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Nectar production and nectar secretion rhythms in sunflower populations and hybrids

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Abstract
Sunflower is a copious source of nectar and pollen to the honey bees from April to June in North Indian states and yields high quality honey to the beekeepers. With the change of varietal complex from composites and populations to the hybrids, beekeepers were unable to extract honey even in presence of abundant crop acreage, believed on hybrids being poor nectar yielders. To verify this hypothesis, nectar secretion rhythms (NSR) of two old populations and six present day hybrids was investigated. Large variations in amount of dry nectar sugar (DNS) production were observed among these cultivars. Two distinct groups of cultivars existed, first where oldest florets (3 day old, DOF) produced maximum DNS and included both the populations HS-1 (0.309 mg/floret) and Morden (0.389) and two hybrids DK-3849 (0.373) and PSH-996 (0.283 mg). In the second group, the youngest florets (1 DOF) produced maximum DNS and consisted of only the hybrids namely HSFH-848 (0.309 mg/floret), SH-3322 (0.373), HSFH-1183 and Pioneer 64A57 (0.238 mg each). In old population HS-1, maximum DNS (0.366 mg/floret) was secreted by 3 day old florets followed by 1 and 2 DOF (0.352 and 0.315 mg) while in population Morden and hybrids PSH-996 and DK-3849 it increased with age of florets being maximum in 3 DOF (0.389, 0.283 and 0.373 mg, respectively).Maximum cultivars produced highest amounts of DNS at 1000 hours and comprised of population HS-1 (0.357 mg) and four hybrids viz. PSH-996 (0.278 mg), DK-3849 (0.348), SH-3322(0.327) and HSFH-1183 (0.253 mg). At peak temperature of 1300 h, nectar amounts peaked in population Morden and hybrid HSFH-848 (0.358 and 0.302 mg) while peak of Pioneer 64A57 was recorded in the evening 1600 h (0.270 mg). The outer or first ring of sunflower capitulum generally produced maximum DNS except in Pioneer 64A57 (3rd ring) and DK-3849 (2 and 3rd rings) while the latter produced lowest DNS in outer ring. Understanding the patterns of nectar secretion of individual cultivars will help their maximum exploitation for planned honey bee pollination as well as a honey extraction by the beekeepers.

Keywords: Sunflower, honey bees, populations, hybrids, dry nectar sugars, florets, rings

Introduction
Sunflower, *Helianthus annuus* (family Compositae) is a major oilseed of India occupying an area of 0.47 million hectares with production of 0.33 million tonnes [2], is primarily grown in three South Indian states of Karnataka, Maharashtra and Andhra Pradesh (87.95% area and 79.96% production) but has significant foot prints in the Northern states of Punjab, Uttar Pradesh and Haryana.

Highly cross pollinated nature of sunflower renders it greatly dependent on floral visitors increasing seed yield from 20.0-101.0 per cent and honey bees in turn are offered abundant nectar and pollen as a reward for this service [1, 7, 15, 17, 19, 25, 30, 31, 33, 47]. Bee pollination improves oil quality [23], seed weight, germination percentage and oil content [9, 6, 49]. Absence of pollinators result in very low seed set [23, 24, 34, 35], phantom seeds [3, 4] and flower heads with almost no oil content [22].

The abundance and foraging behavior of honey bees on flowers is genotype specific and influenced by morphometric variations including flower structure, shape, capitulum size, corolla length, floret length, stigma pigmentation and many other factors [28, 29, 42, 48] but nectar and pollen being the source of honey bees' food act as prime factors for attracting or restricting bees' visits to particular host plant. The honey bees respond to the specific odour of nectar, reflecting in relative attractiveness to flowers. Sunflower flowers produced 0.11-0.25 mg nectar/flower equivalent to 16.8-17.7 kg sugar or 20.2-21.3 kg honey/ha [6, 28]. The quantity of the nectar and its concentration is reported to be plant, genotype and temporal specific [14, 41, 43] that ultimately influences the frequency, temporal abundance of honey bees [36] and ultimately, the surplus extractable honey. The cultivars with higher nectar production attracted more honey bee visits.

Sunflower crop has transited from varieties/composites to the present dayhybrids that are more self-compatible (60.0 to 90.0%) and have shown varied dependence on honey bees for seed setting ranging from an average of 20-50 per cent, that goes up 92 per cent [16].

Sunflower is copious source of nectar and pollen to the honey bees especially during end April to June in North Indian states providing surplus extractable honey to the beekeepers. However, since 1999, there is hardly any production of honey in Haryana even when the flora was sufficiently abundant [9-12]. It is generally believed that the hybrids introduced now are poor nectar yielders. Present investigations were conducted to determine the nectar secretion rhythms among the old populations and the present day hybrids.

Materials and Methods

The studies were conducted in the Oilseeds Section of the Department of Plant Breeding and Genetics, CCS Haryana Agricultural University, Hisar (Latitude 280N, longitude 270 35' E, 266 meters AMSL, 600 mm average rainfall).Nectar secretion rhythms of eight sunflower cultivars that included two old populations (HS-1 and Morden) and six new hybrids (PSH-996, HSFH-848, HSFH-1183, SH-3322, DK-3849 and Pioneer 64A57) were evaluated. Pioneer 64A57was a popular private hybridwhile the rest were state owned (CCS, HAU, Hisar and Punjab Agricultural University, Ludhiana). Seed material was provided by Oilseed Breeder of CCS HAU, Hisar. The Crop was planted in the spring season (12th February 2015) in replicated (n=3), randomized (RBD) plots of 10.0m^2 at 60 x 30 cm spacing, following recommended package of practices except the application of insecticides.

Amount of nectar in florets was measured as dry nectar secretion (DNS) following the method of Roberts (1979). Three capitulums per replication (n=9) were randomly selected and tagged for the observations. As the ray florets are sterile, DNS was estimated from hermaphrodite disc florets of 1, 2 and 3 days old florets (DOF's). The 1 DOF were typically male florets which resulted by pushing the pollens out of the anther tube at the tip. On 2nd day, bifurcated stigma with receptive structure appeared on the anther tubetermed as female florets. On 3rd day, these florets degenerated. Five florets from each age group were collected in capped glass vials (15 ml) that contained 5 ml distilled water, marked as per the treatment and brought to the laboratory for further analysis. In a capitulum, the florets open simultaneously in 4 broad bands, comprising of many rings. The outermost ring (first ring) opened first with three already described phases of florets followed by 2nd and 3rd ring. The inner most (4th ring) opened in the end. From each ring, 5 florets were collected in glass vials (as mentioned above), marked and taken for the determination of DNS. The DNS was determined at three periods of the day at 1000, 1300 and 1600 h.The absorbance of the prepared sample was measured with the help of double beam Spectrophotometer 2203 (Jenway) at 490 nm. The amount of sugar corresponding to the observed absorbance (OD) was then estimated from the standard glucose curve to obtain the total amount for dry sugars per flower (expressed as glucose equivalent).

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

Results indicated wide variations in the production of DNS by different cultivars over different periods of time, age of florets and rings.

Mean amount of DNS production by different cultivars: The mean amount of DNS produced by different sunflower cultivars recorded wide variations in terms of various parameters (Tables 1-9 and Fig. 1). Population HS-1 produced maximum DNS per disc floret (0.344 mg) followed closely by hybrid DK-3849 (0.340 mg) and population Morden (0.323 mg). The minimum amount of DNS (0.215 mg) was produced in hybrid HSFH-1183 followed by Pioneer 64A57 (0.230) and PSH-996 (0.277 mg). Hybrids SH-3322 (0.296) and HSFH-848 (0.292 mg) produced a moderate amount.

Table 1: Nectar secretion rhythms (NSR) in different sunflower cultivars

Cultivars / parameters		HS-1	Morden	PSH-996	HSFH-848	HSFH-1183	SH-3322	DK-3849	Pioneer 64A57	Mean
Time (h)	10:00	0.357	0.298	0.287	0.298	0.253	0.327	0.348	0.228	0.300
	13:00	0.361	0.358	0.273	0.302	0.203	0.303	0.328	0.191	0.290
	16:00	0.314	0.311	0.270	0.277	0.190	0.257	0.343	0.270	0.279
CD	0.003									0.001
SE(m)	0.001									0.000
Day old florets (DOF)	1 DOF	0.352*	0.265	0.271	0.309	0.238	0.324	0.336	0.238	0.292
	2 DOF	0.315	0.314	0.275	0.270	0.196	0.276	0.312	0.215	0.272
	3 DOF	0.366	0.389	0.283	0.297	0.211	0.286	0.373	0.236	0.305
CD	0.003									0.001
SE(m)	0.001									0.000
Rings	1	0.354	0.391	0.308	0.340	0.247	0.341	0.298	0.234	0.314
	2	0.357	0.299	0.297	0.293	0.174	0.288	0.340	0.204	0.282
	3	0.316	0.314	0.257	0.276	0.242	0.309	0.362	0.269	0.293
	4	0.350	0.287	0.244	0.259	0.198	0.244	0.360	0.212	0.269
CD	0.003									
SE(m)	0.001									
Mean		0.344	0.323	0.277	0.292	0.215	0.296	0.340	0.230	

*Values are the mean of 18 observations

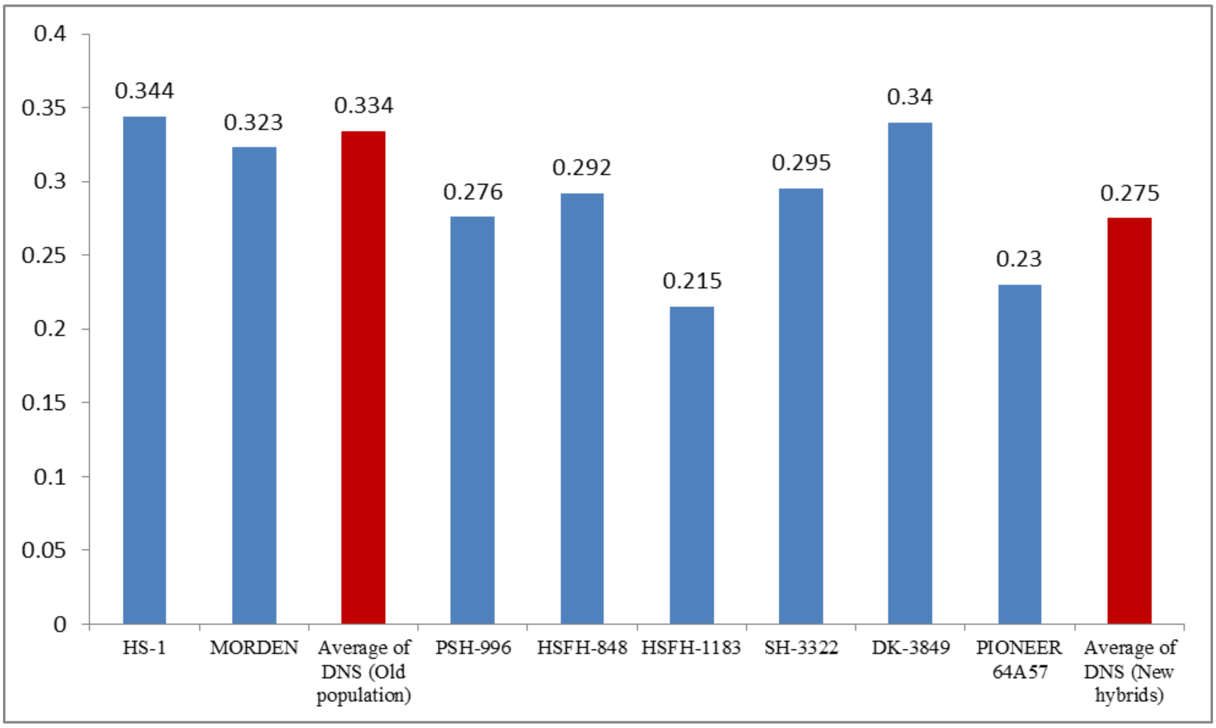

Fig 1: Mean DNS production in different sunflower cultivars

Pattern of DNS production in individual sunflower cultivars: Individual cultivars exhibited their own patterns of DNS production over age, time and space.

Nectar secretion rhythms in population HS-1: In the old population HS-1, maximum dry nectar sugars (Table 2) were secreted by three day old disc florets (0.366 mg/floret) followed by 1 and 2 DOF (0.352 and 0.315 mg). During the morning hours of 1000 h and at 1300 h, DNS production was maximum (0.357 and 0.360 mg) while in the evening hours (1600 h), the production dwindled to the minimum (0.314 mg). The florets in outermost (1^{st} ring) and the 2^{nd} ring of capitulum produced maximum DNS (0.354 and 0.357 mg) while the minimum was in 3^{rd} ring (0.316) and the inner most (4^{th}) ring yielded 0.350 mg DNS.

Nectar secretion rhythms in population Morden: Pattern of DNS production in cultivar Morden (Table 3) varied from other old population HS-1. The amount of DNS production increased with floret age, 1DOF producing the minimum (0.265 mg) that increased substantially in 2DOF florets (0.314) to become the maximum in the oldest (3DOF) florets (0.389mg). Even for the time intervals, the trend was different as maximum DNS was produced at 1300 h (0.358 mg) followed by 1600 (0.311) and 1000 h (0.298 mg). Similarly, variations were recorded in DNS production by different rings. The outer most ring (1^{st}) although produced maximum DNS (0.391 mg), the sequence was different as ring 3 (0.314 mg) and ring 2 (0.299 mg) followed it and the least was in the ring 4 (0.287 mg).

Nectar secretion rhythms in hybrid PSH-996: In the hybrid PSH-996, NSR was reported to be similar as population Morden as the minimum DNS was reported in 1 DOF (0.271 mg), that increased progressively to 0.275 mg in 2 DOF and was maximum in 3 DOF (0.283 mg). During the morning hours (1000), DNS was maximum (0.278 mg) but decrease progressively with the passage of day to 0.273 mg at 1300 h and was least (0.270 mg) in the evening (1600 h). A progressive decline was also recorded in DNS production in capitulum rings, the maximum in the outer most ring (0.308 mg), declining in 2^{nd} (0.297 mg) and was least in 3^{rd} and 4^{th} rings (0.257 and 0.244 mg, respectively).

Nectar secretion rhythms in hybrid HSFH-848: The florets of this hybrid (Table 5) also produced maximum DNS when they were 1 days old (0.309 mg) but became minimum in 2 DOF (0.270) and increased further to medium level (0.297 mg) in 3 DOF. Quantity of DNS was medium (0.298) in the morning hours (1000 h) but peaked at 1300 h (0.302) and at 1600 h was minimum (0.277 mg). With maximum DNS production in the 1^{st} ring (0.340 mg), the amount decreased inwards (0.293, 0.276 in $2^{nd}$and 3^{rd} ring) to become the least in 4^{th} ring (0.259 mg).

Nectar secretion rhythms in hybrid HSFH-1183: In this hybrid (Table 6), maximum DNS was produced by the youngest floret (0.238 mg) followed by the oldest floret (0.211 mg) and the least was recorded in mid aged (2 DOF) florets (0.196 mg/floret). DNS production was the maximum at 1000 h (0.253 mg) which decreased at 1300 h to 0.203 mg and was least at 1600 h (0.190 mg). When the DNS amount was considered for various rings, the 1^{st} ring produced maximum quantity (0.247 mg) followed by 3^{rd} and 4^{th} ring (0.242 and 0.198 mg) and the 2^{nd} ring recorded the minimum amount (0.174 mg).

Nectar secretion rhythms in hybrid SH-3322: NSRin hybrid SH-3322 (Table 7) although were similar to HSFH-1183 in pattern for floret age and time periods but it produced significantly higher amounts. Maximum DNS was recorded in the youngest florets (0.324 mg) followed by the oldest (0.286 mg) and the minimum however, were in 2DOF (0.276 mg). Temporal production of DNS also revealed maximum DNS produced at morning 1000 h (0.327 mg) that decreased significantly at 1300 (0.303 mg) to become minimum at 1600 h (0.257 mg). The outer ring as usual produced maximum DNS (0.341 mg) followed by 3^{rd} and 2^{nd} ring (0.309 and 0.288 mg) and was least 4^{th} ring (0.244 mg).

Nectar secretion rhythms in hybrid DK-3849: In this hybrid (Table 8), oldest floret produced the highest amount of DNS (0.373 mg) and 2 DOF the minimum (0.312 mg) and in the youngest, the amounts were medium (0.336 mg), a pattern it shares with population HS-1. When considered on the time basis, the maximum amount was recorded at early (1000) hours (0.348 mg) that decreased significantly to become minimum later at 1300 h (0.328) but recouped in the late hours 1600 to 0.343 mg. Altogether different pattern was observed for the rings, as the inner (3rd and 4th) rings produced highest DNS (0.362 and 0.360 mg, respectively) that decreased progressively in 2nd ring (0.340 mg) to become the least in 1st ring (0.298 mg).

Nectar secretion rhythms in hybrid Pioneer 64A57: In hybrid Pioneer 64A57 (Table 9), maximum DNS was recorded in youngest (1DOF) florets (0.238 mg) that became lowest in 2 DOF (0.215) but increased further to medium level in 3DOF (0.236 mg). On the temporal basis, amount of DNS was medium at 1000 h (0.228 mg) but became least at 1300 h (0.191 mg) to become maximum at 1600 h (0.270 mg). A typical alternate pattern was observed when rings were considered. Maximum DNS was produced in the 3rd ring (0.269 mg) followed by 1st and 4th ring (0.234 and 0.212 mg, respectively) while it was the minimum in the 2nd ring (0.204 mg).

Careful analysis revealed two distinct groups of cultivars, one exhibiting maximum DNS production by the oldest florets (3 DOF) and included both the old populations HS-1 (0.309 mg/floret) and Morden (0.389) and two hybrids DK-3849 (0.373) and PSH-996 (0.283 mg). The other group with maximum DNS production by the youngest florets (1 DOF) included only the hybrids namely HSFH-848 (0.309 mg/floret), SH-3322 (0.373), HSFH-1183 and Pioneer 64A57 (0.238 mg each). Interestingly, none of the groups exclusively included cultivars producing either higher or lower DNS. In old population HS-1, maximum DNS (0.366 mg/floret) was secreted by three day old florets (DOF) followed by 1 and 2 DOF (0.352 and 0.315 mg) while in population Morden and hybrids PSH-996 and DK-3849 it increased with age of florets being maximum in 3 DOF (0.389, 0.283 and 0.373 mg, respectively).

The temporal production of DNS revealed a far scattered pattern of cultivars although maximum DNS production was in the morning hours of 1000 and included one population HS-1 (0.357 mg/floret) and four hybrids viz. PSH-996 (0.278 mg), DK-3849 (0.348), SH-3322(0.327) and HSFH-1183 with least amount (0.253 mg). A population Morden (0.358 mg/floret) and hybrid HSFH-848 (0.302) registered maximum DNS at peak temperature of 13.00 h while Pioneer 64A57 was the lone hybrid with maximum DNS in the evening 1600 h (0.270 mg).

DNS production in a capitulum showed great variations among the rings too although the outer or first ring produced maximum DNS in maximum number of cultivars (6) that included both thehybrids HS-1 (0.354 mg/floret) and Morden (0.391) and four hybrids namely PSH-996 (0.308 mg/floret), HSFH-848 (0.340), SH-3322 (0.341) and HSFH-1183 (0.247). Higher DNS production in population HS-1 was equally distributed on 1st and 2nd ring while in hybrid DK-3849 it was on 2nd and 3rd ring and in Pioneer 64A57 on the 3rd ring. Hybrid DK-3849 was the only cultivar with least DNS production in the 1st ring (0.298 mg). In most of the cultivars (4) the inner most (4th) ring yielded minimum DNS and included Morden (0.287 mg/floret), PSH-996 (0.244), HSFH-848 (0.340) and SH-3322 (0.244 mg). Population HS-1 and hybrid PSH-996 had least DNS production in the 3rd ring (0.316 and 0.257 mg) whereas in hybrid HSFH-1183 it was in the 2nd ring (0.174 mg).

Table 2: Nectar secretion rhythms in sunflower population HS-1

Age of flowers (Days old flowers)	Dry nectar sugar produced (mg/flower)														
	During different periods of the day (h)				In different rings of flower Capitulum					Periods of day (h)	In different rings of flower capitulum				
	1000	1300	1600	Mean	1	2	3	4	Mean		1	2	3	4	Mean
1 DOF	0.360*	0.372	0.322	0.352	0.412	0.385	0.262	0.347	0.352	1000	0.373	0.373	0.280	0.404	0.357
2 DOF	0.270	0.348	0.328	0.315	0.315	0.300	0.330	0.317	0.315	1300	0.363	0.372	0.366	0.344	0.361
3 DOF	0.442	0.364	0.293	0.366	0.335	0.388	0.356	0.385	0.366	1600	0.326	0.327	0.303	0.301	0.314
C.D. ($p\leq0.05$) SE(m)		(0.009)		(0.005) (0.003)		(0.011)			(0.005) (0.003)			(0.011)			(0.005) (0.003)
Mean	0.357	0.361	0.314		0.354	0.357	0.316	0.35			0.354	0.357	0.316	0.350	
C.D. ($p\leq0.05$) SE(m)		(0.005) (0.003)				(0.006) (0.003)						(0.006) (0.003)			

*Values are the mean of 18 observations

Table 3: Nectar secretion rhythms in sunflower population Morden

Age of flowers	Dry nectar sugar produced (mg/flower)														
	During different periods of the day (h)				In different rings of flower capitulum					Periods of day (h)	In different rings of flower Capitulum				
	1000	1300	1600	Mean	1	2	3	4	Mean		1	2	3	4	Mean
1 Day old	0.187*	0.289	0.318	0.265	0.353	0.245	0.264	0.197	0.265	1000	0.354	0.26	0.272	0.308	0.298
2 Day old	0.315	0.327	0.300	0.314	0.350	0.373	0.240	0.293	0.314	1300	0.427	0.272	0.36	0.373	0.358
3 Day old	0.393	0.458	0.315	0.389	0.471	0.278	0.436	0.371	0.389	1600	0.392	0.364	0.309	0.180	0.311
C.D. ($p\leq0.05$) SE(m)		0.002		0.001 0.001		0.002			0.001 0.001			0.002			0.001 0.001
Mean	0.298	0.358	0.311		0.391	0.299	0.314	0.287			0.391	0.299	0.314	0.287	
C.D. ($p\leq0.05$) SE(m)		0.001 0.001				0.001 0.001						0.001 0.001			

**Values are the mean of 18 observations

Table 4: Nectar secretion rhythms in sunflower hybrid PSH-996

Age of flowers	Dry nectar sugar produced (mg/flower)														
	During different periods of the day (h)				**In different rings of flower Capitulum**					**Periods of day (h)**	**In different rings of flower Capitulum**				
	1000	**1300**	**1600**	**Mean**	**1**	**2**	**3**	**4**	**Mean**		**1**	**2**	**3**	**4**	**Mean**
1 Day old	0.264*	0.274	0.275	0.271	0.240	0.274	0.300	0.269	0.271	1000	0.343	0.277	0.238	0.29	0.287
2 Day old	0.261	0.296	0.269	0.275	0.341	0.318	0.216	0.227	0.275	1300	0.315	0.297	0.287	0.193	0.273
3 Day old	0.336	0.248	0.266	0.283	0.344	0.299	0.255	0.236	0.283	1600	0.268	0.316	0.246	0.25	0.270
C.D. ($p\leq0.05$) SE(m)		0.002		0.001 0.001		0.002			0.001 0.001			0.002			0.001 0.001
Mean	0.287	0.273	0.270		0.308	0.297	0.257	0.244			0.308	0.297	0.257	0.244	
C.D. ($p\leq0.05$) SE(m)		0.001 0.001				0.001 0.001						0.001 0.001			

***Values are the mean of 18 observations

Table 5: Nectar secretion rhythms in sunflower hybrid HSFH-848

Age of flowers	Dry nectar sugar produced (mg/flower)														
	During different periods of the day (h)				**In different rings of flower capitulum**						**In different rings of flower Capitulum**				
	1000	**1300**	**1600**	**Mean**	**1**	**2**	**3**	**4**	**Mean**		**1**	**2**	**3**	**4**	**Mean**
1 Day old	0.293*	0.332	0.303	0.309	0.309	0.325	0.329	0.274	0.309	1000	0.370	0.268	0.259	0.293	0.298
2 Day old	0.274	0.306	0.229	0.270	0.342	0.264	0.22	0.254	0.270	1300	0.385	0.301	0.304	0.217	0.302
3 Day old	0.326	0.268	0.298	0.297	0.370	0.291	0.279	0.248	0.297	1600	0.266	0.31	0.266	0.265	0.277
C.D. ($p\leq0.05$) SE(m)		0.002		0.001 0.001		0.002			0.001 0.001			0.002			0.001 0.001
Mean	0.298	0.302	0.277		0.340	0.293	0.276	0.259			0.340	0.293	0.276	0.259	
C.D. ($p\leq0.05$) SE(m)		0.001 0.001				0.001 0.001						0.001 0.001			

*Values are the mean of 18 observations

Table 6: Nectar secretion rhythms in sunflower hybrid HSFH-1183

Age of flowers	Dry nectar sugar produced (mg/flower)														
	During different periods of the day (h)				**In different rings of flower Capitulum**					**Periods of day (h)**	**In different rings of flower Capitulum**				
	1000	**1300**	**1600**	**Mean**	**1**	**2**	**3**	**4**	**Mean**		**1**	**2**	**3**	**4**	**Mean**
1 Day old	0.269*	0.258	0.188	0.238	0.222	0.183	0.35	0.199	0.238	1000	0.275	0.198	0.295	0.244	0.253
2 Day old	0.225	0.194	0.169	0.196	0.257	0.155	0.142	0.229	0.196	1300	0.277	0.194	0.208	0.131	0.203
3 Day old	0.265	0.155	0.212	0.211	0.262	0.182	0.233	0.166	0.211	1600	0.188	0.129	0.223	0.219	0.190
C.D. ($p\leq0.05$) SE(m)		0.001		0.001 0		0.002			0.001 0			0.002			0.001 0
Mean	0.253	0.203	0.190		0.247	0.174	0.242	0.198			0.247	0.174	0.242	0.198	
C.D. ($p\leq0.05$) SE(m)		0.001 0				0.001 0						0.001 0			

***Values are the mean of 18 observations

Table 7: Nectar secretion rhythms in sunflower hybrid SH-3322

Age of flowers	Dry nectar sugar produced (mg)/flower														
	During different periods of the day (h)				**In different rings of flower capitulum**					**Periods of day (h)**	**In different rings of flower Capitulum**				
	1000	**1300**	**1600**	**Mean**	**1**	**2**	**3**	**4**	**Mean**		**1**	**2**	**3**	**4**	**Mean**
1 Day old	0.344*	0.344	0.283	0.324	0.336	0.304	0.421	0.234	0.324	1000	0.396	0.264	0.362	0.284	0.327
2 Day old	0.288	0.305	0.237	0.276	0.337	0.323	0.189	0.257	0.276	1300	0.392	0.34	0.281	0.2	0.303
3 Day old	0.348	0.261	0.25	0.286	0.352	0.237	0.317	0.24	0.286	1600	0.237	0.26	0.283	0.247	0.257
C.D. ($p\leq0.05$) SE(m)		0.003		0.002 0.001		0.004			0.002 0.001			0.004			0.002 0.001
Mean	0.327	0.303	0.257		0.341	0.288	0.309	0.244			0.341	0.288	0.309	0.244	
C.D. ($p\leq0.05$) SE(m)		0.002 0.001				0.002 0.001						0.002 0.001			

***Values are the mean of 18 observations

Table 8: Nectar secretion rhythms in sunflower hybrid DK-3849

Age of flowers	Dry nectar sugar produced (mg/flower)														
	During different periods of the day (h)				**In different rings of flower capitulum**					**Periods of day (h)**	**In different rings of flower Capitulum**				
	1000	**1300**	**1600**	**Mean**	**1**	**2**	**3**	**4**	**Mean**		**1**	**2**	**3**	**4**	**Mean**
1 Day old	0.370*	0.253	0.385	0.336	0.254	0.385	0.309	0.396	0.336	1000	0.316	0.327	0.344	0.407	0.348
2 Day old	0.325	0.320	0.290	0.312	0.293	0.246	0.423	0.285	0.312	1300	0.267	0.299	0.382	0.365	0.328
3 Day old	0.351	0.412	0.355	0.373	0.347	0.390	0.353	0.400	0.373	1600	0.310	0.394	0.359	0.309	0.343
C.D. ($p\leq0.05$) SE(m)		0.003		0.002 0.001		0.003			0.002 0.001			0.003			0.002 0.001
Mean	0.348	0.328	0.343		0.298	0.340	0.362	0.360			0.298	0.340	0.362	0.360	
C.D. ($p\leq0.05$) SE(m)		0.002 0.001				0.002 0.001						0.002 0.001			

****Values are the mean of 18 observations

Table 9: Nectar secretion rhythms in sunflower hybrid Pioneer 64A57

Age of flowers	Dry nectar sugar produced (mg)/flower														
	During different periods of the day (h)				**In different rings of flower capitulum**					**Periods of day (h)**	**In different rings of flower Capitulum**				
	1000	**1300**	**1600**	**Mean**	**1**	**2**	**3**	**4**	**Mean**		**1**	**2**	**3**	**4**	**Mean**
1 Day old	0.210*	0.216	0.286	0.238	0.170	0.221	0.212	0.348	0.238	1000	0.243	0.236	0.256	0.178	0.228
2 Day old	0.205	0.174	0.266	0.215	0.295	0.154	0.277	0.134	0.215	1300	0.153	0.175	0.204	0.231	0.191
3 Day old	0.270	0.182	0.257	0.236	0.236	0.238	0.318	0.153	0.236	1600	0.304	0.202	0.346	0.226	0.270
C.D. ($p\leq0.05$) SE(m)		0.002		0.001 0.001		0.002			0.001 0.001			0.002			0.001 0.001
Mean	0.228	0.191	0.270		0.234	0.204	0.269	0.212			0.234	0.204	0.269	0.212	
C.D. ($p\leq0.05$) SE(m)		0.001 0.001				0.001 0.001						0.001 0.001			

**Values are the mean of 18 observations

Discussion

Sunflower is copious source of nectar and pollen that are the prime rewards for honey bees and other pollinators. Mean values for the production of dry nectar sugars of selected sunflower cultivars revealed significant variations over the observed parameters. Three daysold florets produced maximum DNS (0.305 mg/floret) while the minimum was in 2 DOF (0.272 mg) and 1 DOF recorded medium amount (0.292mg). Periods of the day also influenced DNS production. The maximum DNS (0.300 mg/floret) was at coolermorning hours (1000 h) that receded at peak temperature of 1300 h (0.290 mg) tobecome the minimum at the evening 1600 h (0.279 mg). The nectar production was recorded throughout the day and similar observations were also reported by Krause and Wilson [32]. On the contrary, Parker [39] reported removal of all the nectar by pollen vectors early in the day andby mid day, no measureable amount was left. Chakrabarty and Sharma [8] indicated lower nectar production by male sterile lines (34.1 µg/floret) in the morning hours than in the afternoon hours (63.3 µg/floret) but higher quantity of nectar sugar was in the morning (56 µg/floret) compared to the afternoon (34 µg/floret).

Floret rings also differed in the amount of DNS production. In general, the outer most (1st) ring produced maximum DNS (0.314 mg/floret) followed by 3rdand 2nd ring (0.293 and 0.282mg, respectively) while the inner most 4th ring yielded a minimum amount of DNS (0.269mg/floret). Large and significant variations in patterns of DNS production in florets, rings and time intervals was also observed among these cultivars denoting the greater variability in this small sample of sunflower germplasm. Populations and hybrids considered as separate groups do not indicate any specific pattern. Similarly, no definite trend for DNS production in relation to age of florets and time periods of the day were observed when evaluated for individual cultivars. Only observable pattern was for the floret rings as in all cultivars except DK-3849, the outer ring (1st) produced the maximum amount of DNS but for the inner three rings, the observations were quite variable. Amount and concentration of nectar is reported to be plant, genotype and temporal specific [14, 41, 43] and generally depends upon the plant variety, growth stage and the environmental conditions at the time of flowering [13]. Quantification of the production and consumption of sugar is a key to the understanding of many of the relationships between plant and insects [27]. These factors inturn influence the frequency and temporal abundance of honey bees [36] and finally result in the surplus extractable honeyfrom a colony.

Sunflower cultivars included in the study varied greatly in plant morphology and flowering phenology traits as reported in our simultaneous studies [41, 42] indicating possession by the old population HS-1 of characters including shortest capitulum (length and breadth), disc florets; calyx, corolla tube, ovary dimensions along with least number of ray florets. The other old population Morden had large capitulum (length and breadth) with the short width higher number of ray florets, short disc florets and corolla tube, long calyx and smaller ovary. New hybrids SH-3322 and DK-3849 possessed longest corolla tube and PSH-996 recorded the maximum dimensions of calyx and ovary. Capitulum was largest in HSHF-1183 but other morphological parameters were low to moderate. DK-3849 with shortest capitulum recorded maximum number of ray florets (2-rows), longest disc florets, corolla tube longest and calyx dimensions. Pioneer 64A57 with short capitulum had longest disc florets and corolla tube along with long ovaries. These factors governed the variable production of nectar and pollen that further influenced the abundance of floral visitors as well as honey bees both at spatial and temporal level [41]. Varietal preference is further governed by variations in floral structures including corolla length, stigma pigmentation, etc [28, 40, 42, 44, 48]. Significant differences in sugar values determined by nectar volume and percentage sugar solids in the nectar were reported among hybrids [28, 48] and parental lines of sunflower hybrids [8]. The cultivars with higher nectar production attracted more honey bee visits [39]. Sunflower flowers produced 0.11-0.25 mg nectar/flower equivalent to 16.8-17.7 kg sugar or 20.2-21.3 kg honey/ha [6, 28]. Skinner [46] related selective preference of *A. mellifera* to certain cultivars of sunflower to the difference in amount of nectar production, inflorescence and size and colour of florets. The florets of some cultivars wee too deep for honey bees to reach the nectarines [44].

Perusal of literature revealed no work on thelines of present study on the selected cultivars for plant and floral morphological traits, but the parameters fall in broad descriptions reported by many workers [6, 18, 23, 29, 37, 35, 45]. The results are also in agreement with the broader approach of plant breeders in breeding more self-compatible hybrids compared to old varieties and composites [16, 20, 21] even though cross pollinated varieties out-produce self-pollinating ones [35, 38]. This thought of plant breeders is valid in situations of pollinator paucity either naturally or by destruction with insecticide use [39].

The growth of corporate sector in agriculture lead to the consistent development of large numbers of hybrids. With fewer state owned hybrids and concentration of their seed production in South India, vital technical statistics are not in the public domain. The varietal composition in the fields is quite heterozygous and unpredictable for a season for a variety of reasons. It is not mandatory for the release of hybrids of entomophilous crops like sunflower, that have co-evolved with the honey bees and other pollinators over millions of years, to generate data on amount of nectar production, nectar secretion rhythms and their interactions. Any change in these vital parameters by the plant breeders may prove catastrophic both for the crop as it may not realize its production potential in the absence of pollinators as well as for the pollinators which may perish in the host's absence or unsuitability, ultimately impacting the food security of the country. Recognition, understanding, generation and sharing of such vital inputs including spatial and temporal variations of DNS production will help in better planning for the maximum exploitation of a particular cultivar in the field both for planned honey bee pollination as well as a honey source by the beekeepers.

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