emergent
Life Sciences Research

Research Article

Pollinator diversity and foraging behavior of *Apis mellifera* Linnaeus and *Apis cerana* Fabricius on Chinese cabbage (*Brassica rapa* Linnaeus subspecies *chinensis*) grown under different farming systems

Ankush Dhuria, Raj Kumar Thakur, Priyanka Rani, Pallavi Rana

Received: 14 March 2022
Accepted: 13 June 2022
Online: 16 June 2022

Authors:
A. Dhuria, R. K. Thakur, P. Rani ✉
P. Rana
Department of Entomology, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan, India

✉ priyankabhargava019@gmail.com

Emer Life Sci Res (2022) 8(1): 165-174

E-ISSN: 2395-6658
P-ISSN: 2395-664X

DOI: https://doi.org/10.31783/elsr.2022.81165174

Abstract

The present study was on pollinator diversity and foraging behavior of *Apis mellifera* Linnaeus and *Apis cerana* Fabricius on Chinese cabbage (*Brassica rapa* Linnaeus subspecies chinensis) grown under different farming systems. A total of 19 insects belonging to 16 genera under 7 families and 3 orders were recorded on Chinese cabbage. Among all insect visitors, *A. mellifera* (8.85 / 100 flowers) was the most dominant visitor. Significantly higher abundance was recorded in SPNF system followed by the control and CF system, respectively. The insect pollinators showed a positive correlation with temperature and a negative correlation with humidity. The average number of flowers visited by both foragers in one minute was significantly more in SPNF system followed by the control and CF system. The average time spent per flower by both foragers was significantly more in the CF system followed by the control and SPNF system. The number of loose pollen grains sticking to the body of insect pollinators recorded in SPNF system and CF system was statistically the same. Hence, it can be concluded that pollinators prefer SPNF system as compared to CF system and control. So, due to enhanced pollination in SPNF system, farmers may obtain more yields if they are consistent with the timely application of indigenous farm products.

Keywords Chinese cabbage, honey bees, pollinators

Introduction

Chinese cabbage (*Brassica rapa* Linnaeus subsp. chinensis) is a non-heading type of cabbage that originated in China [1]. It is a winter season crop and thrives well at a temperature ranging from 15-21°C. It is the most widely grown vegetable in China (northern areas of the country), Korea, and Taiwan.

Natural farming is a type of farming system with a low cost of investment where farmers do not need to purchase fertilizers and pesticides for the healthy growth of their crops. This concept was highlighted by Shri Subhash Palekar in 2016 [2]. In the Subhash Palekar Natural Farming (SPNF) system, the nutrient requirements, as well as protection of plants from various pest and diseases, are mostly met with the application of some indigenous farm products. Four pillars of SPNF help in increasing soil microfauna, preventing soil and seed-borne diseases, conserving soil moisture, improving soil structure, etc., while the plant protection measures in SPNF include jeevamrit, beejamrit, neemastra (neem missile), agniastra (agri missile), and brahmastra indeed preventing pest occurrence [3-4]. The abundance of insect pollinators in the bloom of various crops depends upon the climatic conditions, geographical distribution, edaphic factors, and availability of natural sites. Several sampling methods such as scan sampling, pan traps, and trap nests are used to assess pollinator diversity [5]. In different types of habitat and biogeographical regions, pan traps and transact walk were suitable for recording insect pollinator diversity [6]. Crops belonging to *Brassicaceae* family are predominantly insect-pollinated due to the presence of abundant nectar and pollen [7] recorded wide variety of flower visitors in Brassica crops which include solitary bees (*Leioproctus* and *Lasioglossum*), social bees, some Coleopterans, Lepidopterans, and Dipterans.

Pollination is the movement of pollen from the anthers to the stigma of flowers and is an important phenomenon for maintaining healthy and biodiverse ecosystems. Pollination by bees, birds, bats, and other animals contributes to reproductive success in 88 percent of the world's flowering plants [8]. The individuals that help in pollination are termed as pollinators who play a key role in increasing the yield of cruciferous crops like broccoli, with good quality seeds due to pollination of the total pollination activities, over 80 percent is performed by insects, and bees contribute nearly 80 percent of the total insect pollination [9]. Managed honey bees (*Apis mellifera* L. and *A. cerana* F.) are generally used to supplement pollination services provided by wild bees thus enhancing crop yield.

Foraging behavior in honey bees is one of the distinctive behavior including the location and consumption of resources, as well as their retrieval and storage, within the context of the larger community. Besides foraging behavior, another factor that determines the relative importance of anthophilous insects as pollinators is the number of loose pollen grains on the insect body [10]. The number of loose pollen grains on the body of an insect varies with the species and the plant variety on which it is working [11]. The mortality of forager bees increases when they forage in crops sprayed with pesticides. Due to this reason, alternative approaches like organic farming and natural farming are being adopted by some farmers. A lot of awareness programs and research is required in this context.

Methodology

The present study was carried out in Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan (HP) situated at 31.27° N latitude and 76.94° E longitude during the year 2019-2020. The diversity of insect visitors on mustard was recorded by sweep net capture and scan sampling method. In scan sampling, diversity was recorded on 100 flowers in each of the 3 plots on 3 sunny days. The sampling was done by walking slowly along a set path in between rows. The insect visitors were counted by looking at each flower one by one in sequences. In the sweep net capture method, the net sweeps were taken at five spots equally distributed in the field [12]. Five such transects were used for recording observations. The relative abundance of visitors (number of insect visitors/hundred flowers) was also studied by the above two methods during 1000, 1200, and 1500 h of the day for 3 days a week during the blooming period. The foraging rate and foraging speed of *Apis* spp. were recorded by counting the number of flowers that honey bee visits per minute, using the stopwatch, and 10 replications were taken at 1000, 1200, and 1500 h. The observation was recorded for three sunny days at the full bloom stage. For counting loose pollen grains on the body of insect visitors, it was captured with the help of forceps and kept in 5 ml glass vials with 70 percent alcohol after amputating the leg (except *Eristalis* sp.) of the forager. The vials were then rinsed thoroughly to remove the pollen from the body of the forager. From the rinsate, an aliquot of 0.02 ml (replicated three times) was taken for counting the pollen grains in the hemocytometer by observing under the microscope.

Results

The observations on insect pollinators collected by scan sampling and sweep net capture revealed that 19 insects belonging to 16 genera under 7 families and 3 orders were recorded on Chinese cabbage (Table 1). Hymenopterans were recorded as the most dominant pollinators of Chinese cabbage bloom in all the farming systems. Hymenopteran pollinators belonged to three families namely Apidae (4) Ichneumonidae (1) Halictidae (2). *Apis mellifera, A. cerana, A. florea, Xylocopa* sp. (wild bee), and *Bombus haemorrhoidalis* (wild bee) represented the family Apidae. *Megarhyssa* sp. belonged to Ichneumonidae whereas; *Halictus* sp. (wild bee) and *Sphecodes* sp. (wild bee) belonged to Halictidae.

Table 1. List of insect visitors collected in Chinese cabbage bloom

Order	*Family*	*Name of the species*
Hymenoptera	Apidae	*Apis mellifera* Linnaeus
		Apis cerana Fabricius
		Apis florea Fabricius
		Xylocopa sp. (wild bee)
		Bombus haemorrhoidalis Smith (wild bee)
	Ichneumonidae	*Megarhyssa* sp.
	Halictidae	*Halictus* sp.(wild bee)
		Sphecodes sp. (wild bee)
Diptera	Syrphidae	*Episyrphus balteatus* De geer
		Eristalis tenax Linnaeus
		Eristalis sp.
		Metasyrphus corollae
		Ischidon scutellaris Fabricius
	Calliphoridae	*Calliphora* sp.
Lepidoptera	Nymphalidae	*Agalis cashmiriensis* Kollar
		Danus chrysippus Linnaeus
		Neptis hylas Linnaeus

In diptera, there were 6 insects belonging to two families. Five insect visitors were from the family Syrphidae (*Episyrphus balteatus, Eristalis tenax, Eristalis sp., Metasyrphus corolla, Ischidon scutellaris*) and one insect visitor from Calliphoridae (*Calliphora* sp.). Among Lepidopterans *Agalis cashmiriensis, Danuschrysippus, Neptishylas, Junonia* sp. (family: Nymphalidae), and *Pieris brassicae* (Pieridae) were recorded.

Relative abundance of insect visitors by scan sampling

The data in Table 2, revealed that significantly higher abundance was recorded in the SPNF system followed by the control and CF (Conventional Farming) systems, respectively. Irrespective of the farming system *A. mellifera* was the most abundant visitor followed by *A. cerana*, syrphids, Lepidopterans, and wild bees, respectively. For both farming system and insect visitors, *A. mellifera* was observed to be the most abundant insect pollinator in SPNF system whereas; wild bees were minimum in all farming systems being statistically like Lepidopterans also in the control plot.

Relative abundance of insect visitors by sweep net capture

The observations in Table 3, indicated that the maximum abundance of insect visitors was recorded in SPNF system followed by the CF system and control, respectively. Irrespective of the farming systems, syrphids were the most abundant insect visitor being statistically to *A. mellifera.* The abundance of *A. cerana* was significantly more than wild bees and Lepidopterans in all the farming systems.

Table 2. Relative abundance of insect visitors on Chinese cabbage by scan sampling in different farming systems

Insect visitors	Relative abundance of insect visitors (number/100 flowers) in different farming systems			Mean
	CF**	SPNF***	Control	
A. c. indica	4.96 (2.43)	7.12 (2.84)	4.84 (2.40)	**5.64 (2.56)**
A. mellifera	7.98 (2.99)	9.75 (3.27)	8.83 (3.13)	**8.85 (3.13)**
Syrphids	1.42 (1.55)	2.70 (1.91)	2.11 (1.75)	**2.08 (1.74)**
Wild bees	0.49 (1.21)	0.65 (1.27)	0.44 (1.19)	**0.53 (1.90)**
Lepidopterans	0.67 (1.27)	1.54 (1.57)	1.06 (1.42)	**1.09 (1.46)**
Mean	**3.10 (1.89)**	**4.35 (2.17)**	**3.46 (1.98)**	**3.64 (2.01)**
CD(0.05) Farming systems- 0.047 Insect visitors- 0.061 Farming systems x Insect visitors-0.106				

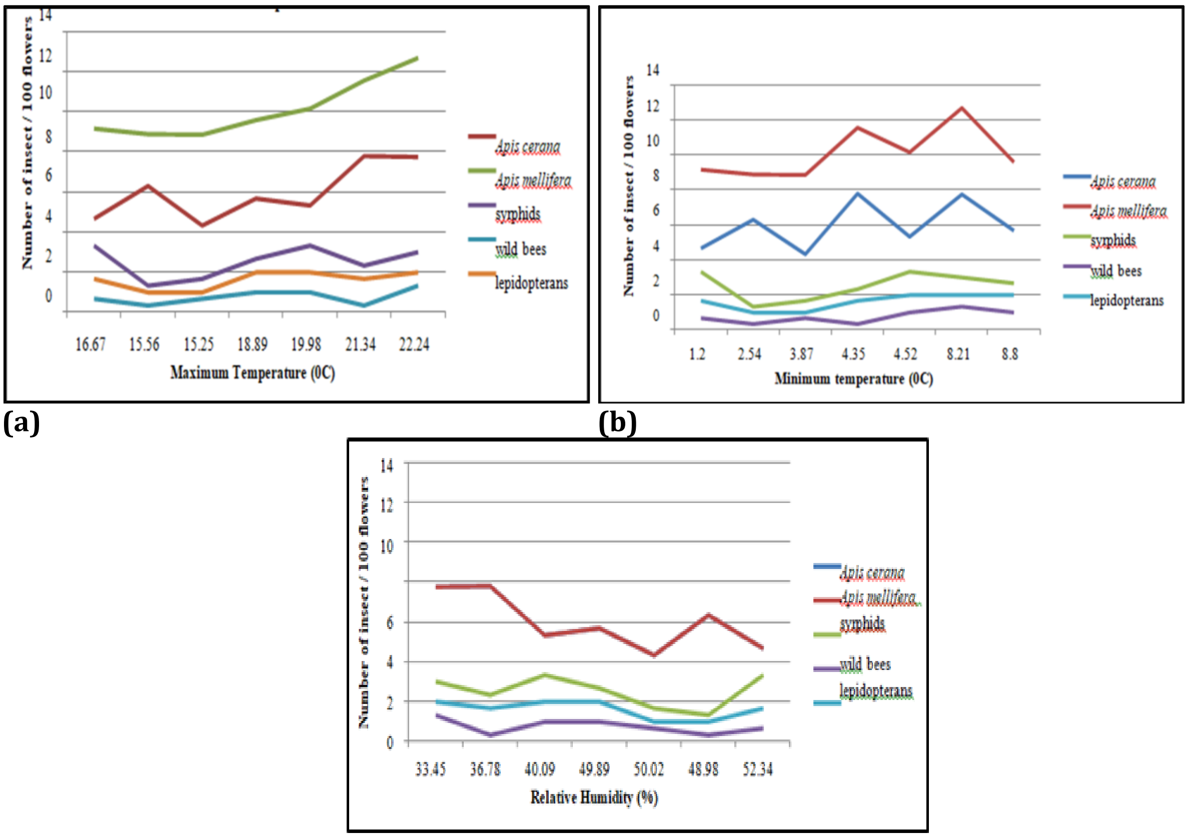
* Figures in the parenthesis are transformed values
**CF- Conventional Farming
***SPNF- Subhash Palekar Natural Farming

Table 3. Relative abundance of insect visitors on Chinese cabbage by sweep net capture in different farming systems

Insect visitors	Relative abundance of insect visitors (number/100 flowers) in different farming systems			Mean
	CF**	SPNF***	Control	
A. c. indica	0.51 (1.22)	1.21 (1.48)	0.41 (1.18)	**0.71 (1.30)**
A. mellifera	1.08 (1.44)	1.16 (1.46)	0.48 (1.21)	**0.90 (1.37)**
Syrphids	0.83 (1.35)	1.38 (1.53)	0.59 (1.25)	**0.93 (1.38)**
Wild bees	0.51 (1.22)	0.65 (1.28)	0.43 (1.19)	**0.53 (1.23)**
Lepidopterans	0.30 (1.14)	0.51 (1.23)	0.36 (1.16)	**0.39 (1.17)**
Mean	**0.64 (1.27)**	**0.98 (1.40)**	**0.45 (1.20)**	**0.69 (1.29)**
CD(0.05) Farming systems- 0.03 Insect visitors- 0.038 Farming systems x Insect visitors- 0.066				

Correlation of abundance of different insect visitors of chinese cabbage with weather parameters

The relative abundance of insect pollinators with weather parameters is presented in Table 4, and Figure.1 (a, b and c). The abundance of *A. cerana*, *A. mellifera* and Lepidopterans showed a significant positive correlation with maximum temperature (r = 0.75, 0.93, and 0.80, respectively) whereas other insect visitors had a non-significant positive correlation with maximum temperature. All insect visitors showed a non-significant positive correlation with minimum temperature. With the



(c)

Figure 1. (a) Relative abundance of insect pollinators in relation to maximum temperature (b) Relative abundance of insect pollinators in relation to minimum temperature (C) Relative abundance of insect pollinators in relation to relative humidity

increase in relative humidity there was a significant decrease in the activity of *A. cerana* and *A. mellifera* (r = -0.80 and -0.94, respectively). Syrphids, wild bees, and Lepidopterans showed a non-significant negative correlation with the relative humidity.

Foraging rate

The data presented in Table 5, revealed that *A. cerana* foraged significantly more flowers in one minute in comparison to the *A. mellifera.* The average number of flowers visited by both foragers in one minute was significantly more in SPNF system followed by the control and CF system. The hive bees visited significantly more flowers per minute during 1200 h followed by 1500 and 1000 h, respectively (Figure. 2).

Table 4. Correlation of abundance of different insect visitors with weather parameters

Weather parameters	Insect visitors				
	A. cerana	*A. mellifera*	*syrphids*	*wild bees*	*Lepidopterans*
Max. Temp. (°C)	0.75	0.93	0.55	0.49	0.80
Min. Temp. (°C)	0.42	0.54	0.20	0.71	0.60
RH (%)	-0.80	-0.94	-0.29	-0.35	-0.49

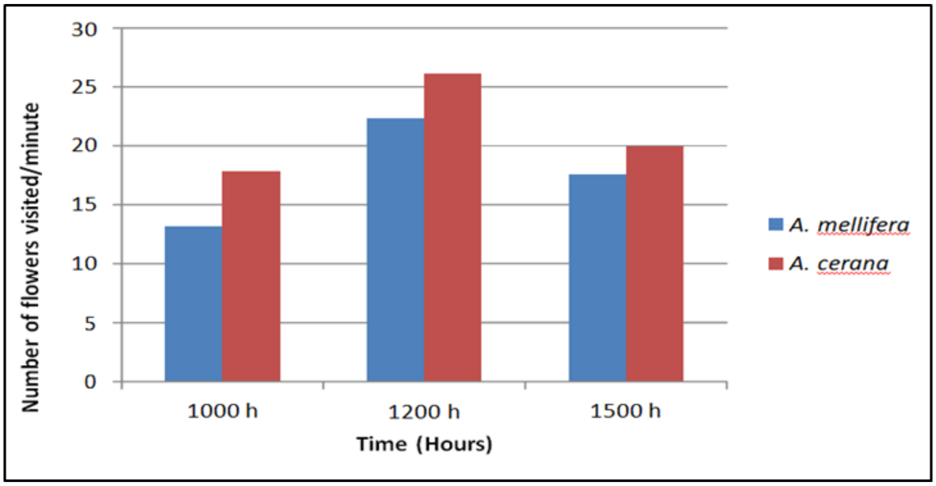


Figure 2. Foraging rate of *A. mellifera* and *A. ceranaduring* different day hours

Foraging speed

The data on foraging speed in different farming systems (Table 6) revealed that *A. mellifera* spent more time per flower as compared to *A. cerana*. The average time spent per flower by both foragers was significantly more in the CF system followed by the control and SPNF system. Time spent per flower by the hive bees was maximum during 1000 h followed by 1500 and 1200 h, respectively (Figure. 3).

Table 5. Foraging rate of *A. cerana* and *A. mellifera* in different farming systems

Farming systems	Number of flowers visited by forager/minute		
	A. mellifera	*A. cerana*	Mean
CF*	16.10	17.89	**17.00**
SPNF**	20.30	22.39	**21.34**
Control	16.64	23.64	**20.14**
Mean	**17.68**	**21.31**	**19.45**
CD(0.05) Farming systems- 0.67 Forager- 0.56 Farming systems x Forager- 0.96 *CF- Conventional Farming, **SPNF- Subhash Palekar Natural Farming			

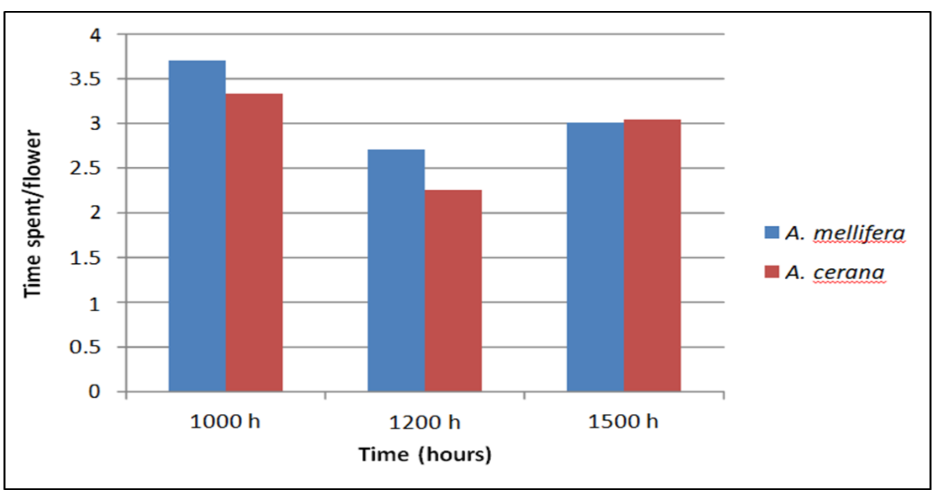


Figure 3. Foraging speed of *A. cerana and A. mellifera* during different day hours

Loose pollen grains

A mellifera carried a maximum mean number of loose pollen grains followed by *A. cerana and Eristali sp.* The number of loose pollen grains sticking to the body of insect pollinators recorded in SPNF system and CF system was statistically the same; however, the lowest number of loose pollen grains was found sticking to bees in control (Figure 4).

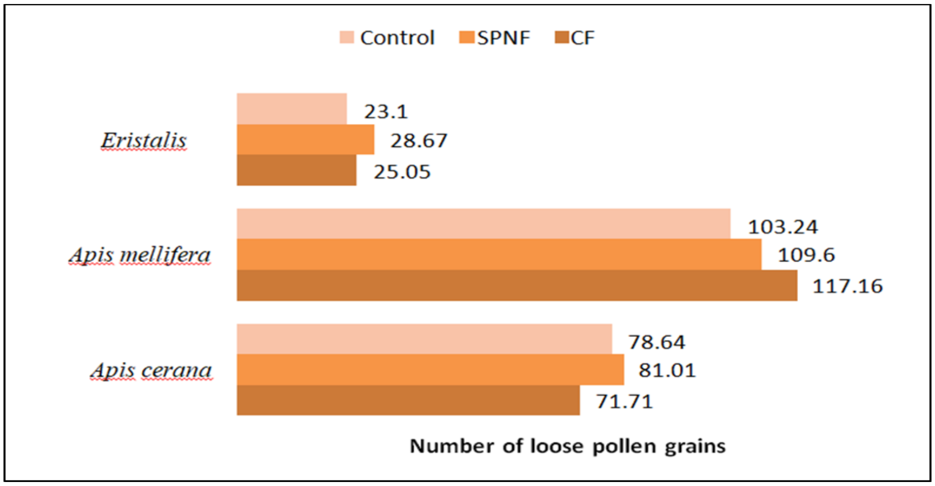


Figure 4. Number of loose pollen grains ('000) on the body of insect visitors in different farming systems

Discussion

Among the insect, visitors collected Hymenoptera was the most dominant order followed by Diptera and Lepidoptera. The data obtained from scan sampling and sweep net capture revealed that *Apis mellifera, A. cerana*, and syrphids were the most frequent visitors that visited mustard bloom in all three farming systems. Several workers [13-17] have also reported Hymenoptera as the most dominant order followed by Diptera visiting the bloom of *brassicaceae* family (mustard, broccoli, and cauliflower) which is in accordance with the present findings. However, the maximum abundance of pollinators was found in SPNF system as compared to other farming systems. This may be due to the higher nectar sugar concentration in the flowering plants of SPNF system. These results are near the study of [18] who observed that varieties with more nectar sugar were found to attract more pollinators. Rader et al., [19] also reported higher pollinator densities in organic farms as compared to conventional farms. In the present findings, *A. mellifera* was the most abundant pollinator followed by *A. cerana* and syrphids in the mustard bloom of all the three farming systems. *A. mellifera* was recorded as the most abundant visitor in the bloom of *brassicaceae* family (mustard, *E. sativa,* and *B. rapa*) [20, 7]. However, the findings by T. Atmowidi [13] and H. Chand [21] revealed *A. ceranaas* the dominant visitor in mustard bloom which is in contradiction to the present findings. The reason for the maximum abundance of *A. mellifera* could be due to the presence of one colony of *A. mellifera* colony in all three farming systems. In our experiments, the catch with sweep net capture was comparatively low as compared to scan sampling. Bhowmik et al., [4] also found low abundance in the sweep net capture method. This could be attributed to the efficiency of insect collectors and pollinators' density at one particular time. In scan sampling, a person works more efficiently as compared to sweep net capture. The present investigations are in contrast with the study of [12] who reported that species composition observed by different sampling methods were similar. So, it can be concluded that only one method is not reliable, all methods have to be employed collectively [22]. H. Chand [21] also recorded a positive correlation between the insect visitors and temperature. Our results are in correlation with Gautam et al., [15] in ridge gourd, pollinators were positively correlated with the temperature and negatively correlated with the relative humidity.

In our observations, the maximum temperature and minimum relative humidity were found during 1100 to 1300 h. This might be the reason for the maximum abundance of insect visitors during this time.

Table 6. Foraging speed of *A. cerana* and *A. mellifera* in different farming systems

Farming systems	Time spent / flower during differenttime		
	A. mellifera	*A. cerana*	Mean
CF*	3.69	2.85	**3.27**
SPNF**	2.75	2.71	**2.73**
Control	3.26	2.89	**3.08**
Mean	**3.23**	**2.82**	**3.03**

CD(0.05) Farming systems 0.17 Forager- 0.14 Farming systems x Forager- 0.24
*CF- Conventional Farming, **SPNF- Subhash Palekar Natural Farming

The present findings revealed that the foraging rate of *A. cerana* was significantly higher as compared to *A. mellifera* in all farming systems. These results are in close confirmation with [23] who observed the maximum foraging rate of *A. mellifera* in mustard sprayed with desi cow urine (20 %). The impact of vermicompost as a soil amendment on plant-pollinator interaction also revealed that the foraging behavior of pollinators is enhanced on plants treated with vermicompost. This may be due to the influence of vermicompost on the floral rewards for pollinators. Our results are in line with where they observed that the foraging rate of *A. cerana* was higher as compared to *A. mellifera. A. mellifera* spent maximum time per flower followed by *A. cerana* revealing that *A. mellifera* is a slow flier in comparison to *A. cerana.* The average time spent per flower by both foragers was significantly more in the CF system followed by the control and SPNF system. Similar results were also reported in radish that maximum time per flower was spent by *A. mellifera* followed by cerana [24-25]. Also recorded was that *A. mellifera* spent maximum time per flower on the mustard crop. In the present investigations, the maximum number of loose pollen grains was carried by *A. mellifera* followed by *A. cerana* and Eristalis sp. These findings are in close conformity with [26] who reported a higher number of loose pollen grains carried by *A. mellifera* followed by *A. cerana* and *Eristalis* sp. in mustard. Similar results were also reported in cherry in which *A. mellifera* carried more loose pollen grains as compared to *A. cerana.* The maximum number of loose pollen grains by *A. mellifera* followed by *A. cerana* and the lowest number was recorded by syrphids [27].

Hence, it can be concluded that pollinators prefer SPNF system as compared to the CF system and control. So, due to enhanced pollination in SPNF system, farmers may obtain more yields if they are consistent with the timely application of indigenous farm products (beejamrit, jeevamrit, ghan-jeevamrit, agniastra, neemastra etc.) used in this system

Conclusion

Hence, it can be concluded that pollinators prefer SPNF system as compared to the CF system and control. So, due to enhanced pollination in SPNF system, farmers may obtain more yields if they are consistent with the timely application of indigenous farm products (beejamrit, jeevamrit, ghan-jeevamrit, agniastra, neemastra etc.) used in this system.

Authors' contributions

AD designed and conducted the field experiments performed data analysis and drafted the manuscript with inputs from all authors. RKT, PR*, PR, collaborated closely with AD in the whole process especially during data analysis. All authors read and approved the final manuscript.

References

[1] P. Hanson, R. Y. Yang, L. C. Chang, L. Ledesma and D. Ledesma **(2009)**. Contents of carotenoids, ascorbic acid, minerals and total glucosinolates in leafy brassica pakchoi (*Brassica rapa* L. chinensis) as affected by season and variety. J. Sci. Food Agric., **89:** 906-914.

[2] R. Bishnoi and A. Bhati **(2017)**. An Overview: Zero Budget Natural Farming. Trends in Biosci., **10:** 9314-9316.

[3] S. Palekar **(2006)**. Shoonya Bandovalada Naisargika Krushi published by Swamy Anand, Agri Prakashana, Bangalore.

[4] T. H. Roultson, S. A. Smith and A. L. Brewster **(2007)**. A comparison of pan trap and intensive net sampling techniques for documenting a bee (Hymenoptera:Apiformes) fauna. J. Kans. Entomol. Soc., **80:** 179-181.

[5] H. K. Sharma, N. Bakshi, R. K. Thakur and M. Devi **(2016a)**. Diversity and density of insect pollinators on sweet cherry (*Prunus avium* I.) in temperate regions of Kullu valley of Himachal Pradesh. J. Entomol. Res., **40:** 123-128.

[6] J. H. Cane, R. L. Minckley and L. J. Kervin **(2000)**. Sampling bees for pollinator community studies: pitfalls of pan-trapping. J. Kans. Entomol. Soc., **73:** 225-231.

[7] R. Rader, W. Edwards, D. Westcott, S. A. Cunningham and B. G. Howlett **(2011)**. Pollen transport differs among bees and flies in a human-modified landscape. Divers. Distrib., **17:** 519-524.

[8] J. Ollerton, R. Winfree and S. Tarrant **(2011)**. How many flowering plants are pollinated by animals? Oikos, **120:** 321-326.

[9] R. Thapa **(2006)**. Honeybees and other insect pollinators of cultivated plants: A review. J. Inst. Agric. Anim., **27:** 1-23.

[10] D. L. Anderson, M. Sedgeley, J. R. T. Short and A. J. Atwood **(1982)**. Insect pollination of Mango in northern Australia. Aust. J. Agric. Res., **33:** 541-548.

[11] N. D. Skrebtsova, **(1957)**. Amounts of pollen on body of bees.) (In Russian), Pchelovodstvo Mosk **34:** 39-42.

[12] C. Westphal, R. Bommarco, G. Carre, E. Lamborn, N. Morison, T. Petanidou, S. G. Potts et al., **(2008)**. Measuring bee diversity in different European habitats and biogeographical regions. Ecol Monogr., **78:** 653-671.

[13] T. Atmowidi, D. Buchori, S. Manuwoto, B. Suryobroto and P. Hidayat **(2007)**. Diversity of insect pollinators in relation to seed set of mustard, Brassica rapa L. Hayati. J. Biosci., **14:** 155-161.

[14] B. Bhowmik, B. Mitra and K. Bhadra **(2014)**. Diversity of insect pollinators and their effect on the crop yield of mustard (Brassica juncea L.), NPJ-93 from southern West Bengal. Int. J. Recent Sci. Res., **5:** 1207-1213.

[15] P. P. Gautam and N. Kumar **(2018)**. Pollinator diversity and relative abundance of insect pollinators on ridge gourd (*Luffa acutangula*) flowers in Bihar (India). J. Entomol. Zool. Stud., **6:** 1177-1181.

[16] A. K. Sharma, H. S. Dhaliwal and K. L. Kaker **(1974)**. Insect visitors and pollinators of cauliflower seed crop bloom. Himachal Journal of Agricultural Research **2:** 74-78.

[17] S. S. Thakur, S. Kumar and K. S. Verma **(2004)**. Bloom visiting insects and their foraging behaviour on broccoli. Pest Management Economic Zool., **12:** 145:151.

[18] D. P. Abrol **(2007)**. Foraging behaviour of *Apis. mellifera* L. and Apiscerana F. as determined by the energetics of nectar production in different cultivar of *Brassica campestris* var. Toria. J Apic Sci., **51:** 19-23.

[19] D. Gabriel and T. Tscharntke **(2007)**. Insect pollinated plants benefit from organic farming. Agric Ecosyst Environ., **118:** 43-48.

[20] R. Pudasaini, R. B. Thapa, N. K. Chaudhary and S. Tiwari **(2015)**. Insect pollinators diversity of rapeseed (*Brassica campestris* var. *toria*) in Chitwan, Nepal. J. Inst. Agric. Anim. Sci., **33:** 73-78.

[21] H. Chand, R. Singh and S. F. Hameed **(1994)**. Population dynamics of insect pollinators in mustard (*Brassica juncea* L.). J. Entomol. Res., **18:** 233-239.
[22] H. S. Devi, B. K. Sontakke, L. N. Mohaptara and J. Padhi **(2011)**. Foraging activities of Italian bee, *Apis mellifera* L. on mustard under coastal conditions of Orissa. J. Plant Protec. Environ., **8:** 34-38.
[23] B. Bisht and R. Tiwari **(2017)**. Effect of plant and animal origin products on quality of honey, growth parameters and foraging behaviour of honeybee Apis mellifera L at Pantnagar, Uttrakhand-An eco-friendly and novel approach. J. Entomol. Zool. Stud., **5:** 394-399
[24] H. K. Sharma, S. Katna, B. S. Rana and K. Rana **(2016b)**. *Apis cerana* F. as an important natural pollinator of radish (*Raphanus sativus* L.) under mid-hill conditions of Himachal Pradesh. Int. J. Bio-resour. Stress Manag., **7:** 1156-1160.
[25] D. P. Singh, S. C. Verma, P. Thakur and S. Kumari **(2017)**. Impact of organic inputs and transplanting dates on insect fauna and seed production in radish (*Raphanus sativus* L.). J. Entomol. Zool. Stud., **5:** 1651-1654
[26] M. Devi and H. K. Sharma **(2017)**. Impact of weather on phenology and its effect on insect pollinators diversity and pollination of mustard (*Brassica juncea* L.) sown on different sowing dates. J. Entomol. Zool. Stud., **6:** 1889-1893.
[27] H. K. Sharma and B. S. Rana **(2000)**. Foraging behaviour of insect pollinators on pollination of cherry. In: Proceedings of the Seventh International Conference on Tropical Bees: Management and Diversity and Fifth Asian Apiculture Association conference. Chiang Mai, Thailand 19-25