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Foraging Frequency of *Apis* Species on Bloom of *Brassica Napus* L.

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ABSTRACT
Study conducted on the foraging frequency of various Apis species on the boom of parental lines of Brassica napus plots raised for hybrid seed production, to evaluate their pollination efficiency, revealed that Apis cerana visited more number of flowers/min., followed by A. mellifera and A. dorsata . The foraging rate of A. florea was significantly low. However there was no significant difference between foraging frequency of A. cerana and that of A. mellifera. Thus these two species were efficient pollinators as far as foraging frequency was concerned, as foraging rate is one of the important factors to determine pollinating efficiency of insect visitors. Foraging rate of all the species of bees was higher on CMS line flowers as compared to that on R Line. Present study will help to manage an efficient and economic hybrid seed production programme in case of B. napus. The motto among research workers now might almost be "Give us a crop and we will find an efficient bee to pollinate it."
Key words *Apis species , foraging frequency, pollination efficiency ,foraging frequency, Brassica napus*

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I. INTRODUCTION

In general, all the species of honeybees are efficient pollinators and bees are believed to account for approximately 90 per cent of the pollination brought about by insects. So it is not surprising that much of the knowledge available about entomophilous pollination of crops has been derived from studies on bees. Such knowledge is of considerable importance because colonies of honeybees can conveniently be used for crop pollination and hybrid seed production programmes. Pollination of crops by bees is the most effective and the cheapest method of increasing crop yield and production of hybrid seeds. However, all types of honeybees are not always the best pollinators of all the crops.

Foraging speed (time spent per flower) or foraging rate (number of flowers visited/min.) is an important factor to determine pollinating efficiency of different *Apis* species because chances of pollination are more when more number of flowers are visited per unit time, as it may pollinate more number of flowers in less time. Foraging frequency depends upon a number of factors including instinctive foraging behaviour of insects, length of proboscis (Inouye, 1980) floral structure (Free, 1970), particularly the corolla depth (Gilbert, 1980), type of floral rewards and density of flowers on particular cultivar of the crop concerned. Foraging speed is a trade between the amount of nectar or pollen expected from a flower and time required to collect it. More is the nectar or pollen available, more will be the time spent per flower. The foraging rate of pollinating insect is also affected by size and structure of the flower and its components such as petals, stamens, anthers, nectarines etc. and their arrangement. Mohr and Jay (1988) found that foraging speed of honeybees on *B. campestris* was more (4.6-6.7 seconds/flower) as compared to the same in case of *B. napus* (6.1-6.9 seconds/flower). The flowers of *B. campestris* are much smaller and more tightly clustered in the inflorescence than that of *B. napus*. Thus on small sized flowers foraging speed of bees is faster. The bees spend more time per flower on *B. napus* than that on *B. campestris*. The flowers of *B. napus* are larger and have greater volume of nectar per flower therefore, foraging speed is slow (Szabo, 1982). In general, greater is the foraging speed, more are the chances of pollination. Thus it can be deduced that *B. campestris* may get more pollinating advantage from bees than *B. napus*. Adverse weather conditions decrease the foraging rate of insect visitors (Wilson, 1926, 1929: Free, 1960) Environmental or weather factors like temperature, relative humidity, light intensity, cold winds and heavy dew etc. affect the foraging rate (frequency). These factors vary at various day hours, thus hours of a day also determine the foraging speed. The main aim of the study was to observe number of flowers visited/min. on parental lines of *Brassica napus* by different *Apis* species to evaluate their pollinating efficiency to enhance the existing knowledge in the field of hybrid seed production, pollination and bee management technology.

II. MATERIALS AND METHODS

Seeds of cytoplasmically male sterile (CMS) line (TCMS-PR-05) and restorer (R) line (TFR-91) of *Brassica napus* hybrid PGSH-51 were obtained from Department of plant breeding, Punjab Agricultural university, Ludhiana (Punjab). Hybrid seed production plots were raised by following standard package of agricultural practices recommended by PAU. In order to obtain synchronous flowering in two lines, early flowering male plants were detopped. In order to conduct the study two colonies of each, *Apis mellifera* and *A. cerana* were managed. Two colonies of *A. florea* were procured from other places and grafted at suitable places near experimental plots. Enough activity of *A. dorsata* bees was observed in study area and management of this bee species was not felt necessary.

Number of flowers visited/min. by different bee species were observed on male and female lines separately with the help of stop clock and meter rod . Observations were taken at four different hours of day (1000, 1200, 1400 and 1600) during flowering season of crop under investigation. Various data collected were consolidated, tabulated, transformed wherever felt necessary and then subjected to analysis of variance and significance was tested at 5 percent level.

III. RESULTS AND DISCUSSION

On an average, foraging frequency of different bee species as observed in the present study can be arranged as: *A. cerana* > *A. mellifera* > *A. dorsata* > *A. florea*. The foraging rate of *A. cerana* was not statistically different from that of *A. mellifera*. Foragers of these two *Apis* species visited significantly more number of flowers as compared to *A. dorsata* and significantly less foraging rate was observed in case of *A. florea*. The findings are in line with the information given by Desh Raj and Rana (1994) from their study on the foraging speed of *A. mellifera* and *A. cerana indica F.* on rapeseed (*Brassica campestris* var. brown sarson). They observed that average foraging speed of *A. mellifera* was lesser than that of *A. cerana indica*, yet there was no significant difference between them as far as time spent per flower was concerned. Similar types of observations were recorded on the foraging speed of these two species on apple (Verma and Dulta, 1986) and plum flowers (Rana, 1990). Jhajj *et al*. (1996) studied the foraging speed of *Apis* species on raya and brown sarson. In case of raya, *A. mellifera*, *A. dorsata* and *A. florea* visited 14.06, 11.36 and 5.81 flowers per minute but on bloom of brown sarson they visited 17.06, 12.89 and 6.05 flowers per minute, respectively. Variation in the foraging speed on different *Brassica* species was due to different flower size and climatic conditions prevalent in different areas.

In contrast to the present observations, Kakar (1981) recorded that bee species according to descending order of their foraging rate were: A. dorsata (9.950 flowers/min.) > *A.mellifera* (8.050 flowers/min.) > *A. cerana* (7.600 flowers/min.) and similar type of observations were recorded by Alam *et al*., (1987) on the same crop. Atwal *et al*., (1970) found that on sarson bloom, *A. florea* had more foraging rate (17.200 flowers/min.), followed by *A. dorsata* (16.600 flowers/min.) and *A. cerana* (12.700 flowers/min.). Tanda (1983) noted that foraging rate of *A. mellifera* was found maximum (5.700 flowers/min.), followed by *A. dorsata* (5.500 flowers/min.) and *A.cerana indica* (4.600 flowers/min.) on Asiatic cotton flowers.

Comparatively more foraging rate of *A. cerana* on *Brassica* crops has been reported by many worker (Latif *et al*., 1960; Kapil *et al*., 1971; Murrell and Nash, 1981; Bhalla *et al*., 1983a; Mishra *et al*., 1988). Foraging rate of *A. cerana* was found to be faster as compared to that of *A. florea* on *B. campestris* (Dorothy *et al*., 1981). Many workers have observed the foraging rate of *A. cerana* and *A. mellifera* on *Brassica* crops (Free and Nuttal, 1968; Tanda, 1984; Mohr and Jay, 1988). In present study, difference between foraging frequencies of two species was not statistically significant, both of them may be considered to have same foraging frequency.

Foraging rate determines the pollination efficiency, higher is the foraging rate of a bee, more will be its pollinating efficiency, as it may pollinate more number of flowers in less time. So in this study, according to foraging frequency, *A. cerana* was the most efficient pollinator but it was not different statistically from *A. mellifera* in this respect. *A. dorsata* was next to above two bee species. Significantly lesser foraging rate or pollinating efficiency was recorded in case of *A. florea*.

It was also found that the average foraging rate of *Apis* specis (irrespective of bee species) was maximum at 1200 h on R and CMS lines. Maximum foraging frequency for *A. mellifera* on *B. napus* has earlier been reported at 1300 h (Anon, 1999). Literature revealed that enough investigations have not been conducted regarding foraging rates of all the four *Apis* species on male and female lines of different crops belonging to *Brassica* genus including *B. napus*. Murrell and Nash (1981) observed that *A. cerana indica* spent comparatively less time per flower (more foraging speed) at 1130-1230 h in case of *Brassica campestris* var. toria, Similar type of informations were given by various authors (Dhaliwal and Bhalla, 1980; Desh Raj and Rana,1994; Panda *et al*. , 1995) on different crops. All these workers also reported that various species of honeybees had maximum foraging speed during 1200-1300 hours.

Maximum foraging rate of *Apis* species at 1200 h on parental lines of *B. napus*, observed in present study might be due to the fact that the supply of available floral rewards declined by this time because of increased foraging activity. So less time was needed to take the forage from a flower and more flowers were visited by a bee to obtain a required load of pollen or nectar. Meyerhoff (1954) also reported that the amount of nectar in swede rape flowers was high in early morning and late afternoon but lower at midday. Thus hours of day seemed to had played an important role in regulating foraging rates of *Apis* species on *B. napus* because floral rewards of parental lines as well as foraging activity of insect visitors were directly linked to them. Prevailing environmental factors such as temperature, humidity, light intensity etc. vary at different day hours, which also played a direct or indirect role on the activities of honeybees. Comparatively less foraging rate of honeybees during morning and evening hours may be due to lower temperature, lower light intensity and higher relative humidity. Heavy dew and cold winds during morning might be the reason of decreased foraging rate, as concluded by some other workers (Wilson, 1926, 1929; Free, 1960)

Data (Table 1A – 1G) of the present study showed that all the four *Apis* species had more foraging frequency (number of flowers visited/min.) on CMS (female) line flowers as compared to that on R (male) line bloom. Foraging rates of honeybees, irrespective of bee species, at all the fixed four day hours, were significantly higher on female than that on male line flowers. Similarly, the values of foraging frequency, irrespective of bee species and day hours, were also higher on CMS line as compared to the same on R line. Thus it may be concluded that foraging rate of honeybees was significantly faster on CMS line as compared to that on R line. Similarly different foraging rates of insect visitors have been observed by Dashad *et al*. (1992) in case of different cultivars of apple.

In present study, difference in foraging rate of *Apis* specie on male and female lines of *B. napus* may be due to the difference in shape and size of the flowers, expansion of their petals, type of floral reward, quantity and quality of floral rewards, some other morphological and physiological traits of flowers of two lines. The R line flowers offer both nectar and pollen, hence the bees visiting to them were pollen and/or nectar gatherers. While the flowers of CMS line provide only nectar as they did not produce pollen, the foraging bees were only nectar gatherers. Therefore, the honeybees spend more time on R line flowers for collection of nectar and/ or pollen than on CMS line flowers for collection of only the nectar. Adegas and Nogueira Couto (1992) have also shown that nectar collecting bees spend less time per flower as compared to pollen gatherers on *B. napus* L. var. oleifera (cultivar CTC-4). Other workers have given such conclusions that foraging speed or foraging frequency depends upon type of flowers (Prasad and Verghese, 1983) as well as type and quantity of foraging rewards (Rao and Suryanarayana, 1990; Rao, 1991; Dashad et al., 1992).

IV. CONCLUSION

From present study it may be concluded that *A. cerana* and *A. mellifera* had statistically same foraging frequency, which was significantly higher as compared to that of *A. dorsata* and *A. florea* on restorer and cytoplasmically male sterile lines of *B. napus.* Significantly lesser foraging rate was recorded in case of *A. florea*. As number of flowers visited per unit time by a particular insect is one of important factors to assess its pollinating efficiency so, study revealed that *A. cerana* and *A. mellifera* were efficient pollinators on parental lines of *B. napus* in hybrid seed production plots. Foraging rate was also governed by hours of day. Maximum foraging rate of all bee species was noticed at 1200 hours. Foraging frequency of bees was more on CMS line flowers as compared to that on R line bloom. This investigation will provide guidelines for hybrid seed production, pollination and honeybee management technology, as pollination of crops by bees is most effective and cheapest method of increasing crop yield and enhance production of hybrid seeds.

Table-1B. : Number of flowers visited per minute by different *Apis* species at different day hours on R and CMS lines of *B. napus.*

Days Hours	*Apis* species	Number of flowers visited on R line by *Apis* species per minute.	Number of flowers visited on CMS line by *Apis* species per minute.
1000 h	*A. mellifera*	15.500 (4.062)	18.357 (4.390)
	A. cerana	16.501 (4.164)	20.621 (4.649)
	A. dorsata	12.333 (3.648)	18.000 (4.358)
	A. florea	7.000 (2.826)	9.444 (3.225)
1200 h	*A. mellifera*	16.125 (4.121)	17.842 (4.631)
	A. cerana	16.609 (4.191)	20.458 (4.631)
	A. dorsata	12.875 (3.721)	15.875 (4.097)
	A. florea	7.400 (2.891)	8.538 (3.084)

1400 h	*A. mellifera*	15.500 (4.061)	19.810 (4.560)
	A. cerana	16.381 (4.168)	20.650 (4.652)
	A. dorsata	12.636 (3.689)	13.500 (3.804)
	A. florea	6.639 (2.757)	8.954 (3.154)
1600 h	*A. mellifera*	15.000 (3.999)	18.879 (4.454)
	A. cerana	16.545 (4.187)	18.938 (4.458)
	A. dorsata	12.500 (3.674)	13.250 (3.773)
	A. florea	4.428 (2.330)	7.875 (2.966)

Table-1B. :Number of flowers visited per minute by different *Apis* species at different day hours, irrespective of parental line.

Day Hours	*Apis* species :			
	A.mellifera	***A.cerana***	***A.dorsata***	***A.florea***
1000 h	17.429 (4.277)	18.060 (4.355)	15.166 (4.003)	8.222 (3.025)
1200 h	16.984 (4.225)	18.534 (4.411)	14.375 (3.909)	7.969 (2.988)
1400 h	18.075 (4.356)	18.096 (4.369)	13068 (3.746)	7.972 (2.956)
1600 h	16.969 (4.228)	17.710 (4.321)	12.875 (3.723)	6.152 (2.648)

Table-1C.: Average number of flowers visited per minute by different *Apis* species on R and CMS line rows, irrespective of day hour.

***Apis* species**	***B napus lines***	
	R Line	**CMS Line**
Apis mellifera	15.782 (4.086)	18.947 (4.457)
Apis cerana	16.259 (4.152)	19.941 (4.574)
Apis dorsata	12.586 (3.683)	15.156 (4.008)
Apis florae	6.364 (2.701)	8.703 (3.107)

Table-1D.: Number of flowers visited per minute by different *Apis* species at different day hours.

***Apis* species**	***B napus lines***	
	R Line	**CMS Line**
1000 h	12.834 (3.675)	15.728 (4.042)
1200 h	13.242 (3.731)	16.606 (4.156)
1400 h	12.786 (3.669)	15.678 (4.035)
1600 h	12.118 (3.547)	14.734 (3.913)

Table-1E.:Number of flowers visited per minute by *Apis* species irrespective of bee species and parental line.

Day hour	1000 h	1200 h	1400 h	1600 h
Number of flower visited per minute	14.465 (3.883)	14.720 (3.915)	14.258 (3.856)	13.426 (3.730)

Table-1F. :Number of flowers visited per minute by different *Apis* species irrespective of day hours and parental line.

Apis species	*A.cerana*	*A.mellifera*	*A. dorsata*	*A.florea*
Number of flower visited per minute	18.100 (4.363)	17.364 (4.272)	13.871 (3.846)	7.534 (2.904)

Table-1G.:Number of flowers visited per minute by *Apis* species, Irrespective of bee species and day hours on R and CMS rows.

Day hour	R Line	CMS line
Number of flower visited per minute	12.748 (3.655)	15.687 (4.036)

$CD_{0.05}$

For day hours = 0.109
For *Apis* spp. = 0.109
For parental lines = 0.077
For interaction day hours x *Apis* spp. = Non significant
For interaction day hours x Parental lines = Non significant
For interaction *Apis* species x Parental lines = Non significant
For interaction day hours x *Apis* spp. x Parental line = Non significant

Figures in parenthesis are $\sqrt{n+1}$ transformations.

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