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CONTENTS

Studies on flower morphological characters of different oilseed *Brassica* species and their effect on the abundance of bee species

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ABSTRACT: Oilseed *Brassica* is an important source of oil for people worldwide. Oilseed *Brassica* crops largely attract hymenopterans because *Brassica* flowers are well adapted to generalist insect pollinators; they produce large amounts of pollen and nectar throughout the entire flowering period, which draws the attention of most of the insects. In the current study, we studied flower morphological characters of different oilseed *Brassica* species in relation to floral visitors along with their abundance rate at Norman E. Borlaug Crop Research Centre in Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (Uttarakhand) during the *rabi* season 2020-21. Results revealed that *Apis mellifera* had the highest relative abundance (42.11%) in oilseed *Brassica*, whereas, among oilseed *Brassica* cultivars, *B. nigra* reported the highest bee abundance (19.05%). However, among bee species and different *Brassica* cultivars, *A. mellifera* (5.06 bees/m^2/5min) showed the highest abundance in *B. carinata* followed by *Halictus* spp. (3.78 bees /m^2/5min) in *B. nigra*. Large size flower structures were found in *B. napus* (variety- GSC-6) and *B. carinata* while small flowers were found in *B. nigra*, therefore *A. mellifera* showed positive significant correlation with flower morphological characters *viz*., petal length (r = 0.791*) and outer stamen (r = 0.732*) and *Halictus* spp. reported negative significant correlation with flower morphological characters viz. sepal length (r = -0.823*) and inner stamen (r = -0.799*). The results suggested *A. mellifera* species could be effective pollinators of large flower sized *Brassica* cultivar, and *Halictus* spp. could be effective pollinators of small flowers sized *Brassica* cultivar. This association also occurs between other bee species and *Brassica* variety, except in case of *A. florea*. On the other hand, the activity of *A. florea* in oilseed *Brassica* is independent of floral morphological characteristics and may be influenced by other factors like as weather conditions, nectar availability of pollen etc.

Key words: *Apis mellifera, Brassica* species*, Halictus* spp., nectar, pollen

Floral biology refers to the understanding of the structure, sexual system and morphological adaptations of the flowers in relation to the breeding system and pollination ecology. Thus, a careful study of the floral biology of a plant is important for discerning the mode of pollination (self or cross), types of pollinators and mechanisms of pollination involved (Belavadi and Ganeshaiah, 2013). The Brassicaceae family can be differentiated by the appearance of conduplicate cotyledons (i.e., cotyledons that are longitudinally folded around the radical) and two-segmented fruits (siliquae) with seeds in one or both divisions. In India, *B. campestris*, *B. juncea*, *B. rapa* syn., *B. napus, B. carinata*, *B. nigra* and *B. oleracea* are the important and widely cultivated oilseed *Brassica* species. *B. juncea* (L.) Czern and Coss, commonly referred to as "Indian mustard" (Jat *et al.*, 2019). *Brassica* species is an ideal research crop for analyzing patterns relay heavily on insects for pollination (Stewart, 2002). Different *Brassica* flowers have a different flower shape that is well suited to generalist insect pollinators these flowers, with colorful petals, large volumes of pollen, fragrance production, and nectar production throughout the flowering period makes them attractive to pollinators for feed (Free, 1970). *B. juncea* was considered as self-compatible, but also an insect-pollinated crop. *B. napus* flowers are bisexual, with four sepals and four petals, four longer stamens and two shorter stamens (Kunjwal *et al.,* 2014). *Apis florea, A. dorsata, A. mellifera, Andrena ilerda,* and *A. leaena* are the dominant visitors while wasps, solitary bees, Dipterans and Lepidopterans are non-dominant visitors of *Brassica* crops (Abrol, 2012). *B. compestris* flowers are visited by *A. cerana indica* F., *A. florea* F., *A. dorsata* F. (Naim and Bisht, 1993). Pollinators like honeybee visited on Indian mustard

cultivars RH-30, *B. carinata* cv. Carinata, *B. compestris* variety Brown Sarson (cv. BSH-1), (Choudhary, 2001).

The pollinating abundance of anthophilous insects is intimately related to the floral biology of the many species (Menzel, 2002). Thompson (2001) quantified how the visitation rates of different pollinators to a multiple *Brassica* species vary in relation to variation in floral design and floral display. After going through aforesaid literature the current research was directed to study the impact of floral structure of different species of oilseed *Brassica* on abundance of different bee species.

MATERIALS AND METHODS

The investigations were carried out at Norman E. Borlaug Crop Research Centre in Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (Uttarakhand) during the rabi season 2020-21 with the oilseed *Brassica* cultivar *B. campestris* (var. BSH-1), *B. rapa* (var. YST-151), *B. juncea* (var. Varuna), *B-nigra, B. juncea* (var. PM-31), *B. napus* (var. GSC-6), *B. alba* and *B. carinata*.

Flower morphological characters

While observing the flower structure, it is important to record special modifications to attract flower visitors. The length and number of anthers, the length of inner and outer stamen, and the length of the style were all observed in flower structure of oilseed *Brassica* crops. Each floral character was determined using a Vernier caliper after measurements were taken from 5 fully opened flowers from an individual variety of oilseed *Brassica.*

Abundance of bee species

A total number of visiting insects/m^2 of randomly selected crop area was counted for five minutes in three replications. The relative abundance of dominant pollinator species was calculated by three-way ANOVA performed using SPSS software Version 20 and expressed as per centage (Srikanta and Shashidhar, 2010).

RESULTS AND DISCUSSION

Flower morphological characters

Flower of oilseed *Brassica* has 4 small greenish sepals, 4 yellowish petals arranged in across formation pattern. There are 6 stamens in a flower, 4 long and 2 short along with a slender pistil. The size of flower structures was significantly different in different varieties of oilseed *Brassica* presented in Table 1. Average petal length of oilseed *Brassica s*pecies was 10.53 mm whereas, *B. carinata* had maximum petal length (13.79 mm), which was statistically similar to *B. napus* var. GSC-6 (13.47 mm) but higher than other *Brassica* species. Petal breadth was significantly maximum in *B. napus* var. GSC-6 (7.92 mm) followed by *B. compestris* var. BSH-1 (6.92 mm) and minimum was observed in *B. nigra* (3.33 mm). *Brassica* flowers are bisexual, sepals are oblong with different length. Average length of sepals in oilseed *Brassica* was 6.15 mm and sepal size in *B. napus* var. GSC-6 (7.82 mm) was found to be similar with sepal length size of *B. carinata* (7.49 mm) being statistically higher than others while sepal length was minimum in *B. nigra* (3.85 mm). The length of style was maximum in *B. carinata* (9.57 mm) which was statistically at par with *B. napus* var. GSC-6 (9.56 mm) and *B. rapa* var. YST-151 (8.80 mm). Length of inner filament in *B. napus* var. GSC-6 (9.75 mm) was significantly higher than other *Brassica* species followed by *B. carinata* (8.53 mm). Whereas, the minimum size of the inner filament was found in *B. nigra* (5.86 mm). *B. napus* var. GSC-6 had higher length of outer stamen (8.17) which was statistically similar with *B. carinata* (7.86 mm) while smallest length was found in *B. juncea* var. PM-31(4.41 mm) which was statistically at par with and *B. nigra* (4.50 mm).

Abundance of different bees on different oilseed *Brassica* species

The relative abundance of insect visitor's *viz.*, *A. mellilera* L. *A. cerana indica*, *A. dorsata*, *A. florea* and *Halictus* spp. were recorded on flowers of 8 species of oilseed *Brassica* crop on day hour. The observations were recorded in Table 2. Data further indicated that mean relative abundance of *A.*

Table 1: Flower morphological characters of different oilseed *Brassica* species

	Flower structures (size in mm)					
Species/Variety	Petal length	Petal breadth	Sepal length	Style length	Inner stamen	Outer stamen
B. compestris (var.BSH-1)	10.19	6.92	6.46	7.28	8.18	5.10
B. rapa (var.YST-151)	10.48	4.02	6.58	8.8	6.90	5.78
B. juncea (var. Varuna)	8.14	4.3	5.61	6.67	7.77	5.44
B. juncea (var.PM-31)	10.38	5.44	5.83	5.87	6.86	4.41
B. alba	9.97	5.55	5.59	6.42	7.73	6.13
B. nigra	7.82	3.33	3.85	4.55	5.86	4.50
B. napus (var. GSC-6)	13.79	7.92	7.82	9.56	9.75	8.17
B. carinata	13.47	6.63	7.49	9.57	8.53	7.86
Mean	10.53	5.52	6.15	7.34	7.7	5.92
CV	8.911	11.56	8.67	15.21	8.232	11.89
SEM	0.42	0.285	0.239	0.499	0.283	0.315
CD 5%	1.222	0.825	0.69	1.446	0.825	0.917

Table 2: Abundance of different bees on different oilseed *Brassica* species

	No. of bee/m^2/5 min						
Brassica species / Bee species	*A. mellifera*	*A. cerana*	*A. dorsata*	*A. florea*	*Halictus* spp.	Mean	Relative abundance (%)
B. compestris (var.BSH-1)	2.54	2.46	0.21	0.88	0.83	1.39	13.44
B. rapa (var.YST-151)	1.83	0.92	0.21	0.17	1.13	0.85	8.22
B. juncea (var. Varuna)	2.08	0.83	0.13	0.5	0.71	0.85	8.22
B. juncea (var.PM-31)	2.56	1.33	0.22	1.33	1.78	1.44	13.93
B. alba	2	0.38	0.55	0.08	0.29	0.66	6.38
B. nigra	2.11	1.78	0.5	1.67	3.78	1.97	19.05
B. napus (var. GSC-6)	3.54	1.83	1.42	0.13	0.42	1.47	14.22
B. carinata	5.06	0.44	0.22	2.61	0.22	1.71	16.54
Mean	2.72	1.25	0.43	0.92	1.14		
Relative abundance (%)	42.11	19.35	6.66	14.24	17.65		

CD at 5% Bee species (0.221), *Brassica* species (0.28), Bee species X *Brassica* species (0.626)

Table 3: Correlation of bees' abundance with floral morphological characters in oilseed *Brassica*

Bee Abundance	Petal length (mm)	Petal Breadth (mm)	Sepal length (mm)	Style length (mm)	Length of Inner stamen (mm)	Length of outer stamen (mm)
A. mellifera	0.791*	0.649	0.647	0.655	0.601	0.732*
A. cerana	-0.109	0.261	-0.098	-0.111	0.043	-0.283
A. dorsata	0.516	0.502	0.347	0.267	0.552	0.57
A. florea	0.096	-0.001	-0.109	-0.004	-0.189	-0.003
Halictus spp.	-0.633	-0.638	-0.823*	-0.669	-0.799*	-0.669

* Correlation is significant at the 0.05 level (2-tailed)

mellifera (42.11%) in various species of oilseed *Brassica* was significantly higher than other bee species, followed by *A. cerana* (19.35%) and *Halictus* spp. (17.65%) (Statistically same). Whereas, least abundance recorded by *A. dorsata* (6.66%) which was at par with *A. florea* (14.24%). Similarly, irrespective of bee species, *B. nigra* (19.05%) had significantly higher abundance among eight varieties of oilseed *Brassica* followed by *B. carinata* (16.54%). The minimum mean relative abundance of bee species was recorded in *B. alba* (6.38% bees /m^2/5min). However, the interaction between bee species and *Brassica* species, showed that the abundance of *A. mellifera* (5.06 bees /m^2/ 5min) in *B. carinata* was maximum and highly significant than other bee species followed by *Halictus* spp. (3.78 bees /m^2/5min) in *B. nigra* which was statistically similar to *A. mellifera* (3.54 bees /

m^2/5min) in *B. napus* var. GSC-6.

Correlation of bee's abundance with floral morphological characters in oilseed *Brassica*

The data on correlation of insect visitor's abundance with floral morphometric in oilseed *Brassica* crop is presented in Table 3. Data revealed that abundance of *A. mellifera* had positive correlation with all morphometric characters of *Brassica* flower while its significant correlation with petal length (r = 0.791*) and length outer stamen (r = 0.737*). Abundance of *A. cerana* had positive correlation with petal breadth (r = 0.261) and inner stamen length (r = 0.043) and negative correlation with other flower structures. Whereas in *A. dorsata* all floral morphometric characters showed positive with their abundance. Flower structures had negative correlation with *A. florea* abundance except for floral size (r = 0.045) and petal length (r = 0.096). All floral morphometric characters of oilseed *Brassica* showed a non-significant negative correlation with the abundance of *Halictus* spp. except for sepal length (r = -0.823*), and length of inner stamen (r = -0.789*) which had a significant negative correlation as presented in Table 3.

In mustard (*B. juncea*), Devi *et al.* (2017) found a significant variation in petal and sepal size, as well as a moderate difference in style length and inner anther filament length. Correlation between bee abundance and flower structures revealed that among the five major bee pollinators in oilseed *Brassica* only *A. mellifera* and *A. dorsata* showed positive association with all floral morphometric characters whereas *A. cerana, A. florea* and *Halictus* spp. showed mostly negative association as depicted in Figure 3 and supported by works of Nevard (2017). This indicates that more is the length of floral morphometric characters more will be the abundance of *A. mellifera* and *A. dorsata* and minimum length of floral morphometric characters more will be the abundance of *Halictus* spp., *A. cerana* and *A. florea* which was found similar as described by Koetz (2013). This statement would be concluded by the data of individual bee abundance on individual *Brassica* species, because among bee species *A. mellifera* (large size bee) showed higher abundance in *B. carinata* (large size flower) as found similar with works of Cornman *et al.* (2015). Whereas *A. cerana* (medium size), *A. dorsata* (large size bee) and *Halictus* spp. (small size bee) showed higher abundance in *B. compestris* var. BSH-1 (medium size flower), *B. napus* var. GSC-6 (large-size flower) and *B. nigra* (small-size flower), respectively (Raghunandan and Basavarajappa, 2014). On the other hand, *A. florea* (small-size bee) was an exception because it had higher abundance of in *B. carinata* (large-size flower) and showed a negative correlation with floral morphometric characters.

CONCLUSION

The present study provides information regarding the correlation between flowers and their pollinators, wherein the attraction of bees towards flowers is not solely dependent on their color and fragrance, but also on the structural features of the flowers and their varying sizes, which in turn attract specific bee species of corresponding sizes. The *B. napus* var. GSC-6 and *B. carinata* varieties exhibit a positive correlation between their morphological characteristics and the attraction of the large-sized bee species (*A. mellifera*), while *B. nigra* displays a negative correlation with the small-sized bee species (*Halictus* spp.), owing to its relatively shorter morphological characteristics. This correlation is observed across various bee species and oilseed *Brassica* varieties, with the exception of *A. florea*. After conducting such analysis, we found that flower morphological characteristics influenced the abundance of bee species except for the *A. florea.* However, the activity of, *A. florea* in oilseed *Brassica* is independent of floral morphological characteristics and may be influenced by other factors like as weather conditions, nectar availability of pollen and nectar.

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