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IMPACT OF HONEY BEE POLLINATION ON POD SET OF MUSTARD (*BRASSICA JUNCEA* L.: CRUCIFERAE) AT PANTNAGAR

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ABSTRACT
The diversity and abundance of different insect visitors on mustard (*Brassica juncea*) were studied at Pantnagar. A total of 19 insect visitors belonging to order Hymenoptera (15) and Diptera (4) were found to visit the mustard blossoms at Pantnagar. The abundance (percentage of insect/m^2/2min.) of Hymenopterans were maximum followed by the Dipterans and others. In Hymenopterans, the honeybees (*Apis* bees) were observed maximum followed by non *Apis* bees and the scolid wasp. Insect pollinations increased the number of pods and percent pod set.

INTRODUCTION

Cruciferous *Brassica* crops are widely grown throughout the world as vegetables for human consumption, as condiments and spices for improved flavour of human diets, and also used as fodder crop for livestock feeding. However, the largest cultivation of these crops is for edible vegetable oil production. Pollination is an essential process for the propagation of the species in sexually reproducing plants. The cross pollinated plants need external agents to get accomplish the task of pollination. More than 75% of the major world crops rely on animal pollinators. Nearly 15% of animal pollinated crops are pollinated by the domestic bees while at least 80% are pollinated by wild bee species and other animals. The valuable oilseed crop *Brassica* is highly cross-pollinated and also require external agents such as insects for transfer of the pollen grains to the stigmas. Insect mediated cross pollination may be, only of secondary importance for brown mustard (*Brassica juncea* L.) which is self fertile and mainly autogamous (Wsyen, 1920; L, Osson 1952; Rives, 1957). 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 (Thakur *et al.*, 1982 ; Bhalla, *et al.*, 1983; Mishra *et al.,* 1988; Prasad *et al.,* 1989; Kakar, 1981; Priti and Gupta, 1992 ; Kumar *et al.,* 1994; Singh, 1994 ; Sinha *et al.,* 1994; Chaudhary 2001 ; Singh *et al.,* 2004)). Floral morphology is well known to affect the efficiency of pollen removal and deposition during pollinator visits (Campbell, 1989; Murcia, 1990; Young & Stanton, 1990; Nishihiro *et al.,* 2000; Yang *et al.,* 2002; Kudo, 2003) and to have the potential to increase or decrease seed production in both self-fertilizing and out crossing plants. Among floral characteristics, the spatial relationship of stigmas and anthers strongly influences pollination efficiencies (Holtsford, 1992; Conner *et al.,* 1995; Karron *et al.,* 1997; Motten & Stone, 2000; Elle & Hare, 2002). Studies on the relationship of insect pollinators with our objectives were to investigate the diversity of pollinator insects in relation to flower phenology and pod set of mustard (*B. juncea*).The diversity of pollinator insects was observed in relation to time and flower phenology.

MATERIALS AND METHODS

The studies were conducted at Apiary site in College of Agriculture, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand (India). The diversity of insect visitors was recorded and the individuals collected by a hand net. Sweeps were made at peak blooming period of mustard crop every day, at fixed time intervals. The abundance of insect visitors per sq. m. area was recorded at hourly intervals from 10:00 to 14:00 hrs, during the blooming period of the crop. The averages of these observations were worked out.

The effect of insect pollination on setting was evaluated by caging plots with muslin cloth with a colony of *Apis mellifera* (T_1) ; caging plots with muslin cloth for excluding insect visitors (T_2) and allowing insect to visit on blossom by keeping plots open (T_3)

Ten plants were randomly selected from each plot at the time of maturation of pods. The total number of pods (healthy and chaffy) in each sampled plant was counted manually. Pod-set percentage (PSP) for each plant was calculated by number of pods/total flowers x 100**.** Seven varieties/ line varities Kranti,

Varuna, Margold, Vardan, Vaibhav, EC399312 and EC399313 were sown three replication in plots of 3 × 2 sizes.

Statistical Analysis - The data collected from field experiments were subjected to the analysis of variance following randomized block design.

RESULTS AND DISCUSSION

Diversity of pollinators

A total of 19 insect visitors belonging to order Hymenoptera (15), and Diptera (4), were found to visit the mustard blossoms at Pantnagar. Which are enlisted in (Table 1) Hymenopteran visitors belonged to six families namely Apidae (6), Scollidae (3), Xylocopidae (1), Halictidae (2), Magachilidae (1), Anthophoridae (1) and Sphecidae (1). Lepidopteran visitors belonged to families Pieridae (1). Besides this some Dipteran visitor belonged to families these were Syrphidae (3) and Muscidae (1) were observed on mustard flowers. From the family Apidae, honeybees (*Apis mellifera, Apis dorsata*, *Apis cerana indica* and *Apis florea*), *Ceratina sexmaculata*, *Xylocopa iridipennis* and stingless bee *Tetragonula laeviceps* family Apidae. *Scolia* (*Discolia*) *binolata, Campsomeriella collaris* and *C. annulata* of family Scollidae, the Alkali Bees (*Nomia* sp.) and *Halictus* sp. of Halictidae, Leaf cutter bee (*Megachile disjuncta*) of Megachilidae, the digger bee *(Anthophora* sp.) of Anthophoridae and *Sphex* sp. of Sphecidae. Three species from family Syrphidae (*Syrphus corollae, Episyrphus valtiatus and Eristalis tenax*) and one species from Muscidae (*Musca domestica*) visited the mustard flowers. Abrol (1989) recorded 20 species belonging to 12 families of Hymenoptera and Diptera and found that *Apis cerana, A. mellifera,* Halictid bees, *Halictus* sp. and *Lasioglossum* sp., were the most numerous visitors and important pollinators of *Brassica* crops**.**

Diversity of pollinator insects related to time and flower phenology

Relative abundance of different pollinators

The abundance (percentage of insect/m^2/2min.) of Hymenopterans were maximum (79.97 %) followed by the Dipterans (16.15 %) and others (3.73 %). (Table 2) The activity of honey bees was higher at 12:00 h (66.31%) as compared to other bees which were equally active at 10:00h (21.74). In Hymenopterans, the honeybees (*Apis* bees) were observed maximum (57.55 %) followed by non *Apis* bees (21.06 %) and the scolid wasp (1.35 %).The data in table 2.2 recorded that the 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 %), *Xylocopa iridipennis* (1.10 %). Among dipterans, *Eristalis tenax* was 8.20 % and *Syrphus* sp. was 7.95 %. Thakur *et al*. (1982) and Rana *et al*. (1997) observed higher foraging activity at 12:00 h of both *A. mellifera* and *A. c. indica* than at 09:00 h. However, in both the species, there were no significant differences of the population of bees between 1200 and 15:00 h. Kumar and Singh (2005) observed that *A. mellifera* was most dominant species followed by other insect visitors.

Flowering phenology of *Brassica* crop included onset of flowering in January, anthesis within one - two day. A few flower buds started to open in the evening a day before anthesis, but the majority of flowers opened in the morning, mainly between 6.00h and 9.00h . Opening of new flowers was usually completed by 10.00h. Stigma was receptive for three days. A single flower may remain open for approximately 2-7 days depending upon climatic condition. Duration of flowering is months.

Impact of different modes of pollination on percent pod set of *B. juncea*

The qualitatively impact of different modes of pollination on pod set of *B. juncea* was evaluated .The results on different parameters have been presented in concerned Table 3-4.

A total ten plants were selected randomly from each plot and the number of flower, pods was counted for each plant. In open pollinated plots the highest number of pods observed in line, EC399312 (232.29; 96.91%), followed by EC399313 (208.44; 92.62%) and least no. of pod formation and percent pod set was recorded in var. Margold i.e. 83.93 pods/plant,

Table 1: Diversity of different insect visitors on flowers of mustard (*B. juncea*) at Pantnagar

S. No.	Insect visitor	Common name	Order	Family
1	*Apis mellifera*	Italian honey bee	Hymenoptera	Apidae
2	*Apis dorsata*	Rock bee	Hymenoptera	Apidae
3	*Apis cerana indica*	Indian honeybee	Hymenoptera	Apidae
4	*Apis florea*	Little honeybee	Hymenoptera	Apidae
5	*Ceratina sexmaculata*	Small carpenter bee	Hymenoptera	Apidae
6	*Tetragonula laeviceps*	Stingless bee	Hymenoptera	Apidae
7	*Scolia (Discolia) binolata*	Scolid wasp	Hymenoptera	Scollidae
8	*Campsomeriella annulata*	Scolid wasp	Hymenoptera	Scollidae
9	*Campsomeriella collaris*	Scolid wasp	Hymenoptera	Scollidae
10	*Megachile disjuncta*	Leaf cutter bee	Hymenoptera	Megachilidae
11	*Xylocopa iridipennis*	Carpenter bee	Hymenoptera	Xylocopidae
12	*Anthophora* sp.	Digger bee	Hymenoptera	Anthophoridae
13	*Halictus* sp.	Sweat bee	Hymenoptera	Halictidae
14	*Nomia* sp.	Alkali bee	Hymenoptera	Halictidae
15	*Sphex* sp.	-	Hymenoptera	Sphecidae
16	*Syrphus corollae*	Syrphid fly	Diptera	Syrphidae
17	*Episyrphus valtiatus*	Syrphid fly	Diptera	Syrphidae
18	*Eristalis tenax*	Drone fly	Diptera	Syrphidae
19	*Musca domestica*	House fly	Diptera	Muscidae

Table 2: Relative abundance of different insect visitors on flowers of mustard during different hours of the day

Insect groups	Per cent abundance (insect visitors/m²/2min)			
	10:00 h	12:00 h	14:00 h	Mean
Hymenopterans	73.97	82.50	80.44	79.97
Apis bees	50.80	66.31	58.55	57.55
Non *Apis* bees	21.74	18.28	21.17	21.06
Wasp	01.43	0.91	1.72	1.35
Dipterans	19.17	16.66	12.64	16.15
Hymenopterans				
Apis mellifera	30.25	35.26	28.42	31.56
Apis dorsata	7.73	8.59	15.37	10.56
Apis cerana indica	10.13	13.31	8.11	10.52
Apis florea	4.69	4.15	6.65	5.16
Trigona laeviceps	9.65	6.61	5.23	7.16
Halictus spp.	5.22	5.06	8.00	6.09
Anthophora sp.	5.87	3.89	5.39	5.05
Nomia sp.	1.83	1.94	1.20	1.66
Campsomeriella collaris	1.43	0.91	1.72	1.35
Xylocopa iridipennis	1.17	0.78	1.35	1.10
Dipterans				
Eristalis tenax	8.87	9.53	5.91	8.20
Syrphus spp.	10.30	7.13	6.73	7.95
Others	2.22	2.85	6.13	3.73

66.33 (%) followed by Varuna (105.59; 74.50 %) Kranti (155.70; 79.69 %), Vaibhav (164.89; 88.55%) and Vardan (162.03; 85.35 %).

In bee pollinated plots the highest pod formation and percent pod set (%) recorded in line EC399312 (194.51; 93.50%), EC399313 (190.34; 89.16%), Vardan (152.49; 82.64%), Kranti (150.49; 79.60%) least no. was observed in Vaibhav with (135.88; 67.60%). In caged plots the highest no. of pods and percent pod set was recorded in EC399313 (179.96; 83.78% followed by EC399312 (166.0; 70.14%). Data in graphic form Fig 1.

The impact of different mode of pollination showed that highest percent pod set was in open pollinated (83.42%) plots followed by bee pollinated (75.41%) and caged pollinated (62.80%) (Table 4). Kranti, Margold, Vaibhav, EC399312, and EC399313 showed significant difference in percent pod set (Table 6-8). The number of individual pollinators affected seed set of *B juncea*. Seed set and abundance of pollinator insects was positively related. Pradhan (2003); Chakaravarty (2000); Thakur and Karnatak (2005) reported that highest number of pods per plant 495 in *A. mellifera* pollinated plants, 438 in *A. cerana* and 417 in open pollinated plants whereas caged plants without pollinators produced 290 pods per plant. Kumar and Lenin (2000); Prasad *et al*. (1989) found highest yield of *B. juncea* in open pollinated plots, followed by the plots caged with honeybees, whereas the caged plots (excluding pollinators) yield the lowest**.** Fujita, 1939; Free and Nutall, 1968 observed that *B juncea* plants caged with bees produced 25 per cent more seed than plants caged without bees.

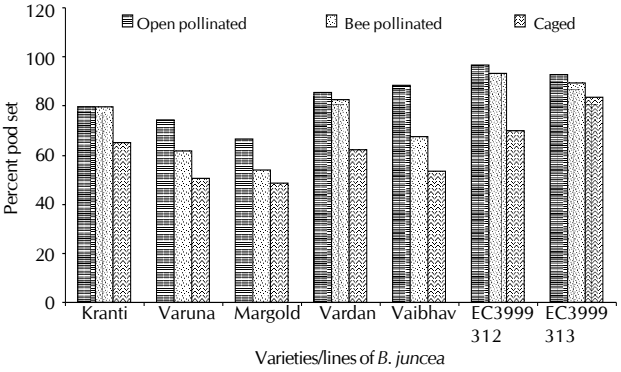

Figure 1: Impact of different modes of pollination on percent pod set of *B. juncea*

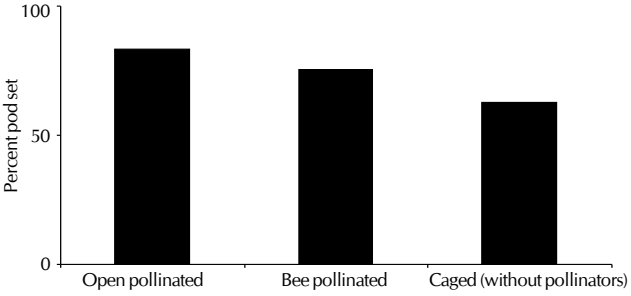

Figure 2: Different modes of pollination on percent pod set of *B. juncea*

Table 4: Effect of different modes of pollination in *B. juncea*

Treatments	Pod/plant	Percent pod set
Open pollinated	142.83	83.42
Bee pollinated	135.42	75.41
Caged (without pollinators)	96.64	62.80
GM	24.99	16.41
SEm ±	23.24	15.37
CD at 5%	75.74	50.09

Insect pollination is one factor influencing the seed set. Other factors are nutrient availability (Juenger & Bergelson 1997), patch size (Agren 1996), flower and interactions between herbivores and their natural enemies (Thies & Tscharntke 1999). Combination of several complementary pollinator species differing in flower-visiting behaviour could be of more importance for high fruit set than only pollinator abundance

Table 3: Effect of insect pollination on percent pod set attributes of *B. juncea*

Varieties/lines	Open pollination		Bee pollination		Caged (without pollinators)	
	Pod/plant	Percent pod set	Pod/plant	Percent pod set	Pod/plant	Percent pod set
Kranti	155.70	79.69	150.67	79.60	131.26	64.97
Varuna	105.59	74.50	98.81	61.66	92.56	50.58
Margold	83.93	66.33	77.15	53.76	72.51	48.41
Vardan	162.03	85.35	152.49	82.64	135.00	62.42
Vaibhav	164.89	88.55	135.88	67.60	79.21	53.57
EC399312	232.29	96.91	194.51	93.50	166.00	70.14
EC399313	208.44	92.62	190.34	89.16	179.96	83.78
GM	142.83	83.42	135.42	75.41	40.78	20.18
SEm ±	3.03	0.27	21.14	14.23	21.57	3.87
CD at 5%	9.01	0.80	65.15	43.84	66.4	11.94

(Klein *et al*. 2003).

In conclusion, this study provides insights into the importance of pollinator insects to help plant pollination, included mustard, an importance crop in the tropic. Our results indicate diversity and abundance of pollinator insects, especially bees, plays a significant role in pod set of mustard. Enhancement of pollinator insects as part of crop management should be considered by farmers. This could be done by a reduced use of pesticides, providing nesting sites for solitary bees, and improving pollen and nectar availability for bees.

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