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Melittophilous Mode of Pollination Predominates in European Plum (*Prunus domestica* L.) in the Semi-Arid Environment of Northwest India

Nidhi Wadhwa and Ram Chander Sihag
Laboratory of Bee Behaviour and Pollination Ecology, Department of Zoology, CCS Haryana Agricultural University, Hisar, 125004, India

Corresponding Author: Ram Chander Sihag, Laboratory of Bee Behaviour and Pollination Ecology, Department of Zoology, CCS Haryana Agricultural University, Hisar, 125004, India

ABSTRACT

European plum (*Prunus domestica* L.) is an important fruit and medicinal plant. This fruit plant is a new introduction in the Northwest region of India. Flowers of this plant need cross-pollination for fruit set. However, the spectrum of pollinators and their relative role in pollination of flowers of this fruit plant in this region is not known. To meet these objectives, the present study was carried out. An entire range of flower visitors of this fruit plant was captured with hand net from its field and were identified. On the basis of foraging mode, the flower visitors were characterized as pollinators and non-pollinators. Their relative abundances, foraging rates, activity durations and number of pollen grains carried on the surface were recorded and these parameters were used to determine their pollinating efficiencies. During the two years of this study, a total of 12 insect species were observed on the three varieties of plum at Hisar. Among these insect visitors, five species belonged to Hymenoptera, five to Diptera, one to Lepidoptera and one to Coleoptera. *Apis dorsata* was the most abundant visitor having maximal foraging rate and carried maximal number of loose pollen grains and proved to be the most efficient pollinator of plum (*P. domestica*) in both the seasons followed by *A. mellifera*, *A. cerana* and *A. florea*; the dipterans were the least efficient pollinators of plum in both the years. On the basis of these parameters, melittophilous mode of pollination was found to predominate in this fruit plant in the semi-arid environment of Northwest India. Conservation of wild honeybees has been recommended.

Key words: Foraging behavior, melittophily, pollination, honey bees, pollinating efficiency, plum, *Prunus domestica*

INTRODUCTION

Pollination is one of the most important ecosystem services; this has direct bearing on the reproduction of angiosperms; the flowering plants. The latter have been considered as one of the most beautiful gift of nature due to their flowers with variant colours and morphs (Sihag, 2001). In fact, angiosperms not only provide the picturesque beauty to the earth ecosystem, but also food, fiber and wood; the three main components of human civilization (Sihag, 2013). A wide variety of visitors are attracted by the flowers, the latter provide nectar and pollen as floral reward to the former (Wadhwa and Sihag, 2012). In return, the visitors provide pollination service to the flowers. In practice, however, not all the flower visitors are equally important to the plant as pollinators. Their role as pollinators is variable depending upon their abundance, foraging modes, foraging

rates, activity duration and the number of pollen grains carried on their body. Some earlier researchers studied the diversity, abundance, foraging behavior and pollination efficiency of pollinators of some plants (Sihag and Rathi, 1994; Arya *et al*., 1994; Priti and Sihag, 1997, 1998, 1999, 2000a, b; Priti *et al*., 2001; Gahlawat *et al*., 2002a, b; Narwania *et al*., 2003; Chaudhary and Sihag, 2003; Chaudhary *et al*., 2009; Wadhwa and Sihag, 2012). On the basis of these parameters, derivation of a single value index for each visitor is possible to make comparison of their relative importance to the plant. Such indices were derived and used for this purpose in many earlier studies. On the basis of the derived pollination indices, Sihag and Rathi (1994) characterized and compared the visitors of pigeon pea (*Cajanus cajan*), Arya *et al*. (1994) did so in sunflower (*Helianthus annuus* L.), Priti and Sihag (1997) in cauliflower (*Brassica oleracea* L. var botrytis cv. Hazipur Local), Priti and Sihag (1998) in carrot (*Daucus carota* L. var. HC-I), Priti and Sihag (1999) in (*Coriandrum sativum* L.), Priti and Sihag (2000a) in fennel (*Foeniculum vulgare* L), Priti and Sihag (2000b) in turnip (*Brassica rapa* L.), Priti *et al*. (2001) in radish (*Raphanus sativus* L.), Gahlawat *et al*. (2002a) in cucumber (*Cucumis sativus* L.), Gahlawat *et al*. (2002b) in *Pracitrullus fistulosus*, Narwania *et al*. (2003) in wanga (*Cucumis melo* s.sp. *melo*), Chaudhary and Sihag (2003) in onion (*Allium cepa* L.), Chaudhary *et al*. (2009) in onion (*Allium cepa* L.), carrot (*Daucus carota* L.) and fennel (*Foeniculum vulgare* L.) and Wadhwa and Sihag (2012) in sarpagandha (*Rauvolfia serpentina*).

European plum (*Prunus domestica* L.) is an important common man's fruit. It has high nutritional and medicinal value; the fruit is rich in proteins, calcium, potassium and phosphorus (Ertekin *et al*., 2006). The plum fruit is a good source of vitamins, minerals, fiber and enzymes that are good for the digestive system and positively associated with nutrient intake, improves anthropometric measurements; the prune is a useful antistresser (Hiramoto, 2008) and reduces risk of hypertension (Beals and Fulgoni, 2005; Ahmed *et al*., 2010a). Besides various sugars, acids, pectins, tannins and enzymes, European plum fruits also contain several important secondary metabolites such as flavonoids and phenolic acids (Tomas-Barberan *et al*., 2001; Gil *et al*., 2002; Walkowiak-Tomczak *et al*., 2008; Slimestad *et al*., 2009), with a strong antioxidant capacity (Kahkonen *et al*., 1999; Nakatani *et al*., 2000; Vinson *et al*., 2001; Kayano *et al*., 2002, 2003, 2004; Kikuzaki *et al*., 2004; Kimura *et al*., 2008; Rop *et al*., 2009; Dhingra *et al*., 2014). Ascorbic acid is another antioxidant present in plum fruit, essential for higher primates and a small number of other species (Gil *et al*., 2002). Prunes improve the liver function (Ahmed *et al*., 2010b), bone health (Hooshmand and Arjmandi, 2009.) and increase bone mass, prevents osteoporosis (Deyhim *et al*., 2005; Bu *et al*., 2008), enhances the resistance to fungal infection (El-Kereamy *et al*., 2011), is anticancerous (Fujii *et al*., 2006) and anti hypercholestremia (Tinker *et al*., 1991).

European plum (*P. domestica*) is hexaploid in its genetical make and its fertility status varies from self-compatibility to partial-incompatibility to self-incompatibility (Hegedus and Halasz, 2006; Nyeki and Szabo, 1995; Dragan and Dragan, 2010). However, cross pollination has been reported to help increase fruit set in all the cultivars of this plant. European plum (*P. domestica*) is a new introduction to the semi-arid environments of North western region of India. Under the 'expansion of Horticulture programme', this plant is being planted in several parts of Northwest India. What conditions prevails in its flowers and what spectrum of pollinators is associated with this plant in the Northwest India is not known. For the maximal yield of this fruit tree in its new abode, study on its pollination dynamics including the pollinator spectrum, their foraging behavior and pollinating efficiency is important. With this aim, the present study was carried out.

MATERIALS AND METHODS

This study was carried out at the Horticulture Research Farm of CCS Haryana Agricultural University, Hisar (India). Observations were recorded on different insects visiting the flowers of three cultivars (viz. Alu Bokhara, Titron and Kala Amritsari) of European plum (*Prunus domestica* L.) during its peak flowering period in 2009 and 2010. Following investigations were made.

Flower visitors of plum: The different insect species visiting flowers of plum (*Prunus domestica* L.) were collected by hand net and preserved to maintain a record in the Laboratory of Bee Behaviour and Pollination Ecology, Department of Zoology, CCS Haryana Agricultural University, Hisar (India). These insects were identified with the help of scientists of Department of Entomology of this University.

Abundances of flower visitors of plum: Five plots of 1×1 m size were randomly selected in each crop area. On a given day, abundances of different insects on each plot were recorded for 5 min at two hourly intervals, starting from commencement to the cessation of insect activity. Observations were repeated at weekly intervals starting from commencement to the cessation of flowering on the experimental crop following Sihag (1986).

Activity duration of the flower visitors of plum: Average number of hours a pollinator species remained active on the reference plant was taken as activity duration of that species. The activity duration was derived from the number of pollinators remained active for the given time period. All the time periods were added and an average value was determined using a mathematical equation given by Sihag and Rathi (1994).

Foraging behaviour of the flower visitors of plum

Foraging modes: On the basis of foraging modes (method of working by a forager on a flower while harvesting pollen and/or nectar reward), foraging behavior of the insects visiting the blossoms of plum plant was recorded following Sihag (1988). Accordingly, visitors were categorized as pollinators/non-pollinators.

Foraging rates: Foraging rates of different types of flower visitors were recorded in terms of number of flowers visited per minute. Time was recorded with the help of a stopwatch (chronometer) with accuracy of 0.1 sec. For this, observations were recorded at two hourly intervals on a day and were repeated at an interval of one week. At a given time, observations were recorded on ten insects of a species.

Number of pollen grains carried on the body of a flower visitor: The number of pollen grains carried on the body of a flower visitor was determined following method of Parker (1981, 1982). Ten foragers of a visiting species were captured randomly from the respective field. Their scopa were clipped and the remaining body was immersed in a solution of 60% alcohol. The contents were shook well and the number of pollen grains present in a given volume was determined with the help of a heamocytometer following the method of Parker (1981, 1982).

Pollinating efficiency ranking: For different pollination parameters viz. abundances of the flower visitors, their foraging rates, mean activity durations and the number of pollen grains carried on the body, the Performance Scores (PS) were derived for each species using following formula suggested by Sihag and Rathi (1994):

$$PS_{ij} = (N_{ij}/N_j) \times s$$

Where:
i = 1 to x and j =1 to r, both taking positive, whole number and finite values
Ps_{ij} = Performance score of ith species for jth parameter
N_{ij} = Importance value of ith species for jth parameter
N_j = Total importance values of all the species for jth parameter
s = Total number of species

From various performance scores for different parameters of a species, Pollinating Index (PI) were derived by multiplying all the PSs of that species. The PIs so derived were then compared and on the basis of their values, different species were ranked for their pollinating efficiency.

Statistical analysis: The experiments were laid down in one factor ANOVA and the recorded data were analyzed in "Completely Randomized Design". Values of 'Least Significant Difference' (LSD) were derived and the treatment means were compared at 1 and 5% level of significance following Snedecor and Cochran (1967).

RESULTS

Flower visitors of plum: During both the years of this study, a total of 12 insect species were observed on the three varieties of plum at Hisar (Table 1, Fig. 1). Among these insect visitors, five species belonged to Hymenoptera, five to Diptera, one to Lepidoptera and one to Coleoptera. Among Hymenopterous species; *Apis dorsata*, *A. mellifera*, *A. florea* and *A. cerana* were from the family Apidae; *Halictus* species belonged to family Halictidae. Among dipterous insect species, *Eristalis* sp., *Episyrphus* sp. and *Syrphus* sp., belonged to family Syrphidae, *Sarcophaga* belonged to family Sarcophagidae, *Chrysoma bezziaidaena* belonged to family Calliphoridae, *Coccinella* sp. belonged to family Coccinellidae and *Psichotoc* sp., belonged to family Arctiidae.

Patterns of abundances of the flower visitors of plum

Diurnal pattern of abundances of pollinators of plum: The foraging activity of insects visiting the blossoms of plum commenced at 0700 h in the morning in both the years (2009-2010) with first appearance of *Apis dorsata*; other pollinators commenced their activity later on at 0900 h. The peak activity of insect visitors of plum was observed in the afternoon from 1200-1500 h in both the years of this study; the diurnal insect activity followed a curvilinear pattern on the blossoms of plum at Hisar (Table 2, 3).

Table1: Insect visitors of plum flowers at Hisar (India) during 2009 and 2010

Insect species	Order	Family
Apis dorsata F.	Hymenoptera	Apidae
Apis mellifera L.	Hymenoptera	Apidae
Apis florea F.	Hymenoptera	Apidae
Apis cerana F.	Hymenoptera	Apidae
Halictus sp.	Hymenoptera	Halictidae
Eristalis sp.	Diptera	Syrphidae
Episyrphus sp.	Diptera	Syrphidae
Syrphus sp.	Diptera	Syrphidae
Sarcophaga sp.	Diptera	Sarcophagidae
Chrysoma bezziana V.	Diptera	Calliphoridae
Psichotoe duvauceli (Boisduval)	Lepidoptera	Arctiidae
Coccinella septumpunctata L.	Coleoptera	Coccinellidae

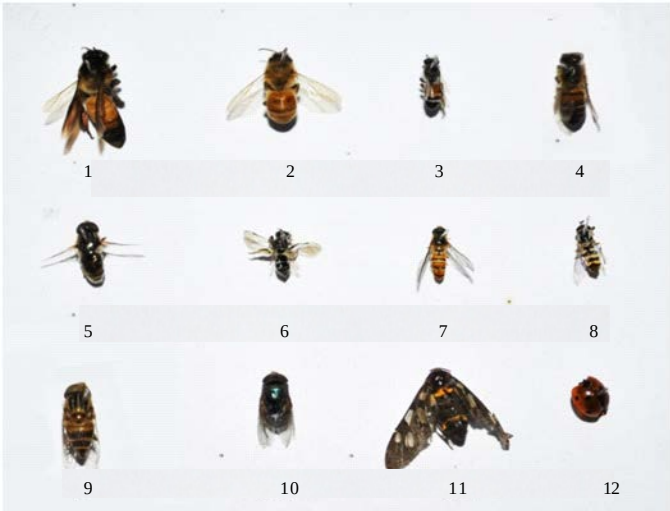

Fig. 1: Insect visitors of plum flowers at Hisar during 2009-2010, (1) *Apis dorsata*, (2) *Apis mellifera*, (3) *Apis florea*, (4) *Apis cerana*, (5) *Halictus* sp., (6) *Eristalis* sp., (7) *Episyrphus* sp., (8) *Syrphus* sp., (9) *Sarcophaga* sp., (10) *Chrysoma bezziana*, (11) *Psichotoe duvauceli* and (12) *Coccinella sepumpunctata*

Table 2: Diurnal pattern of abundances of insect visitors on the flowers of three cultivars of plum (*Prunus domestica*) during January-February, 2009 at Hisar (India)

	No. of insect visitors (per 5 min/m²)*					
Time (h)	*Apis dorsata*	*Apis mellifera*	*Apis cerana*	*Apis florea*	Dipterans	**Mean±SE
Alu Bokhara						
700	*1.21±0.19	0.00	0.00	0.00	0.00	0.24±0.12
900	2.82±0.47	2.27±0.35	0.94±0.55	2.16±0.40	0.00	1.63±0.28^{e}
1100	4.22±0.53	3.38±0.47	2.33±0.67	2.91±0.34	1.33±0.24	2.83±0.47^{c}
1300	6.07±0.59	4.66±0.50	3.22±0.49	4.28±0.72	2.10±0.35	4.06±0.67^{a}
1500	4.77±0.53	5.22±0.63	3.34±0.52	3.12±0.35	1.66±0.24	3.62±0.22^{b}
1700	2.14±0.35	2.38±0.37	1.70±0.25	1.71±0.22	0.66±0.27	1.71±0.28^{d}
***Mean±SE	3.53±0.33^{a}	2.98±0.53^{b}	1.92±0.44^{d}	2.36±0.69^{c}	0.95±0.28^{e}	
Titron						
700	1.44±0.28	0.00	0.00	0.00	0.00	0.28±0.44
900	3.27±0.46	2.55±0.40	1.16±0.24	2.49±0.44	0.00	1.89±0.47^{e}
1100	5.44±0.63	3.49±0.72	2.55±0.44	3.11±0.35	1.55±0.24	3.22±0.82^{c}
1300	6.55±0.67	5.53±0.55	3.38±0.48	4.55±0.57	2.62±0.32	4.52±0.67^{a}
1500	5.55±0.55	5.38±0.58	3.72±0.41	3.55±0.37	1.72±0.22	3.98±0.52^{b}
1700	2.99±0.47	2.71±0.44	1.77±0.24	1.88±0.27	0.77±0.20	2.02±0.44^{d}
***Mean±SE	4.20±0.67^{a}	3.27±0.72^{b}	2.09±0.35^{d}	2.59±0.62^{c}	1.11±0.13^{e}	
Kala Amritsari						
700	1.27±0.26	0.00	0.00	0.00	0.00	0.25±0.12
900	2.88±0.61	2.44±0.65	0.99±0.22	2.26±0.37	0.00	1.71±0.47^{e}
1100	4.25±0.70	3.38±0.48	2.44±0.44	2.94±0.39	1.45±0.24	2.89±0.24^{c}
1300	6.25±0.65	5.05±0.53	3.33±0.90	4.37±0.72	2.21±0.34	4.24±0.26^{a}
1500	4.49±0.55	5.29±0.63	3.44±0.52	3.33±0.46	1.68±0.29	3.64±0.67^{b}
1700	2.93±0.47	2.60±0.34	1.72±0.32	1.79±0.22	0.74±0.19	1.95±0.55^{d}
***Mean±SE	3.67±0.88^{a}	3.12±0.66^{b}	1.98±0.57^{d}	2.44±0.33^{c}	1.01±0.34^{e}	

*Mean±SE of 30 observations, **Mean±SE of 150 observations,***Mean±SE of 180 observations, LSD ($p \leq 0.05$) for time: 0.342, LSD ($p \leq 0.05$) for species: 0.320, LSD ($p \leq 0.05$) for varieties: 0.288, treatment means with different letters differ significantly

The overall abundance of insects in 2009 on Alu Bokhara, irrespective of the insect species, was 0.24 insects/m² at 700 h and increased to 1.68 insects/m² at 900 h followed by 2.97 insects/m² at 1100 h reached maximal level of 4.17 insects/m² at 1300 h. Thereafter, there was a bit decline in abundance to 3.72 insects/m² at 1500 h and then 1.96 insects/m² at 1700 h in the evening. On

Table 3: Diurnal pattern of abundances of insect visitors on the flowers of three cultivars of plum (*Prunus domestica*) during January-February, 2010 at Hisar (India)

	No. of insect visitors (per 5 min/m²)*					
Time (h)	*Apis dorsata*	*Apis mellifera*	*Apis cerana*	*Apis florea*	Dipterans	**Mean±SE
Alu Bokhara						
700	*1.21±0.19	0.00	0.00	0.00	0.00	0.24±0.12
900	2.82±0.47	2.27±0.35	0.94±0.55	2.16±0.40	0.00	1.63±0.28^{e}
1100	4.22±0.53	3.38±0.47	2.33±0.67	2.91±0.34	1.33±0.24	2.83±0.47^{c}
1300	6.07±0.59	4.66±0.50	3.22±0.49	4.28±0.72	2.10±0.35	4.06±0.67^{a}
1500	4.77±0.53	5.22±0.63	3.34±0.52	3.12±0.35	1.66±0.24	3.62±0.22^{b}
1700	2.14±0.35	2.38±0.37	1.70±0.25	1.71±0.22	0.66±0.27	1.71±0.28^{d}
***Mean±SE	3.53±0.33^{a}	2.98±0.53^{b}	1.92±0.44^{d}	2.36±0.69^{c}	0.95±0.28^{e}	
Titron						
700	1.44±0.28	0.00	0.00	0.00	0.00	0.28±0.44
900	3.27±0.46	2.55±0.40	1.16±0.24	2.49±0.44	0.00	1.89±0.47^{e}
1100	5.44±0.63	3.49±0.72	2.55±0.44	3.11±0.35	1.55±0.24	3.22±0.82^{c}
1300	6.55±0.67	5.53±0.55	3.38±0.48	4.55±0.57	2.62±0.32	4.52±0.67^{a}
1500	5.55±0.55	5.38±0.58	3.72±0.41	3.55±0.37	1.72±0.22	3.98±0.52^{b}
1700	2.99±0.47	2.71±0.44	1.77±0.24	1.88±0.27	0.77±0.20	2.02±0.44^{d}
***Mean±SE	4.20±0.67^{a}	3.27±0.72^{b}	2.09±0.35^{d}	2.59±0.62^{c}	1.11±0.13^{e}	
Kala Amritsari						
700	1.27±0.26	0.00	0.00	0.00	0.00	0.25±0.12
900	2.88±0.61	2.44±0.65	0.99±0.22	2.26±0.37	0.00	1.71±0.47^{e}
1100	4.25±0.70	3.38±0.48	2.44±0.44	2.94±0.39	1.45±0.24	2.89±0.24^{c}
1300	6.25±0.65	5.05±0.53	3.33±0.90	4.37±0.72	2.21±0.34	4.24±0.26^{a}
1500	4.49±0.55	5.29±0.63	3.44±0.52	3.33±0.46	1.68±0.29	3.64±0.67^{b}
1700	2.93±0.47	2.60±0.34	1.72±0.32	1.79±0.22	0.74±0.19	1.95±0.55^{d}
***Mean±SE	3.67±0.88^{a}	3.12±0.66^{b}	1.98±0.57^{d}	2.44±0.33^{c}	1.01±0.34^{e}	

*Mean±SE. for 30 observations, **Mean±SE for 150 observations, ***Mean±SE for 180 observations, LSD ($p \leq 0.05$) for species: 0.317, LSD ($p \leq 0.05$) for varieties: 0.290, LSD ($p \leq 0.05$) for time: 0.224, treatment means with different letters differ significantly

Titron, it was 0.42 insects/m² at 700 h, increased to 2.16 insects/m² at 900 h followed by 3.33 insects/m² at 1100 h and reached a maximal level of 4.54 insects/m² at 1300 h. Thereafter, there was a bit decline to 3.99 insects/m² at 1500 h and then 2.23 insects/m² at 1700 h in the evening. Likewise on Kala Amritsari, it was 0.28 insects/m² at 700 h, increased to 1.79 insects/m² at 900 h followed by 3.18 insects/m² at 1100 h and reached a maximal level of 4.20 insects/m² at 1300 h. In this case also, thereafter, there was a decline in the activity to 3.79 insects/m² at 1500 h and then 1.96 insects/m² at 1700 h in the evening (Table 2).

The overall abundance of insects in 2010 on Alu Bokhara, irrespective of the insect species, was 0.24 insects/m² at 700 h and increased to 1.63 insect/m² at 900 h, followed by 2.83 insects/m² at 1100 h, reached maximum 4.06 insects/m² at 1300h, thereafter declined to 3.62 at 1500 h and then 1.71 at 1700 h in the evening. On Titron, It was 0.28 insects/m² at 700 h, increased to 1.89 insect /m² at 900 h, followed by 3.22 insects/m² at 1100 h, reached a maximal level of 4.52 insects/m² at 1300 h, thereafter declined to 3.98 insects/m² at 1500 h and then 2.02 insects/m² at 1700 h in the evening. Likewise, On Kala Amritsari, it was 0.25 insects /m² at 700 h, increased to 1.71 insect/m² at 900 h, followed by 2.89 insects/m² at 1100 h, reached a maximal level of 4.24 insects/m² at 1300 h. Thereafter, it declined to 3.64 insects/m² at 1500 h and then 1.95 insects/m² at 1700 h in the evening (Table 3).

Weekly pattern of abundances of pollinators of plum: During 2009, the abundance of *Apis dorsata* was 4.07 bees/m² on Titron followed by 3.90 bees/m² on Kala Amritsari and 3.60 bees/m² on Alu Bukhara. Second dominant species *A. mellifera* showed maximal abundance on Titron which was 3.43 bees/m² followed by 3.27 bees/m² on Kala Amritsari and 3.05 bees/m² on Alu Bukhara. Third and fourth dominant species *A. florea* and *A. cerana* also showed maximal

Table 4: Weekly pattern of abundances of insect visitors on the flowers of three cultivars of plum (*Prunus domestica*) during January-February, 2009 at Hisar (India)

	No. of insect visitors (per 5 min/m²)*					
Dates	*Apis dorsata*	*Apis mellifera*	*Apis cerana*	*Apis florea*	Dipterans	**Mean±SE
Alu Bokhara						
23/01/09	0.00	1.49±0.25	1.10±0.20	1.16±0.22	0.44±0.15	0.8±0.19^{e}
30/01/09	3.72±0.90	3.27±0.35	2.16±0.30	2.77±0.35	0.60±0.12	2.5±0.51^{c}
6/02/09	4.33±0.72	4.60±0.52	3.33±0.52	3.77±0.40	1.88±0.30	3.58±0.55
13/02/09	5.38±0.63	3.61±0.54	2.55±0.44	2.88±0.34	1.44±0.28	3.17±0.26
20/02/09	4.71±0.55	3.22±0.46	2.05±0.32	1.94±0.29	1.33±0.24	2.65±0.34^{c}
27/02/09	3.50±0.53	2.16±0.33	1.44±0.35	1.60±0.29	1.05±0.22	1.95±0.21^{d}
***Mean±SE	3.60±0.22^{a}	3.05±0.15^{b}	2.10±0.58	2.35±0.33	1.12±0.19^{d}	
Titron						
23/01/09	0.11±0.12	1.57±0.25	1.88±0.30	1.65±0.33	0.79±0.19	1.20±0.22^{f}
30/01/09	3.94±0.48	3.65±0.84	2.43±0.31	2.94±0.45	0.94±0.20	2.78±0.67^{d}
6/02/09	5.33±0.55	4.99±0.52	3.81±0.62	4.60±0.53	1.99±0.35	4.14±0.46^{a}
13/02/09	6.3±0.67	4.21±0.36	2.72±0.47	3.22±0.49	1.68±0.33	3.63±0.52^{b}
20/02/09	4.88±0.59	3.60±0.62	2.50±0.44	2.27±0.33	1.72±0.24	3.00±0.33^{c}
27/02/09	3.88±0.40	2.55±0.35	1.77±0.33	1.71±0.24	1.27±0.23	2.23±0.47^{e}
***Mean±SE	4.07±0.77^{a}	3.43±0.47^{b}	2.51±0.25^{c}	2.73±0.72^{c}	1.39±0.33^{d}	
Kala Amritsari						
23/01/09	0.00	1.52±0.25	1.27±0.26	1.55±0.28	0.49±0.13	0.96±0.19^{e}
30/01/09	3.90±0.42	3.55±0.50	2.33±0.37	2.88±0.47	0.84±0.19	2.70±0.55^{c}
6/02/09	5.23±0.71	4.89±0.52	3.71±0.40	4.20±0.53	1.90±0.29	3.98±0.45^{a}
13/02/09	5.83±0.77	3.92±0.54	2.58±0.48	3.11±0.41	1.55±0.22	3.39±0.16^{b}
20/02/09	4.78±0.55	3.33±0.46	2.25±0.32	2.11±0.36	1.56±0.24	2.80±0.24^{c}
27/02/09	3.68±0.48	2.42±0.35	1.66±0.24	1.65±0.24	1.11±0.22	2.10±0.11^{d}
***Mean±SE	3.90±0.22^{a}	3.27±0.47^{b}	2.30±0.33^{c}	2.58±0.53^{c}	1.24±0.22^{d}	

*Mean±SE of 30 observations, **Mean±SE of 150 observations, ***Mean±SE of 180 observations, LSD ($p \leq 0.05$) for dates: 0.411, LSD ($p \leq 0.05$) for species: 0.383, LSD ($p \leq 0.05$) for varieties: 0.37, treatment means with different letters differ significantly

abundance on Titron (2.73 and 2.51 bees/m², respectively) followed by on Kala Amritsari (2.58 and 2.30 bees/m²) and Alu Bokhara (2.35 and 2.10 bees/m², respectively). Total number of dipterous insects was 1.39 insects/m² on Titron followed by 1.24 insects/m² on Kala Amritsari and 1.12 insects /m² on Alu Bokhara. The differences among the pollinator species as well as the three plant varieties were significant ($p \leq 0.05$, ANOVA, Table 4).

The abundance of different species during 2010 was slightly less as compared to 2009 season, but they followed the same pattern of abundance in different species and varieties as well (Table 5). During 2010, the abundance of *Apis dorsata* was 3.96 bees/m² on Titron followed by 3.68 bees/m² on Kala Amritsari and 3.55 bees/m² on Alu Bokhara. Second dominant species *A. mellifera* showed maximal abundance on Titron which was 3.32 bees/m² followed by 3.01 bees/m² on Kala Amritsari and 2.89 bees/m² on Alu Bokhara. Third and fourth dominant species *A. florea* and *A. cerana* also showed maximal abundance on Titron (*A. florea* = 2.66 bees/m² and *A. cerana* = 2.19 bees/m²) followed by on Kala Amritsari (*A. florea* = 2.40 bees/m² and *A. cerana* = 2.00 bees/m²) and Alu Bokhara (*A. florea* = 2.30 bees/m² and *A. cerana* = 1.91 bees/m²). Total number of dipterous insects was significantly higher on Titron (1.20 insects/m²) followed by on Kala Amritsari (1.11 insects/m²) and Alu Bokhara (0.91 insects/m²). The differences among the pollinator species as well as the three varieties of plum were significant ($p \leq 0.05$, ANOVA, Table 5).

Patterns of varietal preferences of pollinators of plum: If the relative abundance of pollinators is taken as a measure of the varietal preference of pollinators of plum, the order of preference for the three varieties of plum (viz. Alu Bokhara, Titron and Kala Amritsari), in 2009 and 2010 was similar for all the five types of pollinators that was in the order of Titron (2.82 and

Table 5: Weekly pattern of abundances of insect visitors on the flowers of three cultivars of plum (*Prunus domestica*) during January-February, 2010 at Hisar (India)

	No. of insect visitors (per 5 min/m²)*					
Dates	*Apis dorsata*	*Apis mellifera*	*Apis cerana*	*Apis florea*	Dipterans	**Mean±SE
Alu Bokhara						
27/01/10	0.00	1.29±0.22	0.88±0.20	1.10±0.12	0.00	0.65±0.25^{d}
3/02/10	3.77±0.54	3.13±0.52	2.07±0.36	2.76±0.47	0.53±0.12	2.45±0.21^{b}
10/02/10	4.27±0.57	4.19±0.53	3.16±0.42	3.73±0.57	1.27±0.26	3.32±0.45^{a}
17/02/10	5.34±0.59	3.55±0.37	2.16±0.35	2.71±0.40	1.52±0.29	3.05±0.28^{a}
24/02/10	4.55±0.52	2.88±0.33	1.94±0.29	1.98±0.27	1.16±0.22	2.50±0.44^{d}
3/03/10	3.38±0.53	2.33±0.37	1.27±0.28	1.55±0.28	0.99±0.20	1.90±0.22^{c}
***Mean±SE	3.55±0.42^{a}	2.89±0.11^{b}	1.91±0.48^{d}	2.30±0.33^{c}	0.91±0.13^{e}	
Titron						
27/01/10	0.00	1.40±0.28	1.44±0.37	1.44±0.25	0.38±0.23	0.93±0.32^{d}
3/02/10	4.88±0.55	3.44±0.52	2.16±0.32	2.22±0.30	1.38±0.34	2.81±0.23^{b}
10/02/10	4.77±0.55	4.77±0.59	3.49±0.50	4.38±0.52	1.72±0.22	3.82±0.36^{a}
17/02/10	6.49±0.65	4.00±0.49	2.49±0.44	3.10±0.50	1.63±0.24	3.54±0.42^{a}
24/02/10	3.88±0.53	3.83±0.74	2.27±0.36	3.16±0.38	1.05±0.20	2.83±0.57^{b}
3/03/10	3.77±0.41	2.49±0.43	1.33±0.24	1.66±0.25	1.05±0.11	2.06±0.27^{c}
***Mean±SE	3.96±0.67^{a}	3.32±0.44^{b}	2.19±0.22^{d}	2.66±0.52^{c}	1.20±0.27^{e}	
Kala Amritsari						
27/01/10	0.00	1.33±0.24	0.99±0.19	1.33±0.25	0.27±0.11	0.78±0.29^{d}
3/02/10	3.60±0.41	3.22±0.46	2.15±0.30	2.72±0.35	0.85±0.15	2.50±0.52^{b}
10/02/10	4.33±0.53	4.56±0.52	3.21±0.35	3.87±0.40	1.69±0.32	3.53±0.35^{a}
17/02/10	5.94±0.63	3.66±0.62	2.44±0.44	2.83±0.34	1.55±0.21	3.28±0.16^{a}
24/02/10	4.66±0.53	2.94±0.46	1.98±0.33	2.05±0.31	1.27±0.25	2.58±0.14^{b}
3/03/10	3.60±0.50	2.38±0.37	1.27±0.24	1.63±0.24	1.03±0.19	1.98±0.19^{c}
***Mean±SE	3.68±0.12^{a}	3.01±0.27^{b}	2.00±0.13^{d}	2.40±0.29^{c}	1.11±0.15^{e}	

*Mean±SE of 30 observations, **Mean±SE of 150 observations, ***Mean±SE of 180 observations, LSD ($p \leq 0.05$) for species: 0.336, LSD ($p \leq 0.05$) for varieties: 0.362, LSD ($p \leq 0.05$) for dates: 0.396, treatment means with different letters differ significantly

Table 6: Relative abundances of different insect visitors on three cultivars of plum during 2009

	Relative abundance of different insect visitors					
Varieties	*Apis dorsata*	*Apis mellifera*	*Apis cerana*	*Apis florea*	Dipterans	**Mean±SE
Alu Bokhara	*3.60±0.92	3.05±0.88	2.10±0.58	2.35±0.33	1.12±0.19	2.44±0.12^{c}
Titron	4.07±0.77	3.43±0.47	2.51±0.25	2.73±0.72	1.39±0.33	2.82±0.67^{a}
Kala Amritsari	3.90±0.44	3.27±0.27	2.30±0.33	2.58±0.53	1.24±0.22	2.65±0.28^{b}
***Mean±SE	3.85±0.55^{a}	3.25±0.33^{b}	2.30±0.13^{d}	2.55±0.31^{c}	1.25±0.19^{d}	

*Mean±SE. of 180 observations, **Mean±SE of 900 observations, ***Mean±SE of 540 observations, LSD ($p \leq 0.05$) for species: 0.320, LSD ($p \leq 0.05$) for varieties: 0.288, treatment means with different letters differ significantly

Table 7: Relative abundances of different insect visitors on three cultivars of plum during 2010

	Relative abundance of different insect visitors					
Varieties	*Apis dorsata*	*Apis mellifera*	*Apis cerana*	*Apis florea*	Dipterans	**Mean±SE
Alu Bokhara	3.55±0.88	2.89±0.33	1.91±0.18	2.30±0.13	0.91±0.13	2.31±0.12^{c}
Titron	3.96±0.67	3.32±0.17	2.19±0.25	2.66±0.68	1.20±0.38	2.66±0.57^{a}
Kala Amritsari	3.68±0.24	3.01±0.26	2.00±0.31	2.40±0.57	1.11±0.33	2.44±0.18^{b}
***Mean±SE	3.73±0.25^{a}	3.07±0.44^{b}	2.03±0.47^{d}	2.45±0.33^{c}	1.07±0.15^{e}	

*Mean±SE of 180 observations, **Mean±SE of 900 observations, ***Mean±SE of 540 observations, LSD ($p \leq 0.05$) for species: 0.290, LSD ($p \leq 0.05$) for varieties: 0.224, treatment means with different letters differ significantly

2.66 insects/m², respectively) >Kala Amritsari (2.65 and 2.44 insects/m², respectively) >Alu Bokhara (2.44 and 2.31 insects/m², respectively). Therefore, Titron was the best preferred followed by Kala Amritsari and Alu Bokhara was the least preferred variety for the pollinators. The differences among abundances of insects on all the three varieties were significant ($p \leq 0.05$, ANOVA, Table 6 and 7).

Fig. 2: *Apis dorsata* foraging for nectar in the flowers of plum (*Prunus domestica*)

Fig. 3: *Apis mellifera* foraging for nectar in the flowers of plum (*Prunus domestica*)

Relative abundances of the pollinators: During 2009 and 2010, irrespective of the variety, *Apis dorsata* was the most abundant visitor of plum flowers (3.85 and 3.73 bees/m², respectively) followed by *A. mellifera* (3.25 and 3.07 bees/m², respectively), *A. florea* (2.55 and 2.45 bees/m², respectively), *A. cerana* (2.30 and 2.03 bees/m², respectively) and dipterous insects. The difference among the pollinator species in both the years were significant ($p \leq 0.05$, ANOVA, Table 6 and 7).

Foraging behaviour of the insects visiting the flowers of plum

Foraging modes of the insects visiting the flowers of plum: Honey bees and dipterous insects collected pollen from open flowers of plum. Petals were arranged in a broad, open cup around the flower's pollen organs. The bees were found to bite the anthers with their mandibles and used their forelegs to pull the anthers towards their bodies. This may be attributed to the abundant number of anthers carrying pollen on plum flowers, which were easily accessible to the pollinators. All the major pollinators viz. *Apis dorsata*, *A. mellifera, A. cerana*, *A. florea* and dipterous insects followed the sternotribic mode of pollination. In this attempt, the ventral surface of the pollinators got heavily dusted with the pollen grains which were easily transferred to the stigma of other flowers thus making them important pollinators of plum (Fig. 2-5). Nectar

Fig. 4: *Apis florea* foraging for nectar in the flowers of plum (*Prunus domestica*)

Fig. 5: *Sarcophaga* sp., visiting the flower of plum (*Prunus domestica*)

collection by honeybees and dipterous insects followed the same pattern; first they alighted on the flower, then inserted their proboscis into the corolla and pumped the nectar up into the mouth/pharynx.

Foraging rates of the insects visiting the flowers of plum: In 2009, foraging rates of *Apis dorsata*, *A. mellifera*, *A. cerana, A. florea* and dipterous on insects on Alu Bokhara were 6.13, 7.24, 6.53, 5.84 and 5.77 flowers/min, respectively. On Titron, these were 6.03, 7.15, 6.80, 6.06 and 5.42 flowers/min, respectively and on Kala Amritsari the rates were 5.79, 6.62, 6.73, 5.75 and 5.47 flowers/min, respectively (Table 8). Thus foraging rates of *Apis mellifera* were maximal on two varieties (Alu Bokhara and Titron) and on third variety(Kala Amritsari) foraging rates of *A. cerana* were maximal followed by *A. mellifera*, *A. dorsata*, *A. florea* and dipterous insects. In 2010, foraging rates of *Apis dorsata, A. mellifera, A. cerana*, *A. florea* and dipterous insects on Alu Bokhara were 6.04, 6.86, 6.56, 6.03 and 5.32 flowers/min, respectively. On Titron, these rates were 6.33, 6.95, 6.42, 5.79 and 5.49 flowers/min, respectively and on Kala Amritsari these were 6.08, 6.77, 6.39,

Table 8: Diurnal pattern of foraging rates of different insect pollinators of plum (*Prunus domestica*) during 2009

	No. of flowers visited per min*					
Time (h)	*Apis dorsata*	*Apis mellifera*	*Apis cerana*	*Apis florea*	Dipterans	**Mean±SE
Alu Bokhara						
700	3.10±0.36	4.42±0.52	3.40±0.88	3.20±0.68	3.22±0.48	3.46±0.33^{f}
900	3.50±1.12	4.50±0.26	3.98±0.67	4.36±0.54	4.32±0.51	4.13±0.18^{d}
1100	6.11±0.53	7.28±0.47	6.51±0.33	6.11±0.53	5.91±0.67	6.38±0.31^{c}
1300	8.44±0.67	9.24±0.92	10.30±1.50	9.76±1.04	9.53±0.61	9.45±0.29^{a}
1500	7.35±0.92	9.81±0.75	9.69±0.47	8.06±0.72	6.98±0.67	8.37±0.33^{b}
1700	4.55±0.31	3.88±0.22	4.24±0.55	3.88±0.28	3.76±0.26	4.06±0.26
***Mean±SE	6.13±0.94^{c}	7.24±0.88^{a}	6.53±0.82^{b}	5.84±1.02^{d}	5.77±0.26^{e}	
Titron						
700	3.44±0.47	4.46±0.41	4.40±0.58	3.70±0.69	3.80±0.04	3.96±0.31^{e}
900	4.71±0.69	5.71±0.38	5.06±0.55	4.24±0.71	4.38±0.64	4.82±0.26^{d}
1100	7.41±0.52	8.92±1.50	6.90±0.75	5.90±0.69	6.28±0.53	7.08±0.33^{c}
1300	9.28±1.04	10.86±0.79	10.49±0.88	9.33±0.68	8.70±0.82	9.73±0.47^{a}
1500	7.85±0.72	11.55±0.53	9.12±0.75	8.16±0.67	7.30±0.88	8.79±0.28^{b}
1700	4.15±0.33	4.93±0.83	5.20±0.59	4.60±0.46	4.12±0.53	4.60±0.21^{d}
***Mean±SE	6.03±0.86^{d}	7.15±0.41^{a}	6.80±0.61^{b}	6.06±0.50^{c}	5.42±0.63^{e}	
Kala Amritsari						
700	3.94±0.67	3.66±0.72	3.70±0.79	3.20±0.26	3.10±0.41	3.52±0.24^{f}
900	5.22±0.76	6.77±0.67	4.50±0.56	3.72±0.51	3.70±0.62	4.78±0.28^{d}
1100	6.93±0.94	8.82±0.30	7.70±0.67	6.70±0.53	4.30±0.82	6.89±0.33^{c}
1300	9.28±1.04	10.86±0.79	10.49±0.88	9.33±0.68	8.70±0.82	9.73±0.47^{a}
1500	8.47±0.75	9.20±1.01	8.90±1.02	7.91±1.14	7.80±1.03	8.45±0.26^{b}
1700	3.53±0.69	4.93±0.24	5.13±0.23	3.92±0.47	4.42±0.50	4.38±0.19^{e}
***Mean±SE.	5.79±0.83^{d}	6.73±0.75^{a}	6.62±0.67^{a}	5.75±0.68^{b}	5.47±0.94^{c}	

*Mean±SE of 30 observations, **Mean±SE of 150 observations, ***Mean±SE of 180 observation, LSD ($p \leq 0.05$) for species: 0.300, LSD ($p \leq 0.05$) for varieties: 0.232, LSD ($p \leq 0.05$) for time: 0.329, treatment means with different letters differ significantly

5.57 and 5.46 flowers/min, respectively. Thus, on each variety, foraging rate of *Apis mellifera* was maximal followed by *A. cerana, A. dorsata, A. florea* and the dipterous insects; the differences were significant ($p \leq 0.05$, ANOVA, Table 8, 9).

Foraging rates of the insects visiting the flowers of plum differed significantly among the species as well as among the different observational hours of the day on all the varieties in both the years ($p \leq 0.05$, ANOVA, Table 8, 9). In general, foraging rates of hymenopterous insects were significantly higher than those of the dipterous insects in both the years. Foraging rates of all the species were maximal between 1300-1500 h of the day as compared to the rest of the day hours.

Activity duration of the insect pollinators of plum flowers: The insect species visiting plum flowers in 2009-2010 remained active from 900-1700 h; however, *Apis dorsata* remained active from 700-1700 h of the day. Activity was less in the morning and evening as compared to that in the afternoon.

During 2009, among all the insect visitors, *Apis dorsata* remained active for the longest duration on Titron followed by Kala Amritsari and Alu Bokhara (9.29, 9.18, 8.98 h, respectively). The activity durations of *A. mellifera, A. cerana, A. florea* and dipterous insects were 7.44, 6.48, 7.12, 6.98 h on Alu Bokhara, 7.78, 6.84, 7.53, 7.38 h on Titron and 7.65, 6.62, 7.38, 7.15 h on Kala Amritsari, respectively (Table 10). During 2010 too, among all the insect visitors, *Apis dorsata* remained active for the longest duration on Titron followed by on Kala Amritsari and Alu Bokhara (9.19, 9.10, 8.88 h). The activity durations of *A. mellifera, A. cerana*, *A. florea* and the dipterous insects were 7.25, 6.40, 6.98, 6.71 h on Alu Bokhara; these were 7.65, 6.74, 7.38, 7.15 h on Titron; and 7.30, 6.52, 7.15, 7.11 h on Kala Amritsari, respectively (Table 11).

Table 9: Diurnal pattern of foraging rates of different insect pollinators of plum (*Prunus domestica*) during 2010

	No. of flowers visited per min*					
Time (h)	*Apis dorsata*	*Apis mellifera*	*Apis cerana*	*Apis florea*	Dipterans	**Mean±SE
Alu Bokhara						
700	3.08±0.67	3.80±0.82	3.51±0.55	3.11±0.88	3.08±0.68	3.31±0.15^{f}
900	4.71±0.47	3.94±0.39	5.60±0.63	4.10±0.16	3.29±0.33	4.32±0.25^{d}
1100	5.50±0.55	6.58±0.67	7.54±0.47	5.83±0.55	5.66±0.48	6.22±0.20^{c}
1300	9.60±0.44	9.50±0.79	9.26±0.59	9.18±0.50	9.12±0.75	9.33±0.41^{a}
1500	7.82±0.52	8.16±0.82	8.92±0.26	7.26±0.67	7.84±0.61	8.00±0.33^{b}
1700	3.81±0.67	5.38±0.69	3.51±0.22	4.22±0.58	3.53±0.53	4.09±0.28^{e}
***Mean±SE	6.04±0.56^{b}	6.86±0.67^{a}	6.56±0.52^{a}	6.03±0.44^{b}	5.32±0.26^{c}	
Titron						
700	4.16±0.19	4.40±0.83	4.09±0.83	3.22±0.68	3.88±0.82	3.95±0.17^{f}
900	4.71±0.27	5.66±0.88	4.84±0.24	4.31±0.55	4.40±0.59	4.78±0.22^{d}
1100	6.92±0.79	7.81±0.94	7.10±0.58	6.54±0.61	5.92±0.67	6.85±0.27^{c}
1300	8.36±0.42	11.42±1.12	9.36±0.31	10.81±1.04	8.35±0.42	9.66±0.33^{a}
1500	8.26±1.01	8.88±0.50	8.49±0.44	7.75±0.47	7.42±0.52	8.16±0.21^{b}
1700	4.33±0.63	4.70±0.56	4.26±0.30	3.78±0.19	3.10±0.69	4.03±0.18
***Mean±SE	6.33±0.92^{b}	6.95±0.31^{a}	6.42±0.61^{b}	5.79±0.59^{c}	5.49±0.69^{c}	
Kala Amritsari						
700	4.28±0.27	3.42±0.22	3.44±0.52	3.14±0.29	3.10±0.23	3.41±0.19^{f}
900	3.34±0.52	4.21±0.53	5.72±0.44	3.94±0.37	4.97±0.31	4.43±0.21^{d}
1100	6.26±0.42	6.27±0.75	7.48±0.44	5.53±0.33	5.93±0.44	6.29±0.38^{c}
1300	9.60	10.28±1.02	9.78±0.58	9.16±0.75	8.25±0.89	9.41^{a}±0.33
1500	7.812	9.50±0.89	9.33±0.88	8.30±0.40	6.68±0.53	8.32±0.28^{b}
1700	4.20±0.30	5.66±0.26	3.95±0.72	4.22±0.36	3.23±0.26	4.25±0.22^{e}
***Mean±SE	6.08±0.46^{c}	6.77±0.88^{a}	6.39±0.19^{b}	5.57±0.22^{d}	5.46±0.75^{d}	

*Mean±SE of 30 observations, **Mean±SE of 150 observations, ***Mean±SE of 180 observation, Mean with the dissimilar letters differ significantly, LSD ($p \leq 0.05$) for species: 0.305, LSD ($p \leq 0.05$) for varieties: 0.224, LSD ($p \leq 0.05$) for time: 0.321, treatment means with different letters differ significantly

Table 10: Activity duration of insect pollinators of plum (*Prunus domestica*) during 2009

	Activity duration (h) on three varieties of plum		
Insect pollinators	Alu Bokhara	Titron	Kala Amritsari
Apis dorsata	8.98	9.29	9.18
Apis mellifera	7.44	7.78	7.65
Apis cerana	6.48	6.84	6.63
Apis florea	7.12	7.53	7.38
Dipterans	6.98	7.38	7.15
Means	7.42	7.76	7.61

Table 11: Activity duration of insect pollinators of plum (*Prunus domestica*) during 2010

	Activity duration (h) on three varieties of plum		
Insect pollinators	Alu Bokhara	Titron	Kala Amritsari
Apis dorsata	8.88	9.19	9.10
Apis mellifera	7.25	7.65	7.30
Apis cerana	6.40	6.74	6.52
Apis florea	6.48	7.38	7.15
Dipterans	6.71	7.15	7.11
Means	7.14	7.62	7.43

Number of loose pollen grains sticking on the body of pollinators of plum: In 2009, irrespective of the variety, the number of loose pollen grains was maximal (6260.33) on the body of *Apis dorsata* followed by *A. mellifera* (4556.50), *A. cerana* (4353.36) and *A. florea* (2618.20). The number of loose pollen grains was least on the body of dipterous insects (704.60). The differences among the pollinators were significant ($p \leq 0.05$, ANOVA, Table 12). In 2010 too, irrespective of the variety, the average number of loose pollen grains was maximal on the body of *Apis dorsata* (6240.23) followed by *A. mellifera* (4619.66), *A. cerana* (4362.33) and *A. florea* (2606.36). The

Table 12: Number of loose pollen grains carried by the insect pollinators of three varieties of plum (*Prunus domestica*) during 2009

	No. of loose pollen grains*			
Insect pollinators	Alu Bokhara	Titron	Kala Amritsari	Mean±SE
Apis dorsata	5928.60±172.28	6625.30±166.46	6227.10±182.57	6260.33±116.51[a]
Apis mellifera	4466.60±195.15	4771.60±196.63	4431.30±213.97	4556.50±113.37[b]
Apis cerana	4262.60±161.41	4525.00±152.37	4272.50±197.56	4353.36±110.66[c]
Apis florea	2355.30±188.40	2950.60±169.88	2548.10±159.62	2618.20±92.23[d]
Dipterans	545.10±101.19	940.00±100.79	628.70±116.71	704.60±65.32[e]
Mean±SE	3511.64±275.26[c]	3962.50±270.70[a]	3621.54±288.85[b]	

*Mean±SE of 10 observations, Mean with dissimilar letter differ significantly, LSD ($p \leq 0.05$) for pollinators: 170.77, LSD ($p \leq 0.05$) for varieties: 132.27, treatment means with different letters differ significantly

Table 13: Number of loose pollen grains carried by the insect pollinators of three varieties of plum (*Prunus domestica*) during 2010

	No. of loose pollen grains*			
Insect pollinators	Alu Bokhara	Titron	Kala Amritsari	Mean±SE
Apis dorsata	5976.00±200.68	6615.10±210.41	6141.60±145.60	6244.23±104.95[a]
Apis mellifera	4458.30±178.52	4818.30±131.20	4582.40±197.12	4619.66±111.36[b]
Apis cerana	4233.60±145.31	4497.10±102.83	4356.30±125.16	4362.33±125.79[c]
Apis florea	2327.30±185.13	2968.10±209.85	2523.70±152.94	2606.36±109.37[d]
Dipterans	512.20±148.22	918.10±169.04	600.00±101.83	676.33±84.33[e]
Mean±SE	3501.48±175.26[c]	3963.30±145.31[a]	3640.80±275.31[b]	

*Mean±SE of 10 observations, Mean with dissimilar letter differ significantly, LSD ($p \leq 0.05$) for pollinators: 172.91, LSD ($p \leq 0.05$) for varieties: 133.93, treatment means with different letters differ significantly

number of loose pollen grains was least on the body of dipterous insects (676.76). Here too, the differences among the pollinators were significant ($p \leq 0.05$, ANOVA, Table 13).

Pollinating efficiencies of pollinators of plum: On the basis of different pollinating attributes i.e. abundance of the visitors (number of insects/m²/5 min), their foraging rates (number of flowers visited/min), activity durations (h) and number of loose pollen grains carried on the body of a pollinator, the performance scores of pollinators were derived for both the years (Table 14 and 15) and the insect pollinators were tentatively ranked for their pollinating efficiencies. These indices clearly indicate that among the insect pollinators, *Apis dorsata* came out to be the most efficient pollinator in both the years followed by *A. mellifera*, *A. cerana* and *A. florea*. The dipterous insects were the least efficient pollinators of plum in both the years.

Melittophily predominates in the European plum (*Prunus domestica*): In the semi-arid environments of Northwest India, honey bees were the most abundant visitors of European plum (*P. domestica*). The honey bees carried bigger pollen loads than the non-*Apis* pollinators and were the fastest foragers and worked for longer durations. They had higher pollinating efficiencies too. If index values in Table 14 and 15 are taken as face values of the pollinators, in 2009 in the variety Alu Bokhara, honeybees together were found to pollinate 98.86% flowers where as non-*Apis* insects pollinated only 1.14% flowers; the corresponding figures in 2010 were 99.2 and 0.8% flowers, respectively. Similar patterns were observed in other varieties too. These values for the Titron variety were 99.03 and 0.97% flowers in 2009 and 98.90 and 1.10% flowers in 2010. Likewise, values for the Kala Amritsari were 99.18 and 0.82% flowers in 2009 and 99.38 and 0.62% flowers in 2010. On the basis of these parameters, melittophily distinctly predominated in the European plum (*P. domestica*) in the semi-arid environments of Northwest India.

Table 14: Pollinating efficiency ranks of pollinators of three varieties of plum (*Prunus domestica*) based on indices derived from the performance scores of various pollination attributes during 2009

	Performance score for a pollination attribute					
Pollinators	Abundance	Activity duration	Foraging rate	Pollen grain	Pollination index	Rank of pollinators
Variety 1 (Alu Bokhara)						
Apis dorsata	1.48	1.19	0.95	1.67	2.79I	I
Apis mellifera	1.23	1.00	1.13	1.20	1.66I	II
Apis cerana	0.89	0.88	1.08	1.14	0.96	III
Apis florea	0.98	0.96	0.96	0.74	0.66	IV
Dipterans	0.40	0.95	0.86	0.23	0.07	V
Variety 2 (Titron)						
Apis dorsata	1.46	1.21	0.97	1.71	2.93	I
Apis mellifera	1.25	1.00	1.14	1.22	1.73	II
Apis cerana	0.84	0.87	1.03	1.17	0.88	III
Apis florea	0.96	0.96	0.92	0.70	0.59	IV
Dipterans	0.46	0.94	0.91	0.17	0.06	V
Variety 3 (Kala Amritsari)						
Apis dorsata	1.49	1.20	0.95	1.68	2.85	I
Apis mellifera	1.24	1.00	1.09	1.27	1.71	II
Apis cerana	0.80	0.87	1.10	1.21	0.92	III
Apis florea	0.98	0.97	0.94	0.67	0.59	IV
Dipterans	0.47	0.94	0.90	0.15	0.05	V

Table 15: Pollinating efficiency ranks of pollinators of three varieties of plum (*Prunus domestica*) based on indices derived from the performance scores of various pollination attributes during 2010

	Performance score for a pollination attribute					
Pollinators	Abundance	Activity duration	Foraging rate	Pollen grain	Pollination index	Rank of pollinators
Variety 1 (Alu Bokhara)						
Apis dorsata	1.50	1.22	0.98	1.65	2.95	I
Apis mellifera	1.26	1.00	1.11	1.25	1.74	II
Apis cerana	0.81	0.88	1.06	1.19	0.89	III
Apis florea	1.00	0.96	0.97	0.69	0.64	IV
Dipterans	0.41	0.92	0.86	0.16	0.05	V
Variety 2 (Titron)						
Apis dorsata	1.58	1.20	1.02	1.66	3.21	I
Apis mellifera	1.23	1.00	1.12	1.21	1.66	II
Apis cerana	0.78	0.88	1.03	1.13	0.79	III
Apis florea	0.97	0.96	0.93	0.74	0.64	IV
Dipterans	0.41	0.93	0.88	0.23	0.07	V
Variety 3 (Kala Amritsari)						
Apis dorsata	1.50	1.22	1.00	1.70	3.11	I
Apis mellifera	1.27	0.98	1.11	1.31	1.80	II
Apis cerana	0.81	0.87	1.05	1.24	0.91	III
Apis florea	0.99	0.96	0.92	0.74	0.64	IV
Dipterans	0.41	0.95	0.90	0.14	0.04	V

DISCUSSION

Plum flowers attracted insects belonging to many families and genera. However, honeybees have been reported as the major visitors of this plant. It is evident from the present study too, as about 90% of the pollinators of plum were bees (approximately 29.17% *Apis dorsata*, 24.6% *A. mellifera*, 19.3% *A. florea* and 17.4% *A. cerana*) and only 9.5% were the dipterous insects. Among the bees, the wild honey bees (*Apis dorsata* and *Apis florea*) comprised about 54% of the pollinators of this plant. Abrol *et al*. (2005) reported insects of 14 families and 27 species visiting the flowers of plum in North India. Of all these insects, four species of honeybees (*Apis dorsata, A. mellifera, A. cerana* and *A. florea*) were the major flower visitors and comprised more than 93.91% of the total insects visiting the flowers of plum. Their abundance was in the descending order of *Apis dorsata* >*A. mellifera* >*A. cerana* >*A. florea*. Guitian (1994) too found that principal pollinators belonging to the Apidae family accounted for 79% of the visits *to Prunus spinosa.*

All the major five species visiting the flowers of plum acted as pollinators as all were top foragers and none resorted to nectar thieving/robbing. The sternotribic mode of foraging made them reliable pollinators of plum. Although, information on nectar thieving by the pollinators is available on other plants of this region (Sihag and Rathi, 1994), such a behavior was absent among the pollinators of plum at Hisar. Foraging rates of pollinators varied in the two years. In general, foraging rates of hymenopterous insects were significantly higher than those of dipterous insects in both the seasons. Foraging rate was found to be maximal in *Apis mellifera* followed by *A. cerana, A. dorsata*, *A. florea* and least was in the dipterous insects. Similar observations were made by Rana and Gupta (1997); they reported that honey bees collected both nectar and pollen from the flowers of plum. Interestingly, in their study too, the time spent per flower for nectar and pollen collection varied to a great extent during the two years of observation. Nectar collecting *Apis mellifera* and *A. cerana* spent on an average 10.11 and 8.89 sec/flower, respectively during 1996, whereas the respective values for 1997 were 15.66 and 10.96 sec/flower.

Activity duration of the pollinators has a direct bearing on the intensity of pollination. Insect pollinators will pollinate more flowers if they remain active for a longer duration. Foraging activity duration of a pollinator vary from species to species and plant to plant (Free, 1993). Priti and Sihag (1998) reported that the honeybee activity on flowers of carrot was maximal when temperature ranged between 28.3 and 32.3°C; however, the activity declined at higher temperatures. They also reported that bees did not resume foraging when the temperature was favourable in the evening but the light intensity declined. This probably was due to non availability of pollen and nectar. Activity duration of *Apis florea* was maximal followed by all dipterous flies, *A. mellifera* and *A. dorsata*. In the present study, the insect species visiting the plum flowers in 2009-2010 seasons remained active from 900-1700 h; *Apis dorsata* remained active from 0700-1700 h; the activity duration in descending order was *A. dorsata* >*A. mellifera* > *A. cerana* >*A. florea* >dipterous insects in both the seasons (Table 10, 11). Activity was less in the morning and evening hours of the day as compared to afternoon hours.

Pollination process depends upon the transfer of pollen from one flower to another. In the entomophilous crops, insect pollinators accomplish this task. More pollen will be transferred by an insect if it carries larger number of loose pollen grains and may pollinate several flowers one after the other (Crane, 1990; Free, 1993). Bees are considered to be the most important voluntary pollinators because they are better adapted to carry pollen grains due to their morphological adaptations. The structural features of bees which aid in pollination are the presence of pubescent hairs on their bodies adapted for carrying pollen and presence of pollen carrying baskets on their legs or scopa on their abdomen. Verma and Dulta (2011) reported that the foragers of *A. mellifera* carried significantly heavier pollen loads, touched more stigmas and remained longer on individual apple flowers than those of *A. cerana indica.*

In the present study, insect pollinators were ranked for their pollinating efficiencies. Pollinating indices clearly indicate that among the insect pollinators, *Apis dorsata* proved to be the most efficient pollinator of plum followed by *A. mellifera*, *A. cerana*, *A. florea* and the dipterous insects were the least efficient pollinators of plum in both the seasons. In earlier study too, *Apis dorsata* was found to be the natural pollinator of many crops in Northwestern region of India (Sihag, 2014). Therefore, as recommended earlier (Sihag, 2014), for the pollination of crops of this region, conservation of this honeybee is very important. Method of derivation of pollination indices and making comparison of the pollinators on the basis of such indices has already been used in many earlier studies (Sihag and Rathi, 1994; Arya *et al*., 1994; Priti and Sihag, 1997, 1998, 2000a, b;

Priti *et al*., 2001; Gahlawat *et al*., 2002a, b; Narwania *et al*., 2003; Chaudhary and Sihag, 2003; Chaudhary *et al*., 2009; Wadhwa and Sihag, 2012). This method seemed to provide a satisfactory solution for measuring the relative efficiency of pollinators of plum too.

CONCLUSION

In the Northwestern region of India, blossoms of plum attracted 12 insect species. Among the different visitors, hymenopterous insects were the dominant visitors whereas, dipterous insects were comparatively less abundant; the remaining other insects were non- dominant visitors in both the years of the study. Among the hymenopterous insects, *Apis dorsata*, *A. mellifera*, *A. cerana* and *A. florea* were the major visitors in both the years. Maximal abundance of insects was recorded on Titron variety of plum followed by Kala Amritsari and Alu Bokhara in both the years. *Apis dorsata* was the most efficient pollinator of this plant; other three *Apis* sp., were also important pollinators but were at a lower rank in pollinating efficiency. This indicates the prevalence and predominance of melittophilous mode of pollination in plum in the Northwestern region of India and wild honey bees (*Apis dorsata* and *Apis florea*) constituted more than 54% of the major pollinators of plum in this region. Therefore, for the effective pollination of this plant, conservation of its honeybee pollinators is most important.

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REFERENCES

Abrol, D.P., D. Sharma and M. Monobrullah, 2005. Abundance and diversity of different insect pollinators visiting peach and plum flowers and their impact on fruit production. J. Res. SKUAST-J, 4: 38-45.

Ahmed, T., H. Sadia, A. Khalid, S. Batool and A. Janjua, 2010a. Report: Prunes and liver function: A clinical trial. Pak. J. Pharm. Sci., 23: 463-466.

Ahmed, T., H. Sadia, S. Batoo, A. Janjua and F. Shuja, 2010b. Use of prunes as a control of hypertension. J. Ayub Med. College Abbottabad, 22: 28-31.

Arya, D.R., R.C. Sihag and P.R. Yadav, 1994. Diversity, abundance and foraging activity of insect pollinators of sunflower (*Helianthus annuus* L.) at Hisar. Indian Bee J., 56: 172-178.

Beals, K.A. and V.L. Fulgoni, 2005. Consumption of peaches, plums and nectarines is associated with better nutrient intakes, improved anthropometric measurements and reduced risk of hypertension in NHANES 1999-2002. J. Am. Dietetic Assoc., 105: 61-61.

Bu, S.Y., M. Lerner, B.J. Stoecker, E. Boldrin, D.J. Brackett, E.A. Lucas and B.J. Smith, 2008. Dried plum polyphenols inhibit osteoclastogenesis by downregulating NFATc1 and inflammatory mediators. Calcified Tissue Int., 82: 475-488.

Chaudhary, N. and R.C. Sihag, 2003. Diversity, foraging behavior and foraging efficiency of different pollinators visiting onion (*Allium cepa* L.) blossoms. Korean J. Apicult., 18: 103-108.

Chaudhary, N., R.C. Sihag and M.C. Pandey, 2009. Relative abundance, diversity and dominance concentration of two honeybee species on three concurrently flowering crops onion (*Allium cepa* L.), carrot (*Daucus carota* L.) and fennel (*Foeniculum vulgare* L.). Pestology, 7: 9-13.

Crane, E., 1990. Bees and Beekeeping. Heinemann Newnes, Oxford pp: 68-69.

Deyhim, F., B.J. Stoecker, G.H. Brusewitz, L. Devareddy and B.H. Arjmandi, 2005. Dried plum reverses bone loss in an osteopenic rat model of osteoporosis. Menopause, 12: 755-762.

Dhingra, N., R. Sharma and A. Kar, 2014. Evaluation of the antioxidant activities of *Prunus domestica* whole fruit: An *in vitro study*. Int. J. Farmacy Pharmaceut. Sci., 6: 271-276.

Dragan, N. and M. Dragan, 2010. Examining self-compatibility in plum (*Prunus domestica* L.) by fluorescence microscopy. Genetika, 42: 387-396.

El-Kereamy, A., I. El-Sharkawy, R. Ramamoorthy, A. Taheri, D. Errampalli, P. Kumar and S. Jayasankar, 2011. *Prunus domestica* pathogenesis-related protein-5 activates the defense response pathway and enhances the resistance to fungal infection. PLoS One, Vol. 6. 10.1371/journal.pone.0017973

Ertekin, C., S. Gozlekci, O. Kabas, S. Sonmez and I. Akinci, 2006. Some physical, pomological and nutritional properties of two plum (*Prunus domestica* L.) cultivars. J. Food Eng., 75: 508-514.

Free, J.B., 1993. Insect Pollination of Crops. 2nd Edn., Academic Press, London, UK., Pages: 684.

Fujii, T., T. Ikami, J.W. Xu and K. Ikeda, 2006. Prune extract (*Prunus domestica* L.) suppresses the proliferation and induces the apoptosis of human colon carcinoma Caco-2. J. Nutr. Sci. Vitaminol., 52: 389-391.

Gahlawat, S.K., S.K. Narwania, R.C. Sihag and Ombir, 2002a. Studies on the diversity, abundance, activity duration and foraging behaviour of insect pollinators of cucumber (*Cucumis sativus* L.) at Hisar. Korean J. Apicult., 17: 69-76.

Gahlawat, S.K., S.K.O. Narwania and R.C. Sihag, 2002b. Pollination studies on *Pracitrullus fistulosus* at Hisar, India. Ecoprint, 9: 1-6.

Gil, M.I., F.A. Tomas-Barberan, B. Hess-Pierce and A.A. Kader, 2002. Antioxidant capacities, phenolic compounds, carotenoids and vitamin C contents of nectarine, peach and plum cultivars from California. J. Agric. Food Chem., 50: 4976-4982.

Guitian, J., 1994. Selective fruit abortion in *Prunus mahaleb* (Rosaceae). Am. J. Bot., 81: 1555-1558.

Hegedus, A. and J. Halasz, 2006. Self-incompatibility in plums (*Prunus salicina* Lindl., *Prunus cerasifera* Ehrh. and *Prunus domestica* L.). A minireview. Int. J. Horticult. Sci., 12: 137-140.

Hiramoto, K., 2008. *Prunus domestica* and *Prunus armeniaca* seed extracts as anti-stress agents, immunostimulants against UV-induced immunosuppression and health foods. Japanese Tokkyo Koho JP 67 76, 59992 76,599 (Cl. A61K36/73), April 2008.

Hooshmand, S. and B.H. Arjmandi, 2009. Viewpoint: Dried plum, an emerging functional food that may effectively improve bone health. Ageing Res. Rev., 8: 122-127.

Kahkonen, M.P., A.I. Hopia, H.J. Vuorela, J.P. Rauha, K. Pihlaja, T.S. Kujala and M. Heinonen, 1999. Antioxidant activity of plant extracts containing phenolic compounds. J. Agric. Food Chem., 47: 3954-3962.

Kayano, S., N.F. Yamada, T. Suzuki, T. Ikami and K. Shioaki *et al*., 2003. Quantitative evaluation of antioxidant components in prunes (*Prunus domestica* L.). J. Agric. Food Chem., 51: 1480-1485.

Kayano, S.I., H. Kikuzaki, N. Fukutsuka, T. Mitani and N. Nakatani, 2002. Antioxidant activity of prune (*Prunus domestica* L.) constituents and a new synergist. J. Agric. Food Chem., 50: 3708-3712.

Kayano, S.I., H. Kikuzaki, N.F. Yamada, A. Aoki and K. Kasamatsu *et al*., 2004. Antioxidant properties of prunes (*Prunus domestica* L.) and their constituents. Biofactors, 21: 309-313.

Kikuzaki, H., S.I. Kayano, N. Fukutsuka, A. Aoki and K. Kasamatsu *et al*., 2004. Abscisic acid related compounds and lignans in prunes (*Prunus domestica* L.) and their Oxygen Radical Absorbance Capacity (ORAC). J. Agric. Food Chem., 52: 344-349.

Kimura, Y., H. Ito, M. Kawaji, T. Ikami and T. Hatano, 2008. Characterization and antioxidative properties of oligomeric proanthocyanidin from prunes, dried fruit of *Prunus domestica* L. Biosci. Biotechnol. Biochemem., 72: 1615-1618.

Nakatani, N., S.I. Kayano, H. Kikuzaki, K. Sumino, K. Katagiri and T. Mitani, 2000. Identification, quantitative determination and antioxidative activities of chlorogenic acid isomers in prune (*Prunus domestica* L.). J. Agric. Food Chem., 48: 5512-5516.

Narwania, S.K., S.K. Gahlawat, Ombir and R.C. Sihag, 2003. Diversity, Abundance, foraging rates and pollinating efficiency of insects visiting wanga (*Cucumis melo* ssp. Melo) blossoms at Hisar. Korean J. Apicult., 18: 29-36.

Nyeki, J. and Z. Szabo, 1995. Fruit set of plum cultivars under Hungarian ecological conditions. Proceedings of the 2nd International Workshop on Pollination, March 21-22, 1995, Leuven, Belgium, pp: 185-191.

Parker, F.D., 1981. How efficient are bees in pollinating sunflowers? J. Kansas Entomol. Soc., 54: 61-67.

Parker, F.D., 1982. Efficiency of bees in pollinating onion flowers. J. Kansas Entomol. Soc., 55: 171-176.

Priti and R.C. Sihag, 1997. Diversity, visitation frequency, foraging behaviour and pollinating efficiency of insect pollinators visiting cauliflower (*Brassica oleracea* L. var botrytis cv. Hazipur Local) blossoms. Indian Bee. J., 59: 230-237.

Priti and R.C. Sihag, 1998. Diversity, visitation frequency, foraging behaviour and pollinating efficiency of insect pollinators visiting carrot, (*Daucus carota* L. var. HC-I) blossoms. Indian Bee. J., 60: 1-8.

Priti and R.C. Sihag, 1999. Diversity, visitation frequency, foraging behaviour and pollinating efficiency of different insect pollinators visiting coriander (*Coriandrum sativum* L.) blossoms. Asian Bee J., 1: 36-42.

Priti and R.C. Sihag, 2000a. Diversity, Visitation Frequency, Foraging Behaviour and Pollinating Efficiency of Insect Pollinators Visiting Turnip Blossoms. In: Asian Bees and Beekeeping: Progress of Research and Development, Matsuka, M., L.R. Verma, S. Wongsiri, K.K. Shrestha and U. Partap (Eds.). Oxford and IBH Publ. Co. Pvt Ltd., New Delhi, India, ISBN-13: 9781578080847, pp: 190-192.

Priti and R.C. Sihag, 2000b. Diversity, visitation frequency, foraging behaviour and pollinating efficiency of different insect pollinators visiting fennel (*Foeniculum vulgare* L.) blossoms. Asian Bee. J., 2: 57-64.

Priti, R.C. Mishra and R.C. Sihag, 2001. Role of insect pollination in seed production of radish (*Raphanus sativus* L.). Seed Res., 29: 231-234.

Rana, B.S. and J.K. Gupta, 1997. Pollination studies on plum, *Prunus salicina* Lindl., cv. Santa Rosa at Nauni, Himachal Pradesh, India. Indian Bee J., 59: 214-217.

Rop, O., T. Jurikova, J. Mlcek, D. Kramarova and Z. Sengee, 2009. Antioxidant activity and selected nutritional values of plums (*Prunus domestica* L.) typical of the white carpathian mountains. Scientia Horticulturae, 122: 545-549.

Sihag, R.C. and A. Rathi, 1994. Diversity, abundance, foraging behaviour and pollinating efficiency of different bees visiting pigeon pea (*Cajanus cajan* (L.) Millsp.) blossoms. Indian Bee J., 56: 187-201.

Sihag, R.C., 1986. Insect pollination increases seed production in cruciferous and umbelliferous crops. J. Apicult. Res., 25: 121-126.

Sihag, R.C., 1988. Characterization of the pollinators of cultivated cruciferaus and leguminars crops of sub-tropical Hisar, India. Bee Wld., 69: 153-158.

Sihag, R.C., 2001. Why should bee-keeping be utilized as an input in agriculture? Curr. Sci., 81: 1514-1516.

Sihag, R.C., 2013. Bee Diversity for Floral Diversity. In: Nature Science, Islam, M.R. (Ed.). Nova Publishers, New York, pp: 273-278.

Sihag, R.C., 2014. Phenology of migration and decline in colony numbers and crop hosts of giant honeybee (*Apis dorsata* F.) in semiarid environment of Northwest India. J. Insects. 10.1155/2014/639467

Slimestad, R., E. Vangdal and C. Brede, 2009. Analysis of phenolic compounds in six Norwegian plum cultivars (*Prunus domestica* L.). J. Agric. Food Chem., 57: 11370-11375.

Snedecor, G.W. and W.G. Cochran, 1967. Statistical Methods. 6th Edn., Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, India, Pages: 593.

Tinker, L.F., B.O. Schneeman, P.A. Davis, D.D. Gallaher and C.R. Waggoner, 1991. Consumption of prunes as a source of dietary fiber in men with mild hypercholesterolemia. Am. J. Clin. Nutr., 53: 1259-1265.

Tomas-Barberan, F.A., M.I. Gil, P. Cremin, A.L. Waterhouse, B. Hess-Pierce and A.A. Kader, 2001. HPLC-DAD-ESIMS analysis of phenolic compounds in nectarines, peaches and plums. J. Agric. Food Chem., 49: 4748-4760.

Verma, L.R. and P.C. Dulta, 2011. Foraging behaviour of *Apis cerana indica* and *Apis mellifera* in pollinating apple flowers. J. Apicult. Res., 25: 197-207.

Vinson, J.A., X. Su, L. Zubik and P. Bose, 2001. Phenol antioxidant quantity and quality in foods:? Fruits. J. Agric. Food Chem., 49: 5315-5321.

Wadhwa, N. and R.C. Sihag, 2012. Psychophilous mode of pollination predominates in sarpagandha (*Rauvolfia serpentina*). J. Entomol., 9: 187-207.

Walkowiak-Tomczak, D., J. Regula and G. Lysiak, 2008. Physico-chemical properties and antioxidant activity of selected plum cultivars fruit. Acta Sci. Polonorum Technol. Aliment., 7: 15-22.