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Relative preference of honeybees to new hybrids or old populations and prospects of honey extraction

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Abstract
In the present study, relative attractiveness of eight cultivars (2 old populations, 6 hybrids) was analyzed for temporal abundance of different honey bees and floral visitors at Oilseed Section of CCS HAU, Hisar. On sunflower bloom, highly narrow diversity of 14 species of floral visitors was recorded. Apoidea was represented by only four honey bee species but insignificant proportion of wild bees, *Apis florea* and *A. dorsata* reflected their destruction through human interference. Emergence of pests as the most dominant taxa (47.5%) indicated major demographic shift at the cost of pollinators or beneficial insects. Hybrids Pioneer 64A57, DK-3849 and SH-3322 were most preferred by the honey bees (0.69, 0.60 and 0.57 bees) and the old populations HS-1 (0.33) and Morden (0.38) along with hybrid PSH-996 (0.33) were least preferred. Distinct choice patterns of individual honey bees for specific cultivars at different time intervals were also recorded. Dark dwelling *A. mellifera* and *A. cerana* relatively preferred hybrids while open nesting *A. dorsata* and *A. florea* for old population HS-1 along with few hybrids. Knowledge of such distinct preferences will be vital for drafting pollination strategies based on species abundance/availability in the larger varietal canvas. Clear preference of honey bees to the hybrids over the old populations theoretically indicated the possibility of honey extraction from the hybrids than the old cultivars. It further indicated better bee pollination avenues in hybrids. However, they do not fully explain why the shift in varietal scenario from populations to the modern day hybrids did not result in honey extraction that existed on old populations and probably hints to some other factors.

Keywords: Sunflower, honey bees, populations, hybrids, temporal abundance, floral visitors

Introduction
India is chronically oilseed deficit due to low production and poor productivity of oilseeds coupled with high domestic consumer demand that is met through import of edible oils valued at nearly Rs.70,000 crores annually, mainly of poor quality edible oils like palm oil [2]. In a major policy decision the government through National Mission on Oilseeds and Oil Palm (NMOOP) aimed to plug this shortfall by increasing production and productivity of oilseeds [1]. Sunflower (*Helianthus annuus* L.) is valued for its high oil quality but witnessed lowest present acreage of 0.69 million hectare and production values at 0.52 million tonnes [3] since 2000-01indicating low profitability of the crop.

Sunflower being a highly cross pollinated crop attracts a large number of floral visitors, the honey bees being the most important pollinators and they contribute significantly in increasing yield [6, 17, 22, 24, 26, 28, 31] as well as quality through higher seed weight, germination percentage and increased oil content [8, 13, 17, 20, 43] Sunflower is the source of copious nectar and pollen to the honey bees from end April to June in North India [10, 11] providing high quality surplus extractable honey. It also helped colonies to build up enough honey stores that were crucial for their survival during the long dearth period up to October. Since 1999, the scenario has changed as despite abundant acreage of the crop and honey bee foragers visiting the flowers, honey extraction was not possible due to low nectar reserves [11] in the colonies.

Many theories like climate change; non-availability of shades; colony congestion in the migratory sites, change in beekeeping standard practices, etc. were put forward but without improvement in situation. The area consequently fluctuated greatly and beekeepers avoided sunflower crop and this alienation may prove crucial for its productivity in absence of pollinators [9, 18, 19, 24]. It was also believed that the modern day cultivars (hybrids) are low nectar producers compared to older varieties (populations) resulting in no extraction of honey. Cultivars were reported to differ significantly in their attractiveness to the honey bees due to

morphometric variations in plants and flowers as well as differences in nectar volume and sugar concentration, the traits that are genotypic specific [22, 42].

In order to address the mystery, as a first step, the older populations and new hybrids were evaluated for their morphological and phonological traits [37, 38]. Significant variations in phenological traits including initiation of flowering, period, plant height, leaf number and chlorophyll content besides flower morphologica traits like capitulum size, corolla tube length and colour were reported. Five of the six hybrids were reportedly preferred by the honey bees for floral rewards while older populations Morden and HS-1 along with hybrid PSH-996 were least preferred [38]. Despite this affinity to hybrids by the honey bees, the phenomenon of non-extraction of honey from these present day hybrids remained unexplained.

The present investigation was continuation of our previous experiments and included the parameters of temporal abundance of honey bees/floral visitors on these older populations and new hybrids over time and space to determine their attractiveness for floral rewards of nectar and pollen and change in pollinators' foraging strategies in host selection.

Materials and Methods

The present experiment was conducted in the Oilseeds Section of the Department of Plant Breeding and Genetics, CCS Haryana Agricultural University, Hisar (29°10'N, 75°46'E, 215.2 m AMSL). Among the eight sunflower cultivars, two were old populations (HS-1 and Morden) and six were modern day hybrids (PSH-996, HSFH-848, HSFH-1183, SH-3322, DK-3849 and Pioneer 64A57), the latter being a popular private hybrid while the rest were state owned (CCS, HAU, Hisar and Punjab Agricultural University, Ludhiana).

Setting of the experiment to provide free choice to the pollinators to select host plant: The eight cultivars were sown as spring crop on a single day (12th February, 2015) in three replications in complete randomization (RBD) in the field to provide free choice to the pollinators or floral visitors. The spacing maintained was 60 x 30 cm in a plot size of 10.0 m^2 following all the package of practices excluding the application of insecticides.

Marking of the capitulum: From each plot three capitulums were randomly selected and tagged for observations.

Diversity of floral visitors: Employing standard protocol [14, 17] different floral visitors on the capitulum were collected using a cone type hand net at hourly intervals throughout the blooming period. These visitors were killed, preserved and identified by comparing them with reference collection maintained at the Apiculture Laboratory, Department of Entomology, CCS HAU, Hisar (Haryana).

Temporal abundance of floral visitors: From the marked capitulum (n=3), number of different floral visitors were visually recorded continuously for a period of two minutes at 2- hourly intervals from 0600 till 1800 h (7 intervals). These observations were recorded on ten calm, clear and sunny days at peak flowering.

Temporal abundance and foraging strategy of honey bees: The special distribution and foraging strategy/ behaviour of four species of honey bees viz. European honey bee (*Apis mellifera* L.), Indian hive bee (*A. cerana* F.), giant honey bee (*A. dorsata* F.) and dwarf honey bee (*A. florea* F.) were recorded in order to frame species specific planned pollination strategies in case of their relative abundance/absence.

Correlations of plant and flower morphological parameters of sunflower cultivars with abundance of honey bees and all floral visitors: Nineteen plant and flower morphological characters identified by Rinku [38] were correlated with abundance of honey bee species as well as all other floral visitors taken together.

A. mellifera was visiting from 12 managed colonies kept at a distance of 550 m from the experimental site while *A. cerana* visited from their feral nests in the foraging area. The two wild honey bees, *A. dorsata* and *A. florae* foraged from their wild nests in the foraging area. The metrological data for the period of observation was collected from the Department of Agricultural Meteorology, CCS HAU, Hisar.

Statistical analysis

The data was statistically analyzed by two and three factor ANOVA using computer programme (opstat). The correlations among different characters were also drawn.

Results

Diversity of floral visitors: A lower diversity of only 14 floral visitors was recorded on spring sunflower crop (Table 1) that comprised mainly of non-pollinators or of doubtful pollination contribution (10 species, 62.4%). The pollinators (37.6%) comprised solely of four species of honey bees (family Apidae: Hymenoptera). The domesticated honey bee, *A. mellifera* was the most abundant (23.9%) followed by feral Indian hive bee, *A. cerana* (11.1%). Among the wild honey bees, population of dwarf honey bee, *A. florae* was low (2.2%) and that of giant bee: *A. dorsata* was negligible (0.4%).

Abundance of floral visitors: In terms of mean abundance, *A. mellifera* was the most prominent species (1.31 bees/capitulum/minutes^{-2}). Surprisingly, the next three abundant species were the adults of key lepidopteran pests viz. head/capsule borer, *Helicoverpa armigera* (0.84), painted lady caterpillar, *Vanessa cardui* (0.76) and cabbage semilooper, *Trichoplusia ni* (0.62/ capitulum/minutes^{-2}). The *A. cerana* recorded still lower populations (0.61) but the other two wild bees *A. florea* (0.12) and *A. dorsata* (0.02) were alarmingly low and comparable to minor pollinators like *Syrphus confrater* (0.07) and *Musca domestica* (0.01) and bio-control agents *Chysoperla carnea* (0.04) and *Coccinella septumpunctata* (0.13).

Table 1: Diversity and abundance of floral visitors on sunflower bloom

Sr. No.	Common name	Scientific name	Family	Order	Mean population capitulum/minutes^{-2}	Mean proportion (%)
1	European honey bee***	*Apis mellifera* L.	Apidae	Hymenoptera	1.31	23.88
2	Indian hive bee**	*Apis cerana* F.	Apidae	Hymenoptera	0.61	11.08
3	Rock bee*	*Apis dorsata* F.	Apidae	Hymenoptera	0.02	0.38
4	Dwarf honey bee*	*Apis florae* F.	Apidae	Hymenoptera	0.12	2.21
	Total Hymenoptera					**37.55**
5	Head borer**	*Helicoverpa armigera* Hubner	Noctuidae	Lepidoptera	0.84	15.30
6	Painted lady caterpillar**	*Vanessa cardui* L.	Nymphalidae	Lepidoptera	0.76	13.80
7	Cabbage semilooper**	*Trichoplusia ni* Hubner	Noctuidae	Lepidoptera	0.62	11.24
	Total Lepidoptera					**40.34**
8	Blow fly**	*Calliphora* sp. L.	Calliphoridae	Diptera	0.50	9.13
9	Tachnid fly*	*Spogossia bezziana* Baranov	Tachnidae	Diptera	0.08	1.41
10	Syrphid fly*	*Syrphus confrater* Wiedemann	Syrphidae	Diptera	0.06	1.13
11	House fly*	*Musca domestica* L.	Muscidae	Diptera	0.01	0.11
	Total Diptera					**11.77**
12	Stink bug**	*Nezara virudula* L.	Pentatomidae	Hemiptera	0.39	7.19
13	Lady bird beetle*	*Coccinella septumpunctata* L.	Coccinellidae	Coleoptera	0.13	2.45
14	Green lacewing*	*Chrysoperla carnea* Stephens	Chrysoperlidae	Neurooptera	0.04	0.69
	Total others					**10.33**
	Mean Total Population				0.39	

* Less frequent visitors ** Frequent visitor *** Most Frequent visitor

Abundance of floral visitors on sunflower cultivars: When the floral visitors (all) were given free choice to select their host for food resources (nectar and pollen) amongst eight cultivars grown in randomized fashion, they exhibited differential host preferences (Table 2 and Fig. 2). Segregating the foragers of the four honey bee species for such response (as they possess all ideal traits of the perfect pollinators) also exhibited almost similar selection preferences (Table 3 and Fig. 2).

Hybrids Pioneer 64A57 and SH-3322 were the most preferred by the floral visitors (0.47 and 0.43 floral visitors/capitulum/minutes^{-2}) as well as the honey bees (0.69 and 0.57 bees) that also preferred hybrid DK-3849 (0.60). Floral visitors least preferred the old population HS-1 (0.36) and Morden (0.38) while bees were least on population Morden (0.33) followed by hybrid PSH-996 (4.2) and other population HS-1 (0.47 bees). The group with medium attractiveness for the honey bees included hybrids HSFH 848 (0.55) and HSFH 1183 (0.51 bees).

Table 2: Mean abundance of floral visitors on different cultivars of sunflower

Floral visitors	Mean abundance of floral visitors on different cultivars per capitulum / minutes^{-2}								
	HS-1	Morden	PSH-996	HSFH-848	HSFH-1183	SH-3322	DK-3849	Pioneer 64A57	Mean
Apis mellifera	1.16 (1.46)	0.84 (1.35)	1.05 (1.43)	1.38 (1.53)	1.29 (1.50)	1.42 (1.54)	1.50 (1.57)	1.83 (1.67)	1.31 (1.51)
Apis cerana	0.53 (1.23)	0.40 (1.18)	0.53 (1.23)	0.70 (1.30)	0.61 (1.27)	0.69 (1.30)	0.70 (1.30)	0.69 (1.30)	0.61 (1.26)
Apis dorsata	0.07 (1.03)	0.00(1.00)	0.03 (1.02)	0.01 (1.01)	0.05 (1.03)	0.02 (1.01)	0.03 (1.01)	0.02 (1.01)	0.03 (1.01)
Apis florae	0.13 (1.08)	0.10 (1.05)	0.08 (1.04)	0.10 (1.05)	0.09 (1.04)	0.11 (1.05)	0.17 (1.08)	0.20 (1.09)	0.12 (1.06)
Helicoverpa armigera	0.54 (1.21)	1.20 (1.44)	0.94 (1.37)	1.03 (1.39)	0.92 (1.35)	0.94 (1.36)	0.50 (1.20)	0.65 (1.25)	0.84 (1.36)
Vanessa cardui	0.44 (1.18)	0.46 (1.19)	0.71 (1.28)	0.70 (1.28)	0.73 (1.29)	1.10 (1.42)	0.99 (1.38)	0.93 (1.36)	0.76 (1.33)
Trichoplusia ni	0.48 (1.19)	1.08 (1.40)	0.62 (1.24)	0.61 (1.24)	0.60 (1.23)	0.55 (1.22)	0.43 (1.17)	0.57 (1.22)	0.62 (1.27)
Calliphora sp.	0.35 (1.14)	0.50 (1.18)	0.45 (1.18)	0.57 (1.23)	0.52 (1.21)	0.57 (1.23)	0.57 (1.23)	0.52 (1.21)	0.50 (1.23)
Spogossia bezziana	0.21 (1.09)	0.00 (1.00)	0.22 (1.09)	0.00 (1.00)	0.02 (1.01)	0.00 (1.00)	0.07 (1.03)	0.10 (1.04)	0.08 (1.04)
Syrphus confrater	0.10 (1.04)	0.14 (1.06)	0.06 (1.03)	0.10 (1.04)	0.10 (1.04)	0.00 (1.00)	0.00 (1.00)	0.01 1.00)	0.06 (1.03)
Musca domestica	0.05 (1.02)	0.001 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.01 (1.00)
Nezara virudula	0.41 (1.17)	0.46 (1.19)	0.40 (1.16)	0.32 (1.13)	0.15 (1.06)	0.46 (1.18)	0.48 (1.19)	0.48 (1.19)	0.39 (1.18)
Coccinella septumpunctata	0.19 (1.08)	0.18 (1.07)	0.14 (1.06)	0.13 (1.05)	0.11 (1.04)	0.14 (1.06)	0.010 (1.04)	0.11 (1.05)	0.13 (1.07)
Chrysoperla carnea	0.04 (1.02)	0.03 (1.01)	0.18 (1.07)	0.05 (1.02)	0.01 (1.00)	0.01 (1.00)	0.00 (1.00)	0.00 (1.00)	0.04 (1.02)
Mean	0.36 (1.17)	0.38 (1.18)	0.41 (1.19)	0.41 (1.19)	0.37 (1.17)	0.43 (1.20)	0.42 (1.19)	0.47 (1.21)	
C.D. ($p \leq 0.05$) S.E(m)	(0.04) (0.01)	(0.04) (0.01)	(0.03) (0.01)	(0.03) (0.01)	(0.03) (0.01)	(0.04) (0.01)	(0.04) (0.01)	(0.03) (0.01)	(0.04) (0.01)

* Values are mean of 210 observations (No. of days= 10; Periods of observation= 7; Replications= 3)

** Figures in parentheses are$\sqrt{n+1}$ values

Table 3: Mean relative abundance of honey bee species on different sunflower cultivars

Floral visitors	Mean abundance of honey bees on different cultivars per capitulum/minutes^{-2}								Mean
	HS-1	Modern	PSH-996	HSFH-848	HSFH-1183	SH-3322	DK-3849	Pioneer 64A57	
A. mellifera	1.16 (1.46)	0.84 (1.35)	1.05 (1.43)	1.38 (1.53)	1.29 (1.50)	1.42(1.54)	1.50 (1.57)	1.83 (1.67)	1.31 (1.51)
A. cerana	0.53 (1.23)	0.40 (1.18)	0.53 (1.23)	0.70 (1.30)	0.61 (1.27)	0.69 (1.30)	0.70 (1.30)	0.69 (1.30)	0.61 (1.26)
A. dorsata	0.07 (1.03)	0.00 (1.00)	0.03 (1.02)	0.01 (1.01)	0.05 (1.03)	0.02 (1.01)	0.03 (1.01)	0.02 (1.01)	0.03 (1.01)
A. florae	0.13 (1.06)	0.10 (1.05)	0.08 (1.04)	0.10 (1.05)	0.09 (1.04)	0.11 (1.05)	0.17 (1.08)	0.20 (1.09)	0.12 (1.06)
C.D S.E.(m)				0.06 0.02					0.02 0.01
Mean	0.47 (1.20)	0.33 (1.14)	0.42 (1.18)	0.55 (1.22)	0.51 (1.21)	0.57 (1.25)	0.60 (1.27)	0.69 (1.30)	
C.D S.E.(m)				0.02 0.01					

* Values are mean of 210 observations (No. of days=10; Periods of observation=7; Replications=3)
** Figures in parentheses are√ n+1 values

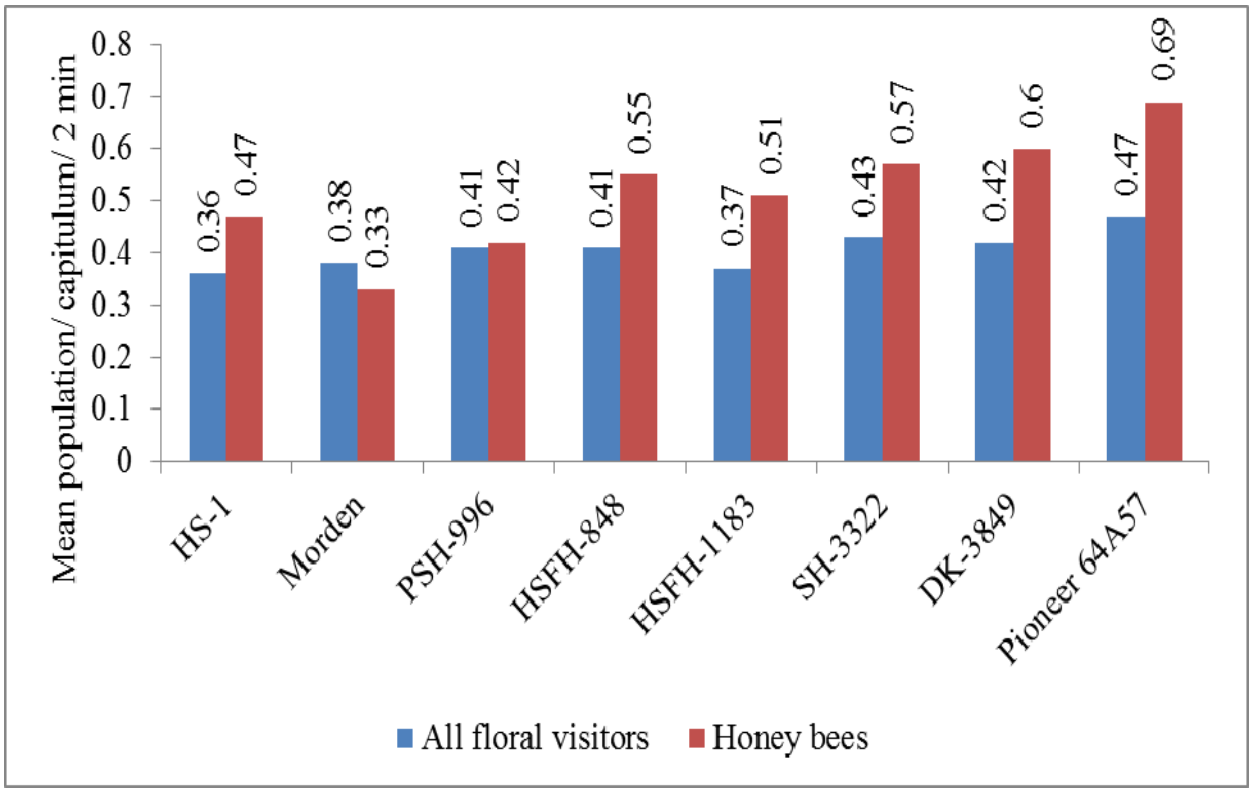

Fig 1: Mean abundance of floral visitors and honey bees on sunflower cultivars

Preferences of individual honey bee species for sunflower cultivars over time and space:

1. Preferences of *A. mellifera*: *A. mellifera*, the most abundant of all the honey bee species (1.31 bees /capitulum/minutes^{-2}) exhibited differential preferential responseto the 8 tested cultivars with distinctive preference to the hybrids than the old cultivars (Table 4, Fig. 3). It was most abundant on hybrid Pioneer 64A57 (1.83) followed by DK-3849 and SH-3322 (1.50 and 1.42). The hybrids with moderate abundance were HSFH-848 and HSFH-1183 (1.38 and 1.29 bees). *A. mellifera* least preferred old cultivar Morden (0.84) but showed relatively higher preference for population HS-1 (1.16) that was similar to the hybrid PSH-996 (1.05 bees). Distribution of *A. mellifera* peaked at 1000 h (1.94 bees) followed by 0800 and1200 h (1.74 and 1.63), and the least population was recorded at early (0600) and late (1800) hours of the day (0.86 and 0.78, respectively). Although lower in the afternoon, populations were relatively moderate even at 1400 h (0.96 bees).

Table 4: Temporal abundance of *A. mellifera* on different cultivars of sunflower

Cultivars	Mean abundance of *A. mellifera* during different hours (per capitulum/minutes^{-2})							Mean
	0600	0800	1000	1200	1400	1600	1800	
HS-1	0.67 (1.28)	1.63 (1.61)	1.79 (1.66)	1.54 (1.57)	0.71 (1.29)	1.04 (1.42)	0.71 (1.29)	1.16 (1.44)
Morden	0.38 (1.16)	1.05 (1.42)	1.29 (1.49)	1.29 (1.50)	0.76 (1.31)	0.71 (1.30)	0.38 (1.16)	0.84 (1.34)
PSH-996	0.77 (1.31)	1.17 (1.45)	1.47 (1.54)	1.33 (1.51)	0.87 (1.36)	1.17 (1.45)	0.57 (1.24)	1.05 (1.41)
HSFH-848	0.80 (1.33)	1.83 (1.67)	1.97 (1.69)	2.03 (1.71)	1.13 (1.44)	1.20 (1.47)	0.67 (1.27)	1.38 (1.51)
HSFH-1183	0.74 (1.31)	1.63 (1.60)	1.96 (1.70)	1.74 (1.63)	1.07 (1.43)	1.26 (1.49)	0.63 (1.26)	1.29 (1.49)
SH-3322	1.15 (1.46)	2.33 (1.81)	2.19 (1.75)	1.37 (1.52)	0.96 (1.38)	1.19 (1.46)	0.78 (1.31)	1.42 (1.53)
DK-3849	1.00 (1.40)	2.17 (1.76)	2.21 (1.77)	1.58 (1.59)	1.04 (1.42)	1.50 (1.56)	1.00 (1.40)	1.50 (1.56)
Pioneer 64A57	1.33 (1.52)	2.15 (1.76)	2.67 (1.90)	2.15 (1.76)	1.15 (1.46)	1.85 (1.68)	1.52 (1.58)	1.83 (1.67)
C.D S.E.(m)				0.11 0.04				0.04 0.01
Mean	0.855 (1.346)	1.744 (1.634)	1.942 (1.689)	1.63 (1.60)	0.96 (1.39)	1.24 (1.48)	0.78 (1.31)	
C.D S.E.(m)				0.04 0.01				

* Values are mean of 210 observations (No. of days=10; Periods of observation=7; Replications=3)

** Figures in parentheses are$\sqrt{\text{n+1}}$ values

2. Preferences of *A. cerana*: Indian hive bee *A. cerana*, although was wiped out from North India during 1983, its resurgent population in the wild from feral colonies is a welcome sign as a moderate mean population (0.61 bees /capitulum/minutes^{-2}, range 0.40 to 0.70) on different sunflower cultivars was recorded (Table 5, Fig. 3). It was also found to prefer hybrids over the older populations as minimum abundance (0.40 bees) was recorded on population Morden while on other (HS-1), it was moderate along with hybrid PSH-996 (0.53 each). On rest of the five hybrids viz. DK-3849, Pioneer 64A57, HSFH-848, SH-3322 and HSFH-1183, *A. cerana* was most abundant (0.61-0.70 bees). The other feature of *A.* cerana was its well distributed pattern over the entire foraging period (0.44-0.93 bees). But it still has its preferential visiting hours from 0800 to 1200 h (0.69- 0.74 bees). Even during the periods when other bees were less abundant at 1400 and 1800 h its population was although least but still at higher proportion (0.44 and 0.47).Although the abundance pattern of *A. cerana* in response to older populations was similar to *A. mellifera* but it equally preferred all other five hybrids.

Table 5: Temporal abundance of *A. cerana* on different cultivars of sunflower

Cultivars	Mean abundance of *A. cerana* during different hours (per capitulum/minutes^{-2})							Mean
	0600	0800	1000	1200	1400	1600	1800	
HS-1	0.29 (1.12)	0.38 (1.16)	0.79 (1.32)	0.58 (1.24)	0.33 (1.14)	0.79 (1.32)	0.54 (1.22)	0.53 (1.22)
Morden	0.33 (1.14)	0.67 (1.28)	0.48 (1.20)	0.43 (1.18)	0.52 (1.22)	0.19 (1.08)	0.19 (1.08)	0.40 (1.17)
PSH-996	0.40 (1.17)	0.53 (1.21)	0.57 (1.23)	0.70 (1.28)	0.50 (1.20)	0.67 (1.26)	0.33 (1.14)	0.53 (1.21)
HSFH-848	0.60 (1.25)	0.90 (1.36)	0.63 (1.26)	1.00 (1.39)	0.43 (1.18)	0.83 (1.33)	0.47 (1.19)	0.70 (1.28)
HSFH-1183	0.59 (1.24)	0.89 (1.36)	0.63 (1.26)	0.89 (1.36)	0.33 (1.14)	0.48 (1.19)	0.48 (1.20)	0.61 (1.25)
SH-3322	0.85 (1.34)	0.74 (1.30)	0.89 (1.35)	0.63 (1.25)	0.37 (1.16)	0.67 (1.27)	0.67 (1.27)	0.69 (1.28)
DK-3849	0.92 (1.37)	0.88 (1.36)	0.75 (1.30)	0.67 (1.28)	0.50 (1.21)	0.58 (1.25)	0.63 (1.25)	0.70 (1.29)
Pioneer 64A57	0.78 (1.31)	0.93 (1.37)	0.82 (1.32)	0.63 (1.25)	0.56 (1.23)	0.67 (1.27)	0.48 (1.20)	0.69 (1.28)
C.D S.E.(m)				0.11 0.04				0.04 0.02
Mean	0.60 (1.24)	0.74 (1.30)	0.69 (1.28)	0.69 (1.28)	0.44 (1.18)	0.61 (1.25)	0.47 (1.19)	
C.D S.E.(m)				0.04 0.01				

* Values are mean of 30 observations (No. of days= 10; Replications=3)

** Figures in parentheses are$\sqrt{\text{n+1}}$ values

3. Preferences of *A. dorsata*: *A. dorsata* visiting from wild nests, were least abundant (0.02 bees /capitulum/minutes^{-2}) of all the honey bees but demonstrated typical cultivar preference behaviour (Table 6, Fig. 3). Strangely, it totally ditched old cultivar Morden and on hybrid HSFH-848 was recorded at very low densities (0.07 bees) only at 0800 h. A distinctive preference for old population HS-1 and hybrid HSFH-1183 (0.065 and 0.053 bees) was evident while and on other hybrids, it was moderate in abundance. *A. dorsata* was emphatically typical in its temporal distribution too, as its population was low at morning 0600 hours (0.03 bees) but peaked at 0800 h (0.09), declined to 0.06 at 1000 h to almost negligible at 1200 (0.02) and was completely absent in the afternoon. In hybrids SH-3322 its foraging period was even restricted from 0600-0800 h and for DK-3849 from 0600-1000 h only.

Table 6: Temporal abundance of *A. dorsata* on different cultivars of sunflower

Cultivars	Mean abundance of *A. dorsata* during different hours (per capitulum/minutes^{-2})							Mean
	0600	0800	1000	1200	1400	1600	1800	
HS-1	0.00 (1.00)	0.21 (1.09)	0.21 (1.09)	0.04 (1.02)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.07 (1.03)
Morden	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
PSH-996	0.00 (1.00)	0.10 (1.04)	0.07 (1.03)	0.07 (1.02)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.03 (1.01)
HSFH-848	0.00 (1.00)	0.07 (1.03)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.01 (1.00)
HSFH-1183	0.04 (1.02)	0.22 (1.09)	0.07 (1.03)	0.04 (1.02)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.05 (1.02)
SH-3322	0.04 (1.02)	0.07 (1.03)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.02 (1.01)
DK-3849	0.08 (1.04)	0.04 (1.02)	0.08 (1.04)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.03 (1.01)
Pioneer 64A57	0.07 (1.03)	0.04 (1.02)	0.04 (1.02)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.02 (1.01)
C.D S.E.(m)				0.03 0.01				0.01 0.004
Mean	0.03 (1.01)	0.09 (1.04)	0.06 (1.02)	0.02 (1.01)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	
C.D S.E.(m)				0.01 0.004				

* Values are mean of 30 observations (No. of days=10; Replications=3)
** Figures in parentheses are√ n+1 values

4. Preferences of *A. florea*: A general lower populations of this wild honey bee was recorded (0.12 bees /capitulum/minutes^{-2}) but exhibited characteristic cultivar preferences irrespective of hybrids or old populations (Table 7, Fig. 3). Hybrids Pioneer 64A57 and DK-3849 were most preferred (0.20 and 0.17 bees /capitulum/minutes^{-2}) followed by population HS-1 (0.13) and least in PSH-996 (0.08) while in others, its population was moderate. Temporal preference was also evident with peaks at 0800 h (0.267 bees) and moderate abundance at 1000 (1.74), 1800 (0.14) and 0600 h (0.12). A further decrease was observed at 1200 and 1600 h (0.07 and 0.06) but the minimum was at 1400 h (0.03 bees). Some of the reasons discussed above for the decline of another single nest bee *A. dorsata* might also be relevant to *A. florae*.

Table 7: Temporal abundance of *A. florea* on different cultivars of sunflower

Cultivars	Mean abundance of *A. florea* during different hours per capitulum/ minutes^{-2}							Mean
	0600	0800	1000	1200	1400	1600	1800	
HS-1	0.00 (1.00)	0.25 (1.11)	0.33 (1.14)	0.21 (1.08)	0.00 (1.00)	0.04 (1.02)	0.04 (1.02)	0.13 (1.05)
Morden	0.14 (1.06)	0.14 (1.06)	0.14 (1.06)	0.05 (1.02)	0.00 (1.00)	0.05 (1.02)	0.14 (1.06)	0.10 (1.04)
PSH-996	0.20 (1.08)	0.10 (1.04)	0.10 (1.04)	0.10 (1.04)	0.00 (1.00)	0.07 (1.03)	0.00 (1.00)	0.08 (1.03)
HSFH-848	0.03 (1.01)	0.23 (1.10)	0.07 (1.03)	0.00 (1.00)	0.20 (1.08)	0.17 (1.07)	0.00 (1.00)	0.10 (1.04)
HSFH-1183	0.00 (1.00)	0.37 (1.16)	0.15 (1.06)	0.00 (1.00)	0.04 (1.02)	0.04 (1.02)	0.00 (1.00)	0.09 (1.04)
SH-3322	0.19 (1.08)	0.26 (1.11)	0.04 (1.02)	0.00 (1.00)	0.00 (1.00)	0.04 (1.02)	0.26 (1.11)	0.11 (1.05)
DK-3849	0.13 (1.05)	0.38 (1.16)	0.25 (1.10)	0.08 (1.04)	0.00 (1.00)	0.08 (1.04)	0.29 (1.12)	0.17 (1.07)
Pioneer 64A57	0.30 (1.12)	0.41 (1.17)	0.22 (1.09)	0.07 (1.03)	0.00 (1.00)	0.04 (1.02)	0.37 (1.16)	0.20 (1.08)
C.D S.E.(m)				0.06 0.02				0.02 0.01
Mean	0.12 (1.05)	0.27 (1.11)	0.16 (1.07)	0.06 (1.03)	0.03 (1.01)	0.07 (1.03)	0.14 (1.06)	
C.D S.E.(m)				0.02 0.01				

* Values are mean of 30 observations (No. of days= 10; Replications= 3)
** Figures in parentheses are√ n+1 values

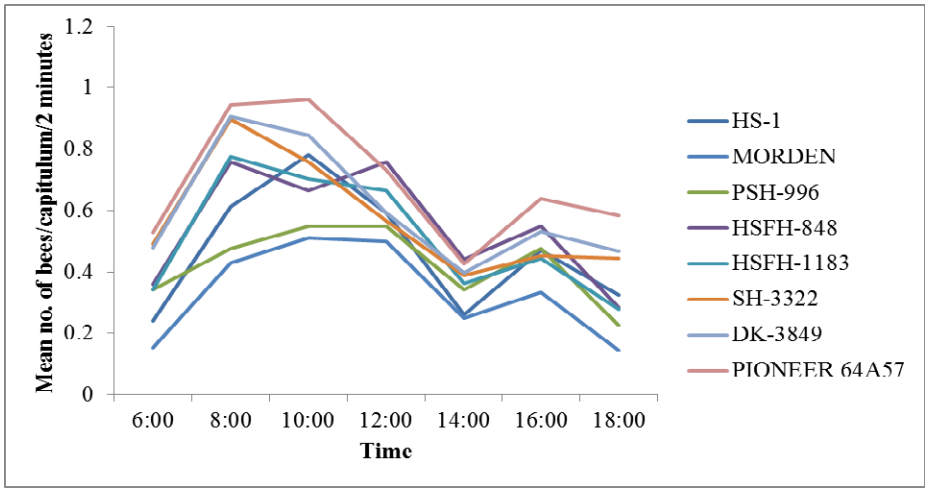

Fig 3: Mean temporal abundance of honey bees on sunflower cultivars

Correlation of honey bee visitors with environment factors in different sunflower cultivars: A highly significant positive correlation with temperature was recorded for *A. dorsata* in cv. DK-3849 and Pioneer 64A57; with *A. florea* in PSH-996 and *A. cerana* in DK-3849. For relative humidity, *A. dorsata* was highly positively correlated with DK-3849 and Pioneer 64A57 and significantly with HSFH-1183. For *A. florea*, PSH-996 was positively and highly significantly while Pioneer 64A57 significantly correlated with RH. In DK-3849, positive correlation was recorded for *A. cerana* (Table 8).

Table 8: Correlations of honey bee foragers with temperature and relative humidity among sunflower cultivars

Honey bee floral visitors	HS-1	Morden	PSH-996	HSFH-848	HSFH-1183	SH-3322	DK-3849	Pioneer 64A57
A. Temperature								
A. mellifera	-0.08	0.19	0.07	-0.01	0.04	-0.39	-0.26	-0.10
A. dorsata	-0.36		-0.31	-0.49	-0.62	-0.49	-0.79**	-0.94**
A. florae	-0.15	-0.31	-0.80**	0.01	-0.44	-0.66	-0.57	-0.62
A. cerana	0.53	0.17	0.36	-0.10	-0.45	-0.57	-0.76**	-0.38
B. Relative Humidity								
A. mellifera	0.31	0.03	0.12	0.22	0.14	0.60	0.43	0.23
A. dorsata	0.58		0.49	0.57	0.73*	0.57	0.88**	0.91**
A. florae	0.38	0.49	0.78**	0.10	0.57	0.65	0.66	0.72*
A. cerana	-0.42	0.00	-0.23	0.19	0.52	0.59	0.75*	0.45

Correlations of plant and flower morphological parameters of sunflower cultivars with abundance of honey bees and all floral visitors: In order to determine the factors the honey bees and floral visitors employ for preferential selection of cultivars, the plant and floral morphological characters, the correlations (Table 9) indicated highly significant positive correlations (r=0.878) with honey bee species only, not with the floral visitors. Length of disc florets positively influenced abundance of honey bees (r= 0.687) as well as floral visitors (r= 0.799), while corolla length was positively correlated with abundance of floral visitors alone (r=0.742).

Table 9: Correlations of plant and floral morphological parameters of sunflower cultivars with abundance of honey bees and floral visitors

Characters	Mean abundance of Honey bees	Mean abundance of all floral visitors
Height of plants	0.878**	0.544
Mean girth	0.198	0.579
No. of leaves	0.545	0.548
Mean length of leave	0.014	0.538
Mean breadth of leave	0.038	0.615
Mean chlorophyll content	0.304	0.400
Capitulum length	-0.271	0.135
Capitulum breadth	-0.217	0.310
Capitulum width	-0.087	0.130
Ray florets	0.468	0.605
Length of disc florets	0.687*	0.799**
Corolla length	0.472	0.742*
Calyx length	0.121	0.442
Calyx breadth	-0.040	0.540
Achene length	0.250	0.574
Achene breadth	-0.427	-0.231
Achene width	0.160	-0.096
Seeds/capitulum	0.339	0.395
Test weight	0.527	0.582

*Significant at p = 0.1, 0.6694 ** Significant at p = 0.05, 0.755

Discussion

The present study reported a narrow spectrum of 14 floral visitors and majority of them (62.4%) comprising of 10 species were mainly pests or non-pollinators or of doubtful contribution toward sunflower pollination. Arya [4] from the same crop in the same location reported 20 floral visitors. Significantly higher species diversity (45) was reported by Krishna [25] from Latur, Maharashtra (India) and Parker [35] from USA (approximately 400 bee species). The species diversity decline is a major concern for the agro-ecosystem of Haryana.

The domesticated *A. mellifera* visiting from 12 managed bee hives was most abundant floral visitor of sunflower species (1.31 bees/ capitulum/ minutes^{-2}) along with *A. cerana*(0.61) but wild honey bees *A. florea*(0.12) and giant bee, *A. dorsata* were significantly lower (0.02). Predominance of *A. mellifera* amongst the honey bees (23.9%) is well reported [5, 15, 25-27]along with *A. dorsta* [16, 26, 30, 32, 36, 41]. Higher proportions of adults of three lepidopteran moths namely *Helicoverpa armigera* (0.84), *Vanessa cardui* (0.76) and *Trichoplusia ni* (0.62/ capitulum/minutes^{-2}) are also listed as minor pollinators [4, 15, 25, 26, 27 35].

The present investigation revealed the relatively higher attractiveness of new hybrids in general, by both the total floral visitors as well as honey bees compared to the old populations. Hybrids Pioneer 64A57, SH-3322 and DK-3849 were most visited for nectar and pollen rewards while the old populations HS-1 and Morden along with hybrid PSH-996 were the least preferred. Present study is the first to report such variations amongst populations and hybrids although cross pollinated varieties were reported to out-produce self-pollinating ones [28][33]. Arya[4] and Parker [35] also reported higher abundance of floral visitors on hybrid MSFH-8 compared to composite variety EC-68415 while Skinner [40] attributed such preferential pattern of *A. mellifera* on different cultivars to difference in nectar production, inflorescence, size and colour of florets [23] and the depth of florets [39].

Honey bees were generally found preferring new hybrids, but the studies also revealed preferences of individual honey bee species towards various cultivars. *A. mellifera* most preferred hybrid Pioneer 64A57 followed by DK-3849 and SH-3322 and least preferred old cultivar Morden but showed relatively higher preference for population HS-1 and hybrid PSH-996. Choice pattern of *A. cerana* for least preference was similar to *A. mellifera* but its population on rest of the five hybrids was higher but similar. *A. dorsata* totally discarded old cultivar Morden and was least on hybrid HSFH-848 that too only at 0800 h but demonstrated distinct preference for population HS-1 over all other hybrids. *A. florea* exhibited characteristic cultivar preferences irrespective of hybrids or old populations. Hybrids Pioneer 64A57 and DK-3849 were most preferred followed by population HS-1 and hybrid PSH-996 least preferred.

Studies indicated the preference of dark dwelling *A. mellifera* and *A. cerana* for hybrids while those of open nesting *A. dorsata* and *A. florea* for old population HS-1 along with few hybrids.

Temporal distribution of four honey bee species also varied across time, space and cultivars. *A. mellifera* population peaked at 1000 h and was lower later while *A.* cerana was well distributed throughout the foraging period. Most typical pattern was observed for *A. dorsata* being low in morning, peaked at 0800 h, declining later and was completely absent in the afternoon. Even in the forenoon, it exhibited extremely restricted foraging on hybrids SH-3322 (0600-0800 h) and DK-3849 (0600-1000 h). As seen for *A. dorsata*, the peak of *A. cerana* was also observed at 0800 h but it was present throughout the day. A highly significant positive correlation with temperature was recorded for *A. dorsata* in cv. DK-3849 and Pioneer 64A57; with *A. florea* in PSH-996 and *A. cerana* in DK-3849. Relative humidity was positively correlated with *A. dorsata* on DK-3849, Pioneer 64A57 and HSFH-1183 while for *A. florea* with PSH-996 and Pioneer 64A57 and for *A. cerana* with DK-3849.

A significant variation in foraging pattern of different honey bee species was recorded that are in general agreement with previous studies with minor variations [7, 13]. Swaminathan and Bhardwaj [41] reported peak of *A. dorsata* at 0600-0800 h while Panda [34] found it at 1100 h along with *A. cerana.* Both these studies reported similar higher peak of *A. florea* during 1400-1600 h. Extremely lower population of *A. dorsata* during the course of investigations is a serious cause of concern as otherwise, sunflower is reported to be a preferred crop [16, 26, 30, 32, 36, 41]. The temporal abundance has been reported to be reward dependent. *A. dorsata* being larger bodied honey bee with large requirement of rewards has been reported to forage on richer sources and during periods of maximum availability of resources [12] that may explain this phenomenon along with individual correlations reported with weather parameters like temperature and RH.

Plant height was found positively correlated (r=0.878) with abundance of honey bees while length of disc florets with both the honey bees and floral visitors but corolla length with floral visitors alone. A considerable variation in the corolla tube length, colour and many other characters has been reported to be the cues of attracting and then arresting the floral visitors [23, 39, 40]. In the present set of experiment, *A. dorsata* with relatively longer tongue length may prove to have still better chances for exploiting wider range of cultivars (even with longer corolla tube), but its restricted preference needs further evaluation. The probable cause may be the availability of more copious nectar producing crop/s in the vicinity which could be Egyptian clover, *Trifolium alexandrinum* L. with almost similar flowering period and *A. dorsata* has been reported to be most abundant (4.90 bees/ m^{-2}/5 min) on it [21] followed by *A. mellifera* (2.69) and *A. florea*(1.20). However, altogether discarding a cultivar in a randomly set experiment is hard to explain and need to be further experimented.

The mean population of the honey bees (all the 4 species taken together) exhibited certain temporal peaks and lows reflecting firstly, the reward presence and preferred temperature zones. Second wider implication ought to be the resulting greater pollination. It generally may be true, but as the honey bee species' abundance is temporal, so will be the pollination efficiency, that varied greatly amongst these species based on many factors, including body size, loose pollen grain carrying capacity, foraging speed, foraging rate, foraging behavior and overall abundance. It is thus, important to analyze such interactions for individual honey bees. Although reports exist for comparative preference of cultivars by honey bee species over time of the days [29], but no detailed literature on above parameters for old varieties and new hybrids exist. Arya [4] recorded higher pollinators including *A. mellifera* and *A. dorsata* at all the periods of the day in hybrid MSFH-8 than composite EC-68415 without providing the probable reasons. Parker [35] in general reported (without specifying varietal preference) the presence of polylectic species in the beginning of flowering while specialist pollinators (honey bees) increased with the progression of

flowering to remain till the end.

Conclusion

Present study highlighting the limited diversity (14 species) of floral visitors during sunflower bloom point to instability of agro-ecosystem. Resurgent A. cerana from feral colonies is a welcome sign but insignificant proportion of wild honey bees reflects their destruction through human interference. Honey bees and floral visitors preferred 3 hybrids Pioneer 64A57, SH-3322 and DK-3849 for floral rewards while old populations HS-1 and Morden along with hybrid PSH-996 were least preferred. Dark dwelling A. mellifera and A. cerana preferred hybrids while open nesting A. dorsata and A. florea for old population HS-1 along with few hybrids. Knowledge of such distinct preferences will be vital for drafting pollination strategies based on species abundance/availability. Preference of honey bees to the hybrids over the old populations theoretically indicates the possibility of honey extraction from the hybrids than the old cultivars. However, they do not explain why the shift in varietal scenario from populations to the modern day hybrids did not resulted in honey extraction thus, hinting to some other factors.

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