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Impact of organic inputs and transplanting dates on foraging activity of honey bees in radish (*Raphanus sativus* L.)

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Abstract
An investigation was carried out during two consecutive years (2014-15 and 2015-16) at Research Farm of Department of Seed Science and Technology, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan-273230 (H. P.). The experiment was conducted on effect of different organic inputs like vermicompost, FYM, *Azotobacter*, PSB and PGPR and transplanting dates on foraging activity of honey bees in radish (*Raphanus sativus* L.). The transplanting was done on three different dates during both years. There were seven treatments including control (RDF) and each treatment was replicated thrice. The data was analysed in factorial randomized block design. The study revealed that among the organic treatments, observations of most frequent pollinators were taken throughout the blooming period of the crop. Syrphids were dominant insect visitors among various pollinators visited to radish flowers bloom followed by honey bees and other pollinators. Hymenoptera were the major floral visitors comparing of other species *viz* Lepidoptera, Coleoptera. Among these, *A. mellifera*, *A. cerana*, *A. dorsata* and *Bombus* sp. were found to be the most frequent visitors. Foraging activity of honey bees was higher 6.99, 6.39, 6.07 honey bees/plot/5 minute on Ist IInd and IIIrd dates of transplanting, respectively at 1200 h followed by 1500 h and 0900 h. Foraging activity of *A. cerana* was higher (Ist: 6.81; IInd : 6.24; IIIrd : 5.39) then *A. mellifera* (Ist: 5.66; IInd :5.07; IIIrd :4.29).

Keywords: Foraging activity, organic inputs, *Raphanus sativus*, transplanting dates

Introduction
Radish (*Raphanus sativus* L.) belongs to the family Brassicaceae where the edible part is root. It is a popular vegetable in both tropical and temperate regions of the world. In India it is cultivated over an area of 1, 83, 000 ha with annual production of 24, 90,000 MT and in Himachal Pradesh it is cultivated over an area of 1, 680 ha with annual production of 32, 970 MT (NHB, 2016) [10]. Radish is a good source of vitamin A and C and minerals like calcium, potassium, iron and phosphorus. The most popular eating part of radish is the tuberous roots although the entire plant is edible and the tops can be used as a leafy vegetable. Radish is entomophilous plant, pollinated by honeybees, wild flower bees, bumble bees, some Hymenopterous, Dipterans, Coleopteran, Lepidopterans etc. Any organic input as well as temporal variation in transplanting will be helpful in increasing the honey bees visits to specific crop and would be of great practical value to harness the benefits of cross pollination. Pollination is one of the limiting factors for crop productivity and is significantly contributing to the agricultural productivity.
Approximately 87.5% of flowering plants use animal-mediated pollination to set seed and fruit, corresponding to 70% of our agricultural crops (Ollerton *et al*. 2011; Klein *et al*. 2007) [11, 8]. Therefore, in order to insure the security of our pollinator-dependent crop species, it is imperative to characterize the mechanisms and practices that can enhance pollinator ecosystem services in managed landscapes. However, populations of honey bees, bumble bees, and other native pollinators have been in decline worldwide (Allen-Wardell *et al*. 1998; Potts *et al*. 2010) [1, 13]. Thus, there has been increasing interest in understanding how landscape ecology, and, in particular, nutrition provided by flowering plants, can affect and potentially improve pollinator populations in natural and managed ecosystems (Dixon 2009) [6]. Improving nutritional resources for pollinators in agricultural landscapes is important (Defries *et al*. 2004) [5]. While most studies of plant-pollinator interactions have focused simply on how the plant community can affect pollinator abundance and diversity.

Soil quality can influence the production of flowers, pollen and nectar and can lead to changes in pollinator visitation patterns (Munoz *et al*. 2005; Burkle and Irwin 2010) [9, 10]. Therefore present study was conducted with aim to know the effect of organic inputs by soil amendment and transplanting dates on pollinators fauna and foraging activity of honey bees.

Materials and methods

Seeds of radish were sown in the month of September, 2014-15 and 2015-16 in a well prepared field. The mature roots were uplifted from the soil after attaining the age of 60 days and only true to type roots were selected for the transplanting purpose. Selected roots were trimmed keeping 10 cm top and 10 cm root portion for use as steckling, which were transplanted in such a way that the upper surface of the shoulder of the stecklings was in the level of ground surface. Experiments were conducted for two consecutive years i.e. 2014-15 and 2015-16 at Pandah Research Farm, Department of Seed Science and Technology, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan-273230 (H. P.), India. Radish var. Japanese White (*Raphanus sativus* L.) was subjected to seven treatments *viz*., (T_1) FYM @ 100 q/ha + NSKE (5%), (T_2) vermicompost @ 50 q/ha + NSKE (5%), (T_3) FYM @ 100 q/ha + PGPR (1 litre/ha) + NSKE (5%), (T_4) Vermicompost @ 50 q/ha + PGPR (1 litre/ha) + NSKE (5%), (T_5) FYM @100q/ha +*Azotobacter* root dip @ 2.5 Kg/ha + PSB root dip @ 2.50 Kg/ha +NSKE (5%), (T_6) Vermicompost @ 50 q/ha) + *Azotobacter* root dip @2.5 Kg/ha + PSB root dip @ 2.5 Kg/ha + NSKE (5%) and (T_7) Control RDF+ Malathion (0.05%). There were three transplanting dates (4th November, 19th November and 4th December in both years).

Insect pollinators: The observations on insect pollinators were recorded in each treatment in each plot during flowering period.

Foraging Activity: The observations on foraging activity of honey bees was made at two hourly intervals from 0900 h-1000 h, 1200 h-1300 h and 1500 h-1600 h. Number of different species of bees visiting in each plot was counted for five minutes. Further, the data was subjected to statistical analysis for time wise and species wise to assess most favourable period of the day for bee species to visit the radish flower and most dominant species in a day and at particular time of the day.

Results and discussion

Insect pollinators collected on radish are listed in Table 1. The observations on insect pollinators of radish flowers showed that in total 18 insects belonging to 15 genera under 9 families and 4 orders were recorded. Syrphids were dominant insect visitors among various pollinators visited to radish flowers bloom followed by bees and other pollinators. The observations on insect pollinators of radish belonging to different insect orders, of which Hymenoptera (5 species) were the most abundant group followed by Diptera (6 species), Lepidoptera (5 species) and Coleoptera (2 species). These findings are in close agreement with the findings of Bhatia *et al.* (1999) [2] who reported 12 insect species on radish flowers of which five belong to Hymenoptera, four species to Diptera and three species to Lepidoptera. Sihag (1986) [15] also reported nine species of Hymenopter, six species of Lepidoptera and three species of Diptera as predominant visitors of radish flower. Similar results were also reported by Priti and Sihag (2001) [14] on radish flowers.

It is evident from Table 2 that there was non significant effect of different treatments on foraging activity of honey bees on Ist, IInd and IIIrd dates of transplanting. However, foraging activity of honey bees differed significantly during different day hours and transplanting dates. Among the organic treatments, significantly higher foraging activity of honey bees (6.99 honey bees/plot/5 minutes) was observed at 1200 h followed by 1500 h (5.88 honey bees/plot/5 minutes) and 0900 h (5.83 honey bees/plot/5 minutes) on Ist date of transplanting. Foraging activity recorded at 1500 h and 0900 were statistically at par with each other. On IInd date of transplanting, significantly higher foraging activity of honey bees (6.39 honey bees/plot/5 minutes) was observed at 1200 h followed by 1500 h (5.31 honey bees/plot/5 minutes) and 0900 h (5.27 honey bees/plot/5 minutes), the last two were statistically at par with each other. Similarly on IIIrd date of transplanting, significantly higher foraging activity of honey bees (6.07 honey bees/plot/5 minutes) was recorded at1200 h followed by 1500 h (4.98 honey bees/plot/5 minutes) and 0900 h (4.96 honey bees/plot/5 minutes), the last two were statistically at par with each other. Comparatively higher foraging activity of honey bees was recorded with Ist date of transplanting (6.23 honey bees/plot/5 minutes) as compared to IInd (5.66 honey bees/plot/5 minutes) and IIIrd (5.34 honey bees/plot/5 minutes) date of transplanting.

Irrespective of transplanting dates, significantly higher foraging activity of honey bees (6.48 honey bees/plot/5 minutes) was recorded at 1200 h followed by 1500 h (5.39 honey bees/plot/5 minutes) and 0900 h (5.35 honey bees/plot/5 minutes), however, foraging activity recorded at 1500 h and 0900 h was statistically at par with each other.

Data presented in Table 3 revealed that there was non significant effect of different treatments on foraging activity of *A. mellifera* and *A. cerana* on different dates of transplanting during (2014-2016). On Ist date of transplanting, among the organic treatments, *A. cerana* recorded significantly higher (6.81 honey bees/plot/5 minutes) foraging activity as compared to *A. mellifera* (5.66 honey bees/plot/5 minutes). On IInd date of transplanting, *A. cerana* recorded significantly higher (6.24 honey bees/plot/5 minutes) foraging activity as compared to *A. mellifera* (5.07 honey bees/plot/5 minutes). Similarly on IIIrd date of transplanting, *A. cerana* recorded significantly higher (5.39 honey bees/plot/5 minutes) foraging activity as compared to *A. mellifera* (4.29 honey bees/plot/5 minutes). Foraging activity of honey bees recorded on Ist date of transplanting (6.23 honey bees/plot/5 minutes) differed significantly with IInd (5.66 honey bees/plot/5 minutes) and IIIrd date of transplanting (4.48 honey bees/plot/5 minutes). Irrespective of transplanting dates, significantly higher foraging activity was recorded with *A. cerana* (6.15 honey bees/plot/5 minutes) as compared to *A. mellifera* (5.01 honey bees/plot/5 minutes). In the present study, there was no effect of different organic and inorganic treatments on foraging activity of *A. mellifera* and *A. cerana* which indicated that honey bees have equal preference for nectar or pollen in each treatment. This may be because of the fact that honey bees do not give preference to a particular plot and visit randomly and non selective manner in various plots in radish crop. The present findings are in agreement with the findings of Yasmin *et al.* (2012) [16] who reported that number of pollinators visit to vermicompost soil and chemically fertilized soil did not differed significantly, although there was a tendency for the plants grown under vermicompost to have a greater number of visitors compared to all other treatments.

The foraging activity of *A. mellifera* and *A. cerana* was seen throughout the day as well as throughout the flowering period of the radish crop. The foraging activity of honey bees at 0900 h was 5.35 bees/plot/5 minutes. The peak foraging activity (6.48 bees/plot/5 minute) was at 1200 h followed by 1500 h (5.39 bees/plot/5 minute). These findings are in line with the findings of Partap and Verma (1994) who observed peak foraging activity between 1100 to 1500 h of *A. cerana* on radish. Chand *et al.* (1994) [4] recorded the peak foraging activity of *A. cerana* at 1100 h on mustard and found that *A. cerana* visitation was positively correlated with maximum relative humidity and minimum temperature. The present results also corroborate the findings of Pudasaini *et al*. (2014) who reported that the peak abundance of *Apis mellifera*, *Apis cerana* and *Apis dorsata* was 4.16, 6.33 and 1.00 numbers per meter square, respectively at 2:00 pm whereas abundance of *A. mellifera, A. cerana* and *A. dorsata* between 10:00 am to 4:00 pm ranged from 1.83 to 4.16, 1.66 to 6.33 and 0.17 to 1.00 numbers per meter square, respectively. Similar to present findings Jakhar *et al*. (2015) [7] recorded peak foraging activity of honey bees between 1230 h to 1400 h in radish crop.

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Table 1: List of insect pollinators of radish at Pandah Farm.

Order	Family	Scientific Name
Hymenoptera	Apidae	*Apis cerana*
		Apis mellifera
		Apis dorsata
		Bombus sp.
	Formicidae	*Formica* sp.
Diptera	Syrphidae	*Episyrphus balteatus*
		Eupeodes frequens
		Metasyrphus confrator
		Betasyrphus serarius
		Metasyrphus serarius
	Muscidae	*Musca* sp.
Lepidoptera	Pieridae	*Pieris brassicae*
		Colias fieldii
	Papilionidae	*Papilio demoleus*
	Nymphalidae	*Vanessa cardui*
	Noctuidae	*Helicoverpa armigera*
Coleoptera	Coccinellidae	*Coccinella septempunctata*
		Hippodamia variegata

Table 2: Effect of transplanting dates on foraging activity of *A. mellifera* and *A. cerana* in radish crop (Pooled 2014-2016)

Treatments	Honey bees/plot/5 minutes											
	Ist Transplanting			IInd Transplanting			IIIrd Transplanting			Interaction		
	Honey bees											
	A. mellifera	*A. cerana*	Mean	*A. mellifera*	*A. cerana*	Mean	*A. mellifera*	*A. cerana*	Mean	*A. mellifera*	*A. cerana*	Mean
T_1	5.67 (2.38)	6.55 (2.56)	6.11 (2.47)	4.96 (2.23)	5.98 (2.44)	5.47 (2.34)	4.28 (2.07)	5.07 (2.25)	4.67 (2.16)	4.97 (2.22)	5.87 (2.42)	5.42 (2.32)
T_2	5.56 (2.36)	6.77 (2.60)	6.16 (2.48)	5.23 (2.29)	6.21 (2.49)	5.72 (2.39)	4.31 (2.08)	5.37 (2.32)	4.84 (2.20)	5.03 (2.24)	6.12 (2.47)	5.57 (2.35)
T_3	5.68 (2.38)	7.11 (2.67)	6.39 (2.52)	4.90 (2.12)	6.54 (2.56)	5.73 (2.38)	4.36 (2.09)	5.71 (2.39)	5.03 (2.24)	4.98 (2.23)	6.45 (2.54)	5.71 (2.38)
T_4	5.94 (2.44)	6.78 (2.60)	6.36 (2.52)	5.37 (2.32)	6.22 (2.49)	5.79 (2.40)	4.50 (2.12)	5.38 (2.32)	4.94 (2.22)	5.27 (2.29)	6.13 (2.47)	5.70 (2.38)
T_5	5.55 (2.36)	6.58 (2.56)	6.07 (2.46)	4.98 (2.23)	6.02 (2.45)	5.50 (2.34)	4.15 (2.04)	5.18 (2.28)	4.67 (2.16)	4.89 (2.21)	5.93 (2.43)	5.41 (2.32)
T_6	5.72 (2.39)	6.96 (2.64)	6.34 (2.51)	5.15 (2.27)	6.39 (2.53)	5.77 (2.40)	4.32 (2.08)	5.56 (2.36)	4.94 (2.22)	5.06 (2.25)	6.31 (2.51)	5.68 (2.38)
T_7	5.49 (2.34)	6.88 (2.62)	6.19 (2.48)	4.93 (2.22)	6.32 (2.51)	5.62 (2.37)	4.09 (2.02)	5.48 (2.34)	4.79 (2.18)	4.84 (2.20)	6.23 (2.49)	5.53 (2.34)
Mean	5.66 (2.38)	6.81 (2.61)	6.23 (2.49)	5.07 (2.25)	6.24 (2.50)	5.66 (2.37)	4.29 (2.07)	5.39 (2.32)	4.84 (2.20)	5.01 (2.23)	6.15 (2.48)	5.58 (2.35)

Figures in parenthesis represent square root transformation

C.D. (0.05)= Transplanting × Treatment- NS, Transplanting × Insect- 0.04, Transplanting × Insect × Treatment- N/S, Transplanting- 0.03, Treatment- NS, Insect - 0.02, Insect × Treatment- NS

Table 3: Effect of transplanting dates and day hours on foraging activity of honey bees in radish crop (Pooled 2014-2016)

Treatments	Honey bees/plot/5 minutes															
	Ist Transplanting				IInd Transplanting				IIIrd Transplanting				Interaction			
	Day hours															
	0900 h	1200 h	1500 h	Mean	0900 h	1200 h	1500 h	Mean	0900 h	1200 h	1500 h	Mean	0900 h	1200 h	1500 h	Mean
T_1	5.60 (2.37)	6.93 (2.63)	5.80 (2.41)	6.11 (2.47)	5.03 (2.24)	6.15 (2.48)	5.23 (2.28)	5.47 (2.33)	4.58 (2.14)	6.03 (2.46)	4.90 (2.21)	5.17 (2.27)	5.07 (2.25)	6.37 (2.52)	5.31 (2.30)	5.58 (2.36)
T_2	5.68 (2.38)	6.98 (2.64)	5.83 (2.41)	6.16 (2.48)	5.47 (2.34)	6.42 (2.53)	5.27 (2.29)	5.72 (2.39)	5.13 (2.26)	6.08 (2.47)	4.93 (2.22)	5.38 (2.32)	5.43 (2.33)	6.49 (2.55)	5.34 (2.31)	5.75 (2.39)
T_3	6.00 (2.45)	7.28 (2.70)	5.90 (2.43)	6.39 (2.52)	5.11 (2.26)	6.72 (2.59)	5.34 (2.31)	5.73 (2.39)	5.11 (2.26)	6.38 (2.53)	5.00 (2.23)	5.50 (2.34)	5.41 (2.32)	6.79 (2.60)	5.41 (2.32)	5.87 (2.42)
T_4	5.92 (2.43)	7.37 (2.71)	5.80 (2.41)	6.36 (2.52)	5.35 (2.31)	6.80 (2.61)	5.23 (2.29)	5.79 (2.40)	5.02 (2.24)	6.34 (2.52)	4.90 (2.21)	5.42 (2.32)	5.43 (2.33)	6.84 (2.61)	5.31 (2.30)	5.86 (2.41)
T_5	5.70 (2.39)	6.77 (2.60)	5.73 (2.39)	6.07 (2.46)	5.13 (2.27)	6.20 (2.49)	5.17 (2.27)	5.50 (2.34)	4.80 (2.19)	5.87 (2.42)	4.83 (2.20)	5.17 (2.27)	5.21 (2.28)	6.28 (2.50)	5.24 (2.29)	5.58 (2.36)
T_6	6.15 (2.48)	6.85 (2.62)	6.02 (2.45)	6.34 (2.52)	5.58 (2.36)	6.28 (2.51)	5.45 (2.33)	5.77 (2.40)	5.25 (2.29)	5.95 (2.44)	5.12 (2.26)	5.44 (2.33)	5.66 (2.38)	6.36 (2.52)	5.53 (2.35)	5.85 (2.42)
T_7	5.77 (2.40)	6.72 (2.59)	6.08 (2.47)	6.19 (2.49)	5.20 (2.28)	6.15 (2.48)	5.52 (2.35)	5.62 (2.37)	4.87 (2.21)	5.82 (2.41)	5.18 (2.28)	5.29 (2.30)	5.28 (2.30)	6.23 (2.49)	5.59 (2.36)	5.70 (2.38)
Mean	5.83 (2.41)	6.99 (2.64)	5.88 (2.42)	6.23 (2.49)	5.27 (2.29)	6.39 (2.53)	5.31 (2.30)	5.66 (2.37)	4.96 (2.23)	6.07 (2.46)	4.98 (2.23)	5.34 (2.31)	5.35 (2.31)	6.48 (2.54)	5.39 (2.32)	5.74 (2.39)

Figures in parenthesis represent square root transformation

C.D. (0.05)= Transplanting × Treatment- NS, Transplanting × Time- 0.05, Transplanting × Time × Treatment- NS, Transplanting- 0.03, Treatment- NS, Time- 0.03, Time × Treatment- NS

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