



Diversity, abundance and pollination efficiency of honey bees on *Raphanus sativus* L. at Hisar, Haryana (India)

Pritish Jakhar*, Yogesh Kumar, Ombir and Arun Janu
Department of Entomology, CCS HAU, Hisar, 125004, India
*e-mail: pritishjakhar23@gmail.com

(Received: May 06, 2015; Revised received: November 17, 2015; Accepted: November 20, 2015)

Abstract: Radish, (*Raphanus sativus* L.) var. Punjab Safed was planted to study the insect pollinator's diversity, abundance and their pollination efficiency, at the Vegetable Sciences Research Farm, CCS Haryana Agricultural University, Hisar, India. Observations of most frequent pollinators were taken throughout the blooming period of the crop during March 2011. The hymenopterans were the major floral visitors, comprising of ten species from three families viz., Apidae, Vespidae and Scoliidae, followed by dipterans (three species from one family) viz., Syrphidae, lepidopterans (five species from four families) viz., Pieridae, Nymphalidae, Papilionidae and Arctiidae. Among these, *A. florea*, *A. mellifera*, *A. dorsata* and *A. cerana* were found to be the most frequent visitors. The abundance of *A. mellifera* was highest (6.8 bees/m²/5 minutes) followed by *A. florea* (5.1 bees/m²/5 minutes), *A. dorsata* (3.5 bees/m²/5 minutes) and *A. cerana* (1.4 bees/m²/5 minutes). Irrespective of species, the bee population was highest at 1100-1300 h of the day. *A. cerana* and *A. florea* had highest and lowest foraging rate 10.3 and 8.9 flowers/minute, irrespective of day hours, whereas (irrespective of species) foraging rate during 0900-1100h was observed highest 14.5 flowers/minute. *A. cerana* had highest foraging speed 7.5 seconds/flower and *A. mellifera* (8.4 seconds/flower) had least, irrespective of day hours whereas (irrespective of species) foraging speed during 1500-1700h was observed highest 14.8 seconds spent per flower. Based on pollination index (Number of loose pollen grains sticking on the body of bee x abundance), *A. mellifera* was found to be the most efficient pollinator of radish flowers followed by *A. dorsata*, *A. florea* and *A. cerana* under agro-ecological conditions of Hisar, (India).

Key words: Abundance, Foraging rate, Foraging speed, Pollination index, Radish

Introduction

Radish, *Raphanus sativus* L. a member of cruciferae family is an important vegetable crop widely cultivated both on commercial scale and in kitchen garden in Asia including India for its roots, pods as well as seed production. In nature, only about 5 per cent of the flowers are self-pollinated and 95 per cent animal pollinated (Tewari and Singh, 1983). Entomophily, accounts for 90 per cent of animal pollination (Richards, 1986; Buchmann and Nabhan, 1996). Radish is a cross pollinated crop which has entomophilous flowers, pollinated by honey bees, flies, bumble bees, some hymenopterans, dipterans, coleopterans, lepidopterans, etc. Bees are the best among all insect pollinators. The honey bees, bumble bees and many species of solitary bees are all prolific pollinators of main field and horticultural crops. Butterflies and moths are occasional pollinators, and do pollination of crops while feeding on nectar from one flower to another. Likewise, many beetles visit flowers to prey on other insects, feed on the nectar and pollen, or on other parts of the plant. Consequently pollens often stick to their body and inadvertently transferred between flowers. Flies, hoverflies and parasitic wasps are effective pollinators because they visit flowers to feed upon nectar (or in some species pollen) for essential nutrients for egg maturation and extending their life-span. Being a cross-pollinated crop, its seed production is expected to be affected by the visits of pollinating insects. Losey and Vaughan (2006) found that native pollinators-almost exclusively bees- may be responsible for almost 3.07 billion dollars of fruits and vegetables produced in the United States.

The present studies were conducted with the objectives to know pollinators diversity, abundance and pollination efficiency of honey bee species.

Materials and Methods

Pollination studies in radish variety, punjab safed conducted at research farm of the department of vegetable sciences at university. The crop was raised as per agronomic practices in the package of practices for horticultural crops of CCS Haryana Agricultural University, Hisar, India (Anonymous, 2009).

Diversity of insect pollinators: Insect visitors and pollinators of radish flowers were collected throughout flowering period of the crop at different hours of the day by using a cone type hand net. The collected insects were preserved and got identified.

Abundance of insect visitors: Abundance (number of visitors/square meter area of crop/5minutes) of major pollinators, was recorded from five randomly selected prescribed areas. These observations were recorded from 7:00 am to 7:00 pm at an interval of 2:00 hours. Observations were recorded for 3 days each after the initiation of 10% flowering in the crop, at peak flowering and before the cessation of flowering in the crop.

Foraging behaviour of insect visitors: Different aspects of foraging behaviour of the most frequent visitors associated as insect pollinators of radish flowers were recorded as follows:

Foraging speed: was recorded in terms of time spent/flower (seconds).

Foraging rate: of major pollinators was recorded in terms of flowers visited/minute. Foraging speed and foraging rate of each pollinator

was recorded at peak flowering period. Ten observations were made for each pollinator.

Working behaviour: whether working from top or side of flower

Loose pollen grains sticking on the body of insects visitors:

For estimating the number of loose pollen grains sticking to the body of major insect pollinator species, the bees were captured gently by forceps from the flowers to avoid shaking of body, and the hind legs of those pollinators, which collect the pollen on their hind legs, were amputated. Insects were captured at the time of peak flowering and was kept in 70% alcohol in vials and were shaken vigorously to wash out pollen grains from their bodies. The numbers of pollen grains were counted with the help of a haemocytometer under the microscope. Ten individuals of each insect species were captured for counting the number of loose pollen grains. Comparative pollination efficiency of different insect pollinators was worked out.

Pollination efficiency: Comparative pollination efficiency of different bee species viz *A. dorsata*, *A. mellifera*, *A. florea*, and *A. cerana*, were calculated based on their relative abundance and the number of loose pollen grains sticking to their bodies by using the formula given below-

Pollination efficacy = Number of loose pollen grains sticking on the body of the bee X Abundance of insect pollinator on radish flowers

Statistical analysis: All the data pertaining to relative abundance, foraging speed, foraging rate, and loose pollen grains, were statistically analyzed by using two factorial CRD

Results and Discussion

Insect visitors collected from flowers of radish seed crop are listed in table-1. The hymenopterans were the major floral visitors comprising of ten species from three families viz., Apidae [(*Apis mellifera* L., *A. cerana indica* F. *A. dorsata* F., *A. florea* F., *Xylocopa fenestrata* F. and *X. aestuans* (L.), *Ceratina viridissima* Dalla Torre)], Vespidae [(*Vespa orientalis* L., and *Polistes olivaceus* F.) and Scoliididae (*Campsomeris* sp)]. They were followed in order of diversity by dipterans (three species from one family) viz., Syrphidae (*Eristalinus* sp., *Syrphus* sp. and *Halophilus fasiatus* Walker), lepidopterans (five species from four families) viz., Pieridae [*Pieris brassicae* (L.), and *Terias hecabe* L.], Nymphalidae [*Danaus chrysippus* (L.)], Papilionidae (*Papilio demoleus* L.) and Arctiidae (*Utethesia pulchella* L.). Sihag (1986) recorded that nine species of Hymenopterans (*Andrena ileradai* Cameron, *A. leaena*, *Apis. florea*, *A. dorsata*, *A. mellifera* L., *Halictus* sp., *Melisodes* spp., *Xylocopa fenestrata* F. and *Pitthus smargdulal*) were abundant visitors of radish for both pollen and nectar collection. Priti et al. (2001) revealed that the pollinators of radish included *A. florea*, *A. mellifera*, *A. dorsata*, *Halictus* sp., *Chrysomya bezziana* Villeneuve, *Gasterophilus* sp., *Sarcophaga* sp. Free (1993) reported that plants with many flowers attract more floral visitors than those with fewer flowers. Coriander flowers were visited by 34 species of insects belonging to 18 families and 8 orders. Apoidea (35.9%), Diptera (47.8%) and Hymenoptera (13.2%) were the three major groups comprising 96.9% of the total visitors (Chaudhary and Singh, 2007). Meena et al., 2015 reported that large population of insects visits coriander and fennel seed spices and other crops right from initiation of flowering to harvesting of crops, normally received 25 and 24

Table-1: List of insect visitors/pollinators of radish (*Raphanus sativus*) flowers during 2011 at Hisar, (India)

Scientific name	Family	Order
<i>A. mellifera</i> L.	Apidae	Hymenoptera
<i>A. cerana indica</i> F.	Apidae	Hymenoptera
<i>A. dorsata</i> F.	Apidae	Hymenoptera
<i>A. florea</i> F.	Apidae	Hymenoptera
<i>X. fenestrata</i> F.	Apidae	Hymenoptera
<i>X. aestuans</i> L.	Apidae	Hymenoptera
<i>C. viridissima</i> Dalla Torre	Apidae	Hymenoptera
<i>Campsomeris</i> sp.	Scoliididae	Hymenoptera
<i>P. olivaceus</i> F.	Vespidae	Hymenoptera
<i>V. orientalis</i> L.	Vespidae	Hymenoptera
<i>Danaus chrysippus</i> (L.)	Nymphalidae	Lepidoptera
<i>Pieris brassicae</i> L.	Pieridae	Lepidoptera
<i>Terias hecabe</i> L.	Pieridae	Lepidoptera
<i>Papilio demoleus</i> L.	Papilionidae	Lepidoptera
<i>Utethesia pulchella</i> L.	Arctiidae	Lepidoptera
<i>Eristalinus</i> sp.	Syrphidae	Diptera
<i>Halophilus fasiatus</i> Walker	Syrphidae	Diptera
<i>Syrphus</i> sp.	Syrphidae	Diptera

Table-2: Abundance of major insect pollinators on blossoms of radish (*Raphanus sativus*) seed crop during March, 2011 at Hisar, (India)

Species	Number of bees/m ² /5 minutes during different day hours						Mean A
	0700-0900	0900-1100	1100-1300	1300-1500	1500-1700	1700-1900	
<i>A. mellifera</i>	1.3	6.9	10.8	9.7	8.2	3.5	6.8
<i>A. dorsata</i>	1.1	3.9	5.3	5.2	3.5	2.2	3.5
<i>A. florea</i>	1.3	3.4	7.6	7.8	6.8	3.4	5.1
<i>A. cerana</i>	0.9	1.3	1.6	1.8	1.6	1.0	1.4
Mean B	1.2	3.9	6.3	6.1	5.0	2.5	

Each value represents mean of 5 observations at each sampling time; Analysis has been done after adding 0.5 in each observation

Factors	SE(m)	SE(d)	C.D.
Bee species	0.7	0.9	1.8
Day hours	0.7	1.0	2.0
Bee species X day hours	1.6	2.251	N/S

floral visitors, respectively in semi-arid and arid conditions of Rajasthan. Honeybees are to be considered as primary pollinators of all seed spice crops and among honeybees, *Apis florea* contributed greatest percentage followed by *A. mellifera* and *A. dorsata* for pollination. Different studies showed that over 50 species of insects visited flowers of different species of selected crops during their flowering periods. The visiting preferences of insects to flowers of different crops differed among the crop species and insect species as well (Devkota, 2000; Dhakal, 2003; Neupane, 2006 and Thapa, 2002).

Abundance of major insect pollinators on blossoms of radish seed crop during March, 2011 is presented in table-2. The mean population of different bee species ranged from 1.4 (*A. cerana*) to 6.8 (*A. mellifera*) bees/m²/ 5 minutes. *A. mellifera* had highest population (6.8 bees/m²/ 5 minutes) followed by *A. florea* (5.1 bees/m²/ 5 minutes), *A. dorsata* (3.5 bees/m²/ 5 minutes) and *A. cerana* (1.4 bees/m²/ 5 minutes), irrespective of day hours. The mean abundance of major bee pollinators ranged from 1.2 (0700-0900h) to 6.3 (1100-1300h) bees/m²/ 5 minutes, irrespective of bee

Table-3: Foraging rate of different honey bee species on radish (*Raphanus sativus*) flowers at different hours of the day during March, 2011 at Hisar, (India)

Species	Foraging rate (number of flowers visited per minute)						Mean A
	0700-0900	0900-1100	1100-1300	1300-1500	1500-1700	1700-1900	
<i>A. mellifera</i>	12.0	15.4	11.9	7.7	6.4	5.2	9.8
<i>A. dorsata</i>	11.2	14.6	12.7	7.7	6.1	4.5	9.5
<i>A. florea</i>	11.1	12.3	13.3	6.9	5.7	4.5	8.9
<i>A. cerana</i>	11.5	15.7	14.2	8.7	6.2	5.6	10.3
Mean B	11.5	14.5	13.1	7.8	6.1	4.9	

Each value represents mean of 10 observations at each sampling time

Factors	SE(m)	SE(d)	C.D.
Bee species	0.5	0.7	N/S
Days	0.6	0.9	1.7
Bee species X day hours	1.2	1.7	N/S

Table-4: Foraging speed of different honey bee species on radish (*Raphanus sativus*) flowers at different hours of the day during March, 2011 at Hisar, (India) *Raphanus sativus* flowers at different hours of the day during March, 2011 at Hisar

Species	Foraging speed (seconds spent per flower)						Mean A
	0700-0900	0900-1100	1100-1300	1300-1500	1500-1700	1700-1900	
<i>A. mellifera</i>	1.8	2.1	4.1	11.7	17.8	12.9	8.4
<i>A. dorsata</i>	1.8	2.9	3.4	11.4	16.8	13.9	8.3
<i>A. florea</i>	1.7	2.6	3.5	13.9	11.9	12.1	7.6
<i>A. cerana</i>	1.8	1.8	2.4	11.7	12.5	14.7	7.5
Mean B	1.8	2.4	3.3	12.1	14.8	13.4	

Each value represents mean of 10 observations at each sampling time

Factors	SE(m)	SE(d)	C.D.
Bee species	0.6	0.8	N/S
Days	0.7	0.9	1.9
Bee species X day hours	1.3	1.9	N/S

Table-5: Pollination efficiency of different bee species on radish (*Raphanus sativus*) flowers during March, 2011 at Hisar, (India)

Species	No. of pollen grains sticking on the body of insect pollinators	Average abundance (insect pollinators /m ² /5 min)	Pollination efficiency	Rank
<i>A. mellifera</i>	332500 ± 11,516.9	6.8	2261000	1 st
<i>A. dorsata</i>	448750 ± 11,996.8	3.5	1570625	2 nd
<i>A. florea</i>	90000 ± 5,204.2	5.1	459000	3 rd
<i>A. cerana</i>	211250 ± 8,003.9	1.4	295750	4 th

Each value represents mean of 10 observations

population. The maximum abundance of bee species was observed during 1100-1300h (6.3 bees/m²/ 5 minutes) followed by 1300-1500h (6.1 bees/m²/ 5 minutes), 1500-1700h (5.0 bees/m²/ 5 minutes), 0900-1100h (3.9 bees/m²/ 5 minutes), 1700-1900h (2.5 bees/m²/ 5 minutes) and 0700-0900h (1.2 bees/m²/ 5 minutes). Kim Chance (2006) reported that honey bees as the most important pollinators of radish constituting 77 to 94 per cent of the insect visitors' population and bee pollination increased seed crop yield by 22 per cent. In present investigation it was found that *A. dorsata*

F., *A. mellifera* L., *A. florea* F. *A. cerana* F., *C. viridissima* Dalla Torre, *X. aestuans* L., *X. fenestrata* F., *V. orientalis* L., *P. olivaceus* F. and *Campsomeris* sp. were visiting the flowers. Kant et al., 2013 noticed that different honey bees visited on different seed spice crops in which, *Apis florea* L. was most abundant and active foraging on these crops during entire flowering period followed by *Apis dorsata* L. and *Apis mellifera* L., respectively. The peak abundance of *Apis mellifera*, *Apis cerana* and *Apis dorsata* was recorded 4.16, 6.33 and 1.00 numbers per meter square, respectively at 2:00 pm whereas abundance ranged from 1.83 to 4.16, 1.66 to 6.33 and 0.17 to 1.00 numbers per meter square *A. mellifera*, *A. cerana* and *A. dorsata* between 10:00 am to 4:00 pm (Pudasaini et al., 2014)

Data in table-3 and 4 revealed that mean foraging rate of *A. cerana* during peak flowering was observed maximum (10.3 flowers visited/minute) followed by *A. mellifera* (9.8 flowers visited/minute), *A. dorsata* (9.5 flowers visited/minute), and *A. florea* (8.9 flowers visited/minute). Mean foraging rate irrespective of honey bee species during different day hours was highest between 0900-1100h (14.5 flowers visited/minute) and minimum between 1700-1900h (4.9 flowers visited/minute). *A. cerana* had higher foraging rate (15.2 flower-1) than *A. mellifera* (13.1) and *A. dorsata* (10.6) and likewise visited more number of plants per minute (3.6, 2.7 and 2.1 min-1, respectively) (Chaudhary and Singh, 2007). Pudasaini et al., (2014) showed that higher numbers of flowers were visited by *Apis cerana* F. (6.5 and 26.0 flowers) as compared to *Apis mellifera* L. (2.33 and 21.67 flowers) and *Apis dorsata* F. (9.33 and 15.83 flowers) at 10:00 am and 2:00 pm of the day, respectively under natural condition.

Foraging speed of *A. mellifera* during peak flowering irrespective of day hours was observed minimum (8.4 seconds/flower) followed by *A. dorsata* (8.3 seconds/flower), *A. florea* (9.8 seconds/flower), and *A. cerana* (7.5 seconds/flower). Foraging speed of honey bee species during different day hours was observed maximum between 1500-1700h (14.8 seconds/flower) and minimum between 0700-0900h (1.8 seconds/flower). Kapil et al. (1971) recorded that *A. dorsata*, *A. florea*, and *A. cerana indica* began foraging at 0700 to 1000 hr on rape seed and mustard. Peak foraging activity was recorded between 1230 to 1400 hr and ceased by 1700 hr. Foraging preference of *Apis dorsata* was recorded between 7.30 to 11.00 am and 3.00 to 5.30 pm during early, mid and late periods of flowering (Neupane et al., 2006)

Data in table-5 revealed that *A. dorsata* had maximum number of pollen grains (average 448750 pollen grains) followed by *A. mellifera* (average 332500 pollen grains), *A. cerana* (average 211250 pollen grains), and *A. florea* (average 90000 pollen grains). The abundance of *A. mellifera* (6.8/m²/5 minutes) was highest followed by *A. florea* (5.1/m²/5 minutes), *A. dorsata* (3.5/m²/5 minutes) while the abundance of *A. cerana* was least (1.4/m²/5 minutes). The pollination index calculated for *A. mellifera* was highest (2261000) followed by *A. dorsata* (1570625), *A. florea* (459000), and *A. cerana* (295750). Therefore, it is concluded that *A. mellifera* was most efficient pollinator followed by *A. dorsata*, *A. florea*, and *A. cerana* on *R. sativus* flowers under agro-ecological conditions of Hisar (India). Though the number of loose pollen grains sticking on the body of *A. dorsata* was much higher than that of *A. mellifera* yet

it was observed to be the most efficient pollinator due to its higher abundance on radish flowers. All the foragers (100%) of Dalio, 2015 reported that all the foragers (100%) of *Apis mellifera* and *Apis dorsata* visiting parental lines (R and CMS) lines of *Brassica napus* were top workers and touched the reproductive parts of flowers followed by *Apis cerana* (88.14 & 97.35% and 86.32 & 96.12%) and *Apis florea* (66.25 & 83.94% and 62.75 & 83.83%), respectively. It was concluded that *A. mellifera* and *A. dorsata* were the best pollinators with best pollination efficiency followed by *A. cerana* and *A. florea*.

References

- Anonymous: Radish In: Package of practices for horticultural crops. Chaudhary Charan Singh Haryana Agricultural University, Hisar, India, p. 182-183 (2009).
- Buchmann, L.S. and Nabhan, P.G.: The Forgotten Pollinators. Island Press, Washington DC, USA, p 292 (1996).
- Chaudhary, O. P. and Singh, J.: Diversity, temporal abundance, foraging behaviour of floral visitors and effect of different modes of pollination on coriander (*Coriandrum sativum* L.). *Journal of Spices and Aromatic Crops*, **16**: 8-14 (2007).
- Dalio, J. S.: Comparison of foraging behavior of *Apis* species related to pollinating efficiency on parental lines of *Brassica napus* L. *International Journal of Development Research*, **5**: 3681-3682 (2015).
- Devkota, F. P.: Impacts of bee pollination on the yield of broccoli (*Brassica campestris* var. *botrytis* L.) under Chitwan condition. M. Sc. Thesis, Institute of Agriculture and Animal Sciences, Rampur, Chitwan, Nepal (2000).
- Dhakal, G.: Efficiency of *Apis mellifera* L. and *Apis cerana* F. for pollinating mustard and buckwheat. M. Sc. Thesis, Institute of Agriculture and Animal Sciences, Rampur, Chitwan, Nepal (2003).
- Free, J. B.: Insect pollination of Crops (2nd ed.). Academic Press, London, U.K., p. 684 (1993).
- Kant, K., Singh, B., Meena, S.R., Ranjan, J.K., Mishra, B.K., Solanki, R. K. and Kumar, M.: Relative abundances and foraging behaviour of honey bee species on minor seed spice crops. *International Journal of Seed Spices*, **3**: 51-54 (2013).
- Kapil, R.P. and Brar, H.S.: Foraging behaviour of *Apis florea* F. in relation to *Brassica campestris* var. *Toria* In: Proc. XXII Intern. Apic. Cong., Moscow, p 335 (1971).
- Kim Chance, M. L. C.: <http://www.agric.wa.gov.au/servlet/page> (2006).
- Losey, J. and Vaughan, M.: The economic value of ecological services provided by Insects. *Bioscience*, **56**: 311-323 (2006).
- Meena, N.K., Singh, B., Kant, K., Meena, R.D. and Solanki, R.K.: Role of insect pollinators in pollination of seed spices-A review. *International Journal of Seed Spices*, **5**: 1-17 (2015).
- Neupane, K.R., Dhakal, D.D., Thapa, R.B. and Gautam, D.M.: Foraging preference of giant honeybee, *Apis dorsata* F., to selected horticultural crops. *Journal of Institute of Agriculture and Animal Sciences*, **27**: 87-92 (2006).
- Pudasaini, Rameshwar, Thapa and Bahadur, R.: Foraging Behavior of Different Honeybee Species under Natural Condition in Chitwan, Nepal. *European Journal of Academic Essays*, **1**: 39-41 (2014).
- Priti, Mishra, R.C. and Sihag, R.C.: Role of insect pollination in seed production of radish (*Raphanus sativus* L.). *Seed Research*, **29**: 231-234 (2001).
- Richards, A.J.: Plant Breeding Systems. Chapman and Hall, New York, USA, p 135-188 (1986).
- Sihag, R.C.: Insect pollination increases seed production in cruciferous and umbelliferous crops. *Journal of Apicultural Research*, **25**: 121-126 (1986).
- Tewari, G.N. and Singh, K.: Role of pollinators in vegetable seed production. *Indian Bee Journal*, **45**: 51 (1983).
- Thapa, R. B.: Insect pollinators of some crop plants in Chitwan. *NAHSON Bull.*, **12-13**: 19-21 (2002).