, the lowest oil content (42.50 %) was recorded in without insect pollination treatment. Similarly, in HT-2, there was 47.00, 46.05, 45.45, 45.10 and 43.20 percent oil content in BP-8F, BP-6F and BP-4F, OP and WIP treatments, respectively. Sajjanar and Eswarappa (2015) also found significantly higher oil content in honeybee pollinated plots (52.84) followed by open pollination (49.46) and it was lowest in the control plot with pollinator exclusion (42.96). Results are also in line with Kumari *et al.* (2013) recorded increased oil content in open and bee pollination plots than pollinator excluded plots of *Brassica napus*. Panda *et al.* (1988) also found that open pollination resulted in 10.0 to 11.1 percent increase in oil content over control, whereas, bee pollination resulted in an increase of 3.16 to 8.75 percent over control in sesame and niger.

CONCLUSION

The present study provided evidence that insect pollination can improve sesame yield parameters. The impact of open pollination (OP) and a variety of bee-pollinated treatments (8F, 6F, 4F) on yield parameters were significantly greater than that of the without insect pollination treatment (WIP). In both the selected varieties, the plot with eight framed beehive was found superior followed by a plot with six framed and four framed hives. Bees were successful in transferring pollen from anthers to stigma, allowing ovules in the ovary to fertilize on time. As a result of frequent visits of *A. mellifera* hive bees, the ovary was properly filled, resulting in an increase in capsule setting percentage, capsule weight, seeds per capsule, and seed yield. Further, there was the enhancement in other important quality parameters *viz.*, seed germination, seed vigour and oil content. These results imply that pollinators visiting crops at the right time of phenology could boost sesame yields.

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Conflict of Interest. None.

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