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Effect of weather factors and nitrogen application on nectar secretion and honey production potential in sunflower

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ABSTRACT

Sunflower is a highly important bee floral crop. The nectar secretion governs this parameter and is greatly influenced by cultivar, environmental factors and fertilizer application. Studies were conducted at Punjab Agricultural University, Ludhiana on sunflower hybrids (PSH 996 and PSH 1962) sown on different dates (January 31, February 10, February 20 and March 2) with three levels of nitrogen (45, 60 and 75 kg ha^{-1}). Delay in sowing from January 31 to March 2 caused significant reduction in nectar secretion (12.66%) and increase in its concentration (5.38%). The daily mean temperature had significant positive (R^2 = 0.52 and 0.54) while mean relative humidity had negative (R^2 = 0.55 and 0.37) correlation with nectar total soluble solids (TSS).Nectar secretion and its TSS increased significantly only at nitrogen dose of 60 kg ha^{-1} as compared to 45 kg ha^{-1}.Weather parameters have more pronounced effects on TSS at 45 kg ha^{-1}.Delay in sowing by one month resulted in reduction in honey production potential by 1.5- 1.8 kg ha^{-1}. In addition to this, the reduced nectar availability due to delay in sowing may negatively effect in attracting and sustaining pollinators' populations and crop yield.

Keywords : Honey production, humidity, nitrogen, nectar secretion, sunflower, temperature

Over the course of evolution, bees and cross-pollinated plants have developed a mutualistic relationship. Such relationship does exist between (*Helianthus annuus* Linnaeus) and bees as well. Sunflower produces abundant nectar and pollen for bees which itself get benefitted for seed setting through bees' visits. In addition to this, surplus nectar from sunflower is converted into honey by bees and thereby contributes towards providing livelihood security to thousands of families engaged in beekeeping. Sunflower is photo and thermal insensitive crop which enables its cultivation in *kharif, rabi* as well as summer seasons (Singh and Sinha, 1997) thus provides food and nutrition to pollinators even during food scarcity period i.e. May-June. It is an important bee pasturage as it was grown over an area of 400 thousand ha in India (FAO, 2017) while in Punjab, it was cultivated on an area of 5.7 thousand ha (Anon. 2019).

Sunflower needs a vector for transporting pollen for pollination. Enhanced pollination has been reported to increase sunflower seed setting, seed weight and seed yield along with oil content (Swaminathan and Bharadwaj, 1998). Significant improvement in yield has been reported by augmenting the honey bees' population in the vicinity of the crop (Sathyanarayana and Seetharam, 1982). Hence, bees are most important pollinators. The mutualistic relationship between bees and sunflower is of great importance for sustaining bee diversity through provision of ample nourishment, augmentation in seed yield and providing livelihood through production of surplus honey. Thus, any change in production of floral rewards may have disruptive effect on this system.

The attraction of bees to a particular flower is directly correlated with the quantity of nectar and its sugar-concentration (Neff and Simpson, 1990) which in turn depends largely upon the plants own potential to secrete nectar and nutritional status along with the prevailing weather conditions. Sowing time is an important non-monetary inputthat can be varied to avail the congenial environment for attaining best yield (Dhillon *et al*., 2017) but it also affects floral rewards. There are several reports which indicate that there exists the natural variability in terms of nectar production among various varieties of a crop which is affected by weather factors (Neff and Simpson, 1990) and agronomic practices (Singh, 1991). Roy and Bhat(2005) reported a considerable variation in the

attractiveness of different varieties of sunflower to honey bees. Hence, determining the nectar production ability would directly indicate the apicultural importance which can be a measure for yield stability in sunflower assured through pollination. To enumerate this, the present study was carried out at Punjab Agricultural University (PAU), Ludhiana in which the effect of various weather factorsand level of different nitrogen application on nectar secretion and honey production potential was studied.

MATERIALS AND METHODS

Two sunflower hybrids (PSH 996 and PSH 1962) were grown at Experimental Farm of Oilseeds Section, Department of Plant Breeding & Genetics, Punjab Agricultural University, Ludhiana, as per recommendations of the University. To enumerate the effect of weather factors, these hybrids were sown on January 31, February 10, February 20 and March 2in replicated (three) plots each of size 4.5 x 3.6 m. The experiment was laid out in split-plot design with different dates of sowing as the main factor and fertilizer doses as sub-factor. The three levels of nitrogen were 45 kg ha^{-1}(25% lesser than the recommended dose), 60 kg ha^{-1} (recommended dose) and 75 kg ha^{-1} (25% higher than the recommended dose).

Determination of quantity of nectar production

In sunflower, nectar is secreted from the base of corolla or style and accumulates in the corolla tube. It was collected from the ten marked florets from every selected flower head from the randomly selected plants by using a disposable glass micropipette with a rubber tube as an extension hose. The glass micropipettes were weighed on a digital balance to know the collected nectar from the nectaries of 30 florets.Nectar was collected from same florets consecutively for 2 days during morning (0900-1000 h), noon (1200-1300 h) and evening (1500-1600 h) time and sum of the quantity of nectar collected from three such plantswas taken as nectar quantity per 30 florets. The capitulum was covered with nylon netting to prevent robbing of nectar by other insects. The nectar sugar concentration was determined with the hand-held refractometer with measuring range of 28-68 per cent T.S.S. (with sensitivity of 0.20 %).

Honey production potential was worked out by using the following formula

Honey production potential per ha = pfq x corrected T.S.S.x 80^{-1}

where, p is number of plants in one hectare, f is number of florets per plant andq is quantity of nectar (mg) per floret, 80 is the T.S.S. (%) of a representative honey.

Statistical analysis

The data on nectar quantity and TSS were subjected to standard statistical procedure for Split plot design using SAS software. The differences among the various treatment means were compared using LSD at five per cent level of significance.

RESULTS AND DISCUSSION

Effect of weather factors on nectar secretionin sunflower

The pooled data (Table 1) over the years 2014 and 2015 revealed significantly the highest mean nectar secretion per 30 florets (7.3$\pm$0.8 mg) from timely sown (31stJanuary) sunflower hybrid PSH 996 followed by February 10 sown crop(7.2±0.8 mg). These were followed by nectar production of 6.9±0.7 mg on February 20 sown crop while the March 2 sown crop produced significantly the lowest nectar quantity (6.4±0.7 mg).Similar trend was recorded in sunflower hybrid PSH 1962. It was found that with the delay in sowing, blooming of thecrop also got delayed. Hence, flower heads of different dates of sowing experienced different weather parameters like temperature, relative humidity and sunshine hours. This caused 12.33 and 12.99 per cent reduction (7.3 to 6.4 and 7.7 to 6.7 mg/30 florets) in nectar secretion in PSH 996 and PSH 1962, respectively. Jociæ (2000) too reported that stressful climatic conditions affect the nectar production to a greater extent.

It was found that the crop sown on January 31 came into blooming during April 10-11 which experienced mean maximum and minimum temperature of 31.53 and 17.12°C and mean relative humidity during morning and evening as 80.55 and 43.87 per cent, respectively and sunshine hours of9.10 hours/day (Fig. 1). Unlike this, thelate sown crop i.e. on March 02 came into blooming during May 1-3 and thus experienced a mean maximum & minimum temperature, mean relative humidity at morning and evening and mean sunshine hours as 37.28 & 21.97°C, 60.33 & 29.80 per cent and 9.03 hours/day. These values were relatively higher than the values for crop sown on earlier date (January 31). The higher temperature reduces the relative humidity. Thus, under such conditions moisture in the nectar get evaporated and thereby the lesser quantity of nectar was available. Shuel (1964) also recorded these parameters to play a major role in determining the quantity of nectar secretion due to these floral rewards

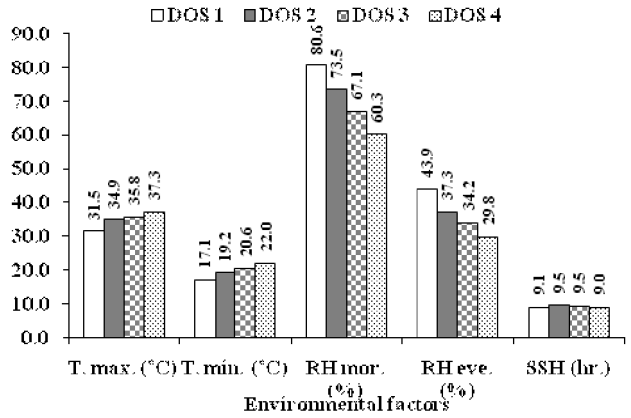

Fig. 1: Weather factors to which blooms of sunflower sown at various dates (DOS) were exposed

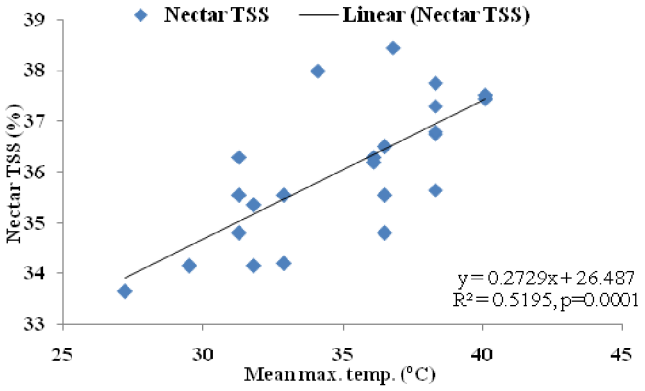

Fig. 2: Relationship of mean maximum temperature (°C) with nectar TSS

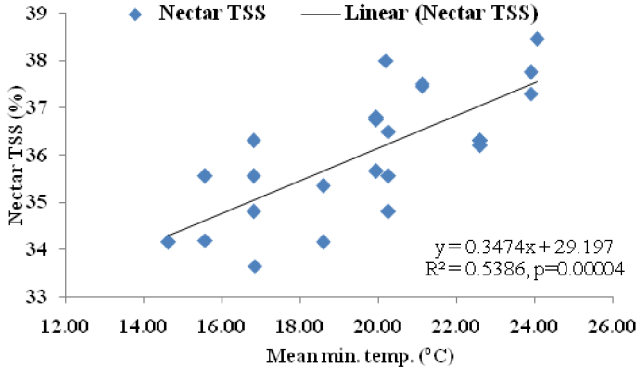

Fig. 3: Relationship of mean minimum temperature (°C) with nectar TSS

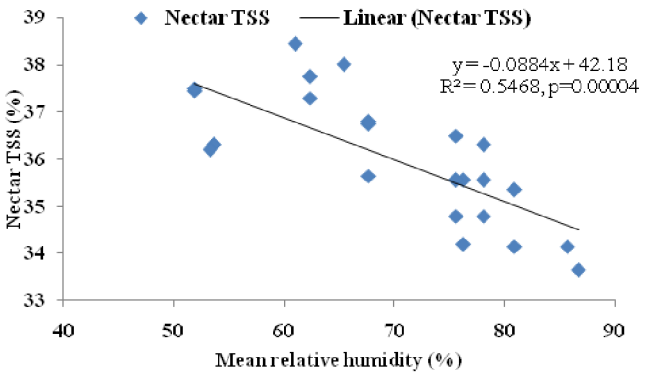

Fig. 4: Relationship of mean relative humidity at morning(%) with nectar TSS

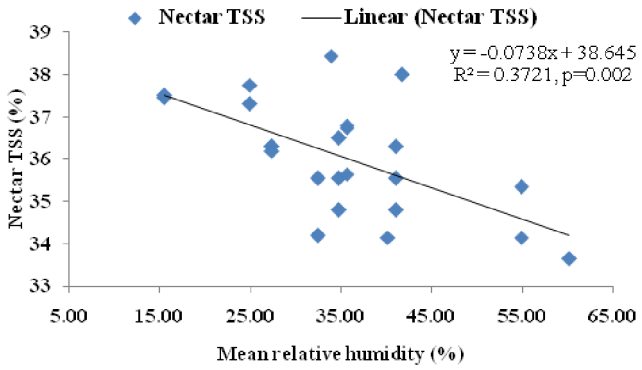

Fig. 5: Relationship of mean relative humidity at evening (%) with nectar TSS

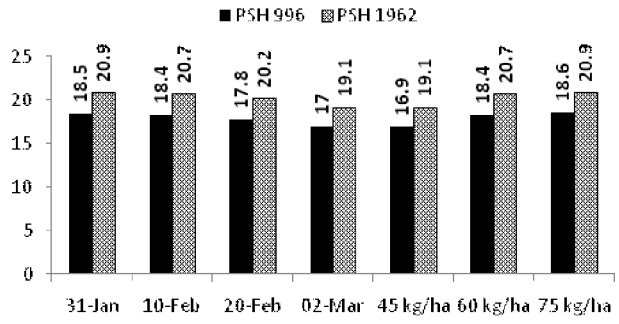

Fig. 6: Effect of different dates of sowing and nitrogen application on honey production potential of sunflower

get reduced and florets become less attractive to pollinators (Singh 1991). Thus, finally the pollination services get adversely affected (Goluboviæ *et al* 1992).

Diurnal mean nectar secretion in sunflower hybrid, PSH 996 (Table 1) was the lowest (4.1±0.2 mg) in the morning hours (0900-1000 h) which significantly increased to 9.1±0.4 mg during noon hours and then again decreased to 7.5±0.3 mg in the evening. The increase in nectar secretion from 0900 h to 1200 h was attributed to the exposure of plants to sunlight which induced rapid development and so the nectar secretion was high(Fota *et al.*,1977; Singh 1991).

The mean nectar secretion was significantly the highest i.e. 6.5±1.4 and 7.8±1.6 mg per 30 florets in the 2nd week.Similar trend was observed in sunflower hybrid PSH 1962 (Table 2).

Effect of weather factors on nectar-sugar concentration in sunflower

Pooled data presented in Table 3 revealed that in sunflower hybrid PSH 996 there was a significant increase in floral nectar-sugar concentration with delay in sowing date from January 31 (35.8±1.3 %) to February 20 (36.6±1.4 %) and to March 2 (37.7±1.4 %). Mean floral nectar-sugar concentration in February 10th sown crop (36.0±1.4 %) was statistically on par with that from January 31. Similar trend was recorded in PSH 1962 (Table 4). Overall, delay in sowing eg. crop sown on March 2, resulted in delayed blooming in sunflower, during bloomingperiod the prevalent temperature was relatively higher than the crop sown on January 31. The higher temperature caused evaporation of moisture and thus nectar sugar concentration got increased. Temperature (max. and min.) was having significant positive correlation with nectar sugar concentration(R^2 = 0.52 (p=0.0001; n=24) and 0.54 (p=0.00004; n=24), respectively (Fig. 2-3). An increase of 0.27 and 0.35 per cent nectar sugar concentration with a rise of one degree centigrade mean maximum and minimum temperature, respectively was noticed. The relative humidity (morning and evening) was negatively correlated with nectar sugar concentration (R^2= 0.55 (p=0.00004) and 0.37 (p=0.002), respectively (Fig. 4-5). An increment of one unit in morning and evening relative humidity caused a reduction of 0.09 and 0.07 per cent in nectar sugar concentration. Sunshine hours did not significantly affect this parameter (R^2 = 0.006; p=0.71; n=24). These results are strongly supported by Oertel (1946) who found a positive correlation between temperature and the nectar sugar concentration in white clover flowers. A decrease in atmospheric humidity from April to May resulted in higher evaporation rate thereby resulting in the production of more concentrated nectar. Park (1929) also reported negative correlation of nectar sugar concentration with relative humidity.Shashibala and Singh (2013) too reported the lowest nectar sugar concentration (32.22 %) during morning while the highest (36.02 %) at 1500 h in sunflower. The increase in nectar sugar concentration during noon hours was due to increase in temperature (Oertel, 1946;Shashibala and Singh, 2013).

Effect of various levels of nitrogen application on nectar secretion in sunflower

Sunflower hybrid PSH 996 had lowest floral nectar secretion (6.6±0.7 mg) with 45 kg ha^{-1}nitrogen dose (Table 1) which significantly increased to 7.0±0.8 mg with increase in nitrogen dose (60 kg ha^{-1}), however, the later being at par with 75 kg ha^{-1}dose (7.1±0.8 mg). Similar trend was recorded in sunflower hybrid PSH 1962 (Table 2). The results are in corroboration with the findings of Kaziev (1967) who reported an increase of 43-44 per cent in nectar production with the addition of nitrogen above the control. Similarly, Suryanarayana (1985) reported sunflower hybrids to produce 65.4 per cent more nectar when N, P and K fertilizers were applied at recommended dose as compared to lower dose. The results of present study are strongly supported by mean nectar secretion reported by Singh (1991), Atlagic *et al.* (2003) and Gowda *et al.* (2003) i.e. 0.88-0.89 mg, 0.10-0.78 and 0.21-0.58 mg per floret per two days, respectively.

Effect of various levels of nitrogen application on nectar-sugar concentration in sunflower

The floral nectar-sugar concentration in PSH 996 (Table 3) was 35.8±1.2 per cent when a nitrogen dose of 45 kg ha^{-1}was applied. The increase in nitrogen dose to 60 kg ha^{-1}caused significant increase in floral nectar-sugar concentration (37.0±1.4%). The further increase in nitrogen dose to 75 kg ha^{-1}caused a reduction in floral nectar sugar concentration (36.7±1.5 %) which did not differ significantly from that observed at 60 kg ha^{-1}.In sunflower hybrid PSH 996 (Table 4), the floral nectar-sugar concentration was significantly the highest (37.7±2.7 %) during 3rd week of blooming. During a day, floral nectar secreted was the most concentrated at 1200-1300 h (41.2±1.0 %). Similarly trend was recorded in PSH 1962.

The nectar-sugar concentration increased with increase in nitrogen dose from 45 to 60 kg ha^{-1} and but further increase in nitrogen dose to 75 kg ha^{-1}resulted in decrease in nectar-sugar concentration. Regression equations have been developed for temperature (max. & min.) and relative humidity (morning & evening) with the mean (PSH 996 & PSH 1962) nectar sugar concentration at various levels of nitrogen fertilization to know their effect on TSS. The respective regression equations showed that the maximum effect of temperature (max.) was at 45 kg ha^{-1} followed by at 60 and 75 kg ha^{-1} with respective values of slope as 2.0, 1.85 and 1.74. Similar trend was found with temperature (min.). The relative humidity (morning) too showed maximum effect was at 45 kg ha^{-1} followed by at 60 and 75 kg ha^{-1}. The respective values were -6.57, -5.90 and -5.76, respectively. The relative humidity at evening did not affect nectar sugar concentration too much.Popovic (1987)

Table 1: Effect of weather factors and nitrogen doses on diurnal floral-nectar secretion after various weeks of blooming initiation in *Helianthus annuus* hybrid PSH 996 (Pooled data of 2014 & 2015)

Date of sowing	Nitrogen dose (kg ha^{-1})	Mean nectar secretion (mg) per 30 florets												Overall mean	Grand mean for nitrogen dose
		Week I				Week II				Week III					
		0900-1000 h	1200-1300 h	1500-1600 h	Mean	0900-1000 H	1200-1300 h	1500-1600 h	Mean	0900-1000 h	1200-1300 h	1500-1600 H	Mean		
Jan. 31	45	3.8±0.2	8.8±0.2	7.1±0.4	6.6±1.5	4.5±0.3	10.0±0.4	8.1±0.7	7.5±1.6	4.1±0.2	9.0±0.5	7.4±0.4	6.8±1.4	7.0±0.8	6.6±0.7[a]
	60	4.1±0.1	9.1±0.5	7.4±0.2	6.9±1.5	4.7±0.2	10.5±0.6	8.6±0.3	7.9±1.7	4.4±0.2	9.5±0.3	8.0±0.5	7.3±1.5	7.4±0.8	7.0±0.8[b]
	75	4.2±0.3	9.3±0.6	7.6±0.3	7.0±1.5	4.9±0.2	10.6±0.3	8.6±0.4	8.0±1.7	4.3±0.1	9.8±0.3	8.0±0.5	7.4±1.6	7.5±0.9	7.1±0.8[b]
	Mean	4.1±0.1	9.0±0.2	7.4±0.2	6.8±1.5	4.7±0.2	10.3±0.3	8.4±0.2	7.8±1.7	4.3±0.2	9.4±0.2	7.8±0.2	7.2±1.5	7.3±0.8[a]	
Feb. 10	45	3.9±0.3	8.5±0.2	7.2±0.3	6.5±1.4	4.5±0.1	9.9±0.3	8.1±0.6	7.5±1.6	4.1±0.3	8.9±0.1	7.3±0.5	6.8±1.4	6.9±0.7	
	60	4.1±0.2	9.0±0.1	7.4±0.2	6.8±1.4	4.7±0.2	10.3±0.4	8.6±0.5	7.8±1.7	4.3±0.2	9.5±0.4	7.8±0.3	7.2±1.5	7.3±0.7	
	75	4.2±0.3	9.2±0.4	7.5±0.4	7.0±1.5	4.8±0.2	10.4±0.4	8.6±0.5	7.9±1.7	4.5±0.2	9.7±0.2	7.9±0.3	7.3±1.5	7.4±0.8	
	Mean	4.1±0.2	8.9±0.2	7.3±0.2	6.8±1.4	4.7±0.2	10.2±0.2	8.4±0.2	7.8±1.6	4.3±0.1	9.4±0.2	7.7±0.1	7.1±1.5	7.2±0.8[a]	
Feb. 20	45	3.6±0.2	8.1±0.1	6.8±0.2	6.1±1.4	4.3±0.1	9.4±0.3	7.7±0.3	7.1±1.5	3.8±0.2	8.4±0.4	6.9±0.4	6.4±1.4	6.6±0.6	
	60	3.9±0.3	8.5±0.3	7.0±0.6	6.5±1.4	4.5±0.4	9.9±0.5	8.1±0.5	7.5±1.6	4.1±0.3	9.0±0.5	7.4±0.5	6.8±1.4	6.9±0.7	
	75	4.0±0.2	8.7±0.4	7.2±0.4	6.6±1.4	4.6±0.2	10.1±0.4	8.2±0.6	7.6±1.6	4.2±0.3	9.2±0.6	7.5±0.5	7.0±1.5	7.1±0.7	
	Mean	3.8±0.1	8.4±0.2	7.0±0.2	6.4±1.4	4.4±0.1	9.8±0.2	8.0±0.2	7.4±1.6	4.0±0.2	8.9±0.2	7.3±0.2	6.7±1.4	6.9±0.7[b]	
Mar. 2	45	3.4±0.3	7.5±0.1	6.1±0.2	5.7±1.2	3.9±0.1	8.8±0.2	7.2±0.5	6.6±1.5	3.5±0.2	7.8±0.4	6.4±0.4	5.9±1.3	6.1±0.7	
	60	3.6±0.2	7.9±0.5	6.5±0.4	6.0±1.3	4.2±0.3	9.2±0.4	7.6±0.2	7.0±1.5	3.8±0.1	8.4±0.3	7.0±0.2	6.4±1.4	6.5±0.7	
	75	3.7±0.2	8.1±0.4	6.6±0.5	6.2±1.3	4.3±0.3	9.3±0.2	7.7±0.1	7.1±1.4	3.9±0.1	8.5±0.2	7.0±0.2	6.5±1.3	6.6±0.6	
	Mean	3.6±0.1	7.8±0.2	6.4±0.2	5.9±1.3	4.1±0.2	9.1±0.2	7.5±0.2	6.9±1.5	3.8±0.1	8.2±0.2	6.8±0.2	6.3±1.3	6.4±0.7[c]	
Overall	45	3.7±0.2	8.2±0.3	6.8±0.1	6.2±1.3	4.3±0.1	9.5±0.3	7.8±0.3	7.2±1.5	3.9±0.1	8.5±0.2	7.0±0.3	6.5±1.4		
mean	60	3.9±0.2	8.6±0.3	7.1±0.2	6.5±1.4	4.5±0.1	10.0±0.2	8.2±0.3	7.6±1.6	4.1±0.1	9.1±0.2	7.5±0.3	6.9±1.5		
	75	4.0±0.2	8.8±0.2	7.2±0.2	6.7±1.4	4.6±0.2	10.1±0.2	8.2±0.2	7.7±1.6	4.2±0.2	9.3±0.3	7.6±0.2	7.0±1.5		
Grand mean		3.9±0.1	8.6±0.2	7.0±0.2	6.5±1.4	4.5±0.1	9.9±0.2	8.1±0.3	7.5±1.6	4.1±0.1	9.0±0.2	7.4±0.2	6.8±1.4		
Grand mean for time		4.1±0.2	9.1±0.4	7.5±0.3											

Data values: Mean±S.E.mean

LSD (p=0.05) for:

A	0.2	C	0.3	ABC	0.2	BD	NS	ACD	NS
B	0.1	AC	0.6	D	0.3	ABD	NS	BCD	NS
AB	NS	BC	NS	AD	0.5	CD	0.2	ABCD	NS

A= Date of sowing; B= Nitrogen dose; C= Week, and D= Time of the day

Table 2: Effect of weather factorsand nitrogen doses on diurnal floral-nectar secretion after various weeks of blooming initiation in *Helianthus annuus* hybrid PSH 1962 (Pooled data of 2014 & 2015)

Date of sowing	Nitrogen dose (kg ha^{-1})	Mean nectar secretion (mg) per 30 florets												Overall mean	Grand mean for nitrogen dose
		Week I				Week II				Week III					
		0900-1000 h	1200-1300 h	1500-1600 h	Mean	0900-1000 h	1200-1300 h	1500-1600 h	Mean	0900-1000 h	1200-1300 h	1500-1600 h	Mean		
Jan. 31	45	3.9±0.2	9.2±0.5	7.5±0.2	6.8±1.5	4.8±0.3	10.6±0.1	8.7±0.1	8.0±1.7	4.5±0.3	9.9±0.2	8.0±0.8	7.4±1.6	7.4±0.8	6.9±0.8[a]
	60	4.3±0.3	9.6±0.3	7.9±0.6	7.2±1.5	5.0±0.4	10.9±0.6	9.0±0.3	8.3±1.7	4.8±0.2	10.5±0.3	8.6±0.6	7.9±1.7	7.8±0.8	7.4±0.7[b]
	75	4.4±0.2	9.7±0.3	8.0±0.2	7.4±1.6	5.0±0.4	11.1±0.4	9.1±0.2	8.4±1.8	4.9±0.4	10.7±0.5	8.7±0.4	8.1±1.7	7.9±0.7	7.6±0.8[c]
	Mean	4.2±0.1	9.5±0.2	7.8±0.3	7.2±1.5	4.9±0.3	10.9±0.2	8.9±0.2	8.2±1.7	4.7±0.1	10.3±0.2	8.4±0.2	7.8±1.7	7.7±0.8[a]	
Feb. 10	45	3.9±0.4	9.0±0.6	7.4±0.3	6.8±1.5	4.7±0.3	10.2±0.1	8.5±0.6	7.8±1.6	4.4±0.1	9.7±0.4	7.9±0.1	7.3±1.6	7.3±0.6	
	60	4.3±0.1	9.5±0.4	7.7±0.5	7.1±1.5	4.9±0.2	10.8±0.7	8.8±0.4	8.2±1.7	4.7±0.3	10.3±0.7	8.4±0.3	7.8±1.6	7.7±0.7	
	75	4.3±0.2	9.7±0.2	8.0±0.2	7.3±1.6	5.0±0.6	11.0±0.6	8.9±0.4	8.3±1.7	4.8±0.3	10.5±0.6	8.7±0.5	8.0±1.7	7.9±0.7	
	Mean	4.2±0.2	9.4±0.2	7.7±0.3	7.1±1.5	4.9±0.1	10.7±0.2	8.7±0.2	8.1±1.7	4.6±0.2	10.2±0.3	8.3±0.1	7.7±1.6	7.6±0.8[a]	
Feb. 20	45	3.9±0.1	8.5±0.3	7.0±0.6	6.5±1.4	4.4±0.2	9.7±0.2	8.0±0.4	7.4±1.6	4.0±0.1	8.8±0.4	7.2±0.2	6.7±1.4	6.8±0.8	
	60	4.0±0.2	9.0±0.5	7.4±0.5	6.8±1.5	4.7±0.2	10.2±0.8	8.4±0.5	7.8±1.6	4.3±0.2	9.6±0.7	7.8±0.1	7.2±1.5	7.3±0.8	
	75	4.3±0.2	9.2±0.5	7.6±0.2	7.0±1.5	4.8±0.3	10.4±0.4	8.5±0.4	7.9±1.6	4.4±0.3	9.8±0.6	8.0±0.3	7.4±1.6	7.4±0.7	
	Mean	4.0±0.1	8.9±0.2	7.3±0.2	6.8±1.4	4.6±0.1	10.1±0.3	8.3±0.2	7.7±1.6	4.2±0.2	9.4±0.2	7.7±0.3	7.1±1.5	7.2±0.6[b]	
Mar. 2	45	3.6±0.3	7.8±0.5	6.4±0.2	5.9±1.3	4.0±0.3	8.9±0.6	7.3±0.3	6.7±1.4	3.6±0.2	8.1±0.2	6.5±0.5	6.1±1.3	6.2±0.6	
	60	3.9±0.2	8.5±0.6	7.0±0.7	6.4±1.4	4.4±0.2	9.5±0.5	7.9±0.6	7.3±1.5	4.0±0.6	8.9±0.2	7.4±0.4	6.8±1.5	6.8±0.7	
	75	4.1±0.2	8.7±0.2	7.0±0.3	6.6±1.4	4.4±0.1	9.8±0.4	8.0±0.6	7.4±1.6	4.2±0.3	9.1±0.3	7.5±0.1	6.9±1.5	7.0±0.7	
	Mean	3.8±0.1	8.4±0.3	6.8±0.2	6.3±1.3	4.2±0.2	9.4±0.2	7.7±0.1	7.1±1.5	3.9±0.1	8.7±0.3	7.1±0.2	6.6±1.4	6.7±0.7[c]	
Mean	45	3.8±0.2	8.6±0.3	7.1±0.2	6.5±1.4	4.5±0.3	9.8±0.4	8.1±0.2	7.5±1.6	4.1±0.3	9.1±0.2	7.4±0.3	6.9±1.5		
	60	4.1±0.2	9.1±0.3	7.5±0.2	6.9±1.5	4.7±0.2	10.3±0.3	8.5±0.2	7.9±1.7	4.5±0.3	9.8±0.1	8.0±0.3	7.4±1.6		
	75	4.3±0.1	9.3±0.4	7.6±0.2	7.1±1.5	4.8±0.1	10.6±0.2	8.6±0.3	8.0±1.7	4.6±0.3	10.1±0.1	8.2±0.2	7.6±1.6		
Grand mean		4.1±0.1	9.0±0.2	7.4±0.2	6.8±1.5	4.7±0.2	10.3±0.1	8.4±0.1	7.8±1.6	4.4±0.2	9.7±0.1	7.9±0.2	7.3±1.5		
Grand mean for time		4.4±0.2	9.6±0.4	7.9±0.3											

Data values: Mean±S.E.mean

LSD (p=0.05) for:

A	0.2	C	0.3	ABC	NS	BD	NS	ACD	NS
B	0.2	AC	0.6	D	0.3	ABD	NS	BCD	NS
AB	NS	BC	NS	AD	0.5	CD	0.3	ABCD	NS

A= Date of sowing; B= Nitrogen dose; C= Week, and D= Time of the day

Table 3: Effect of weather factors and nitrogen doses on diurnal floral nectar-sugar concentration after various weeks of blooming initiation in *Helianthus annuus* hybrid PSH 996 (Pooled data of 2014 & 2015)

Date of sowing	Nitrogen dose (kg ha^{-1})	Mean nectar-sugar concentration (TSS%)*												Overall mean	Grand for mean nitrogen
		Week I				Week II				Week III					
		0900-1000 h	1200-1300 h	1500-1600 h	Mean	0900-1000 h	1200-1300 h	1500-1600 h	Mean	0900-1000 h	1200-1300 h	1500-1600 h	Mean		
Jan. 31	45	30.0±0.3 (33.2)	37.8±0.3 (37.9)	34.0±0.2 (35.6)	33.9±2.3 (35.6)	31.4±0.3 (34.0)	38.8±0.4 (38.5)	35.1±0.1(36.3)	35.1±2.1 (36.3)	32.2±0.4 (34.5)	39.7±0.3 (39.0)	36.4±0.2 (37.1)	36.1±2.2 (36.9)	35.0±1.1 (36.3)	35.8±1.2 (36.7)[a]
	60	30.5±0.0 (33.5)	38.8±0.3 (38.5)	34.6±0.3 (36.0)	34.6±2.4 (36.0)	32.5±0.4 (34.7)	42.3±0.5 (40.6)	36.1±0.1 (36.9)	36.9±2.9 (37.5)	33.0±0.2 (35.1)	42.3±0.3 (40.5)	37.0±0.5 (37.4)	37.4±2.7 (37.7)	36.3±1.4 (37.1)	37.0±1.4 (37.4)[b]
	75	30.1±0.2 (33.3)	38.5±0.1 (38.3)	34.4±0.2 (35.9)	34.3±2.4 (35.9)	32.6±0.5 (34.8)	41.9±0.4 (40.3)	35.7±0.3 (36.7)	36.7±2.7 (37.4)	32.9±0.2 (35.0)	42.1±0.3 (40.4)	36.5±0.3 (37.2)	37.2±2.7 (37.6)	36.1±1.4 (37.0)	36.7±1.5 (37.3)[b]
	Mean	30.2±0.1 (33.3)	38.4±0.3 (38.3)	34.3±0.2 (35.9)	34.3±2.4 (35.8)	32.1±0.4 (34.5)	41.0±1.1 (39.3)	35.6±0.3 (36.7)	36.3±2.6 (37.1)	32.7±0.3 (34.9)	41.4±0.8 (40.5)	36.6±0.2 (37.2)	36.9±2.5 (37.4)	35.8±1.3 (36.7)[a]	
Feb. 10	45	30.1±0.4 (33.2)	38.7±0.2 (38.5)	34.6±0.2 (36.0)	34.5±2.5 (36.0)	31.6±0.4 (34.2)	39.3±0.2 (38.8)	35.1±0.3 (36.3)	35.3±2.2 (36.5)	32.4±0.4 (34.6)	40.2±0.3 (39.3)	35.8±0.3 (36.7)	36.1±2.3 (36.9)	35.3±1.2 (36.4)	
	60	30.3±0.4 (33.4)	39.0±0.2 (38.6)	34.7±0.2 (36.1)	34.7±2.5 (36.1)	32.8±0.2 (34.9)	42.1±0.5 (40.5)	36.4±0.3 (37.1)	37.1±2.7 (37.6)	33.1±0.2 (35.1)	43.1±0.3 (41.0)	36.7±0.2 (37.3)	37.6±2.9 (37.8)	36.5±1.4 (37.2)	
	75	29.9±0.2 (33.1)	38.9±0.4 (38.6)	34.5±0.3 (35.9)	34.4±2.6 (35.9)	32.4±0.1 (34.7)	42.2±0.6 (40.5)	36.0±0.2 (36.9)	36.9±2.9 (37.5)	32.9±0.3 (35.0)	42.9±0.3 (40.9)	36.6±0.3 (37.2)	37.5±2.9 (37.8)	36.3±1.5 (37.1)	
	Mean	30.1±0.1 (33.2)	38.9±0.1 (38.6)	34.6±0.1 (36.0)	34.5±2.6 (35.9)	32.3±0.4 (34.7)	41.2±0.9 (39.4)	35.8±0.4 (36.7)	36.4±2.6 (37.1)	32.8±0.2 (34.9)	42.1±0.9 (40.5)	36.4±0.3 (37.1)	37.1±2.7 (37.5)	36.0±1.4 (36.8)[b]	
Feb. 20	45	30.3±0.4 (33.4)	39.0±0.2 (38.6)	34.8±0.2 (36.2)	34.7±2.5 (36.1)	32.1±0.5 (34.5)	39.9±0.3 (39.1)	35.6±0.3 (36.6)	35.8±2.2 (36.7)	33.6±0.4 (35.4)	41.5±0.3 (40.1)	37.1±0.3 (37.5)	37.4±2.3 (37.7)	36.0±1.2 (36.8)	
	60	30.5±0.4 (33.5)	39.3±0.2 (38.8)	35.0±0.3 (36.2)	34.9±2.5 (36.2)	33.3±0.3 (35.2)	42.7±0.5 (40.8)	36.9±0.4 (37.4)	37.6±2.7 (37.8)	34.0±0.2 (35.6)	43.9±0.3 (41.5)	37.5±0.2 (37.8)	38.5±2.9 (38.3)	37.0±1.5 (37.4)	
	75	30.1±0.2 (33.3)	39.2±0.4 (38.7)	34.7±0.2 (36.1)	34.7±2.6 (36.1)	33.0±0.1 (35.0)	42.7±0.7 (40.8)	36.6±0.3 (37.2)	37.4±2.9 (37.7)	33.4±0.3 (35.3)	43.5±0.6 (41.2)	37.1±0.3 (37.5)	38.0±2.9 (38.0)	36.7±1.5 (37.2)	
	Mean	30.3±0.1 (33.4)	39.2±0.1 (38.7)	34.8±0.1 (36.2)	34.8±2.6 (36.2)	32.8±0.4 (34.9)	41.7±0.8 (40.2)	36.3±0.4 (37.1)	37.0±2.6 (37.4)	33.7±0.2 (35.5)	43.0±0.8 (41.0)	37.2±0.2 (37.5)	38.0±2.7 (38.0)	36.6±1.4 (37.2)[c]	
Mar. 2	45	31.7±0.4 (34.3)	40.4±0.2 (39.4)	36.2±0.2 (37.0)	36.1±2.5 (36.9)	33.2±0.7 (35.2)	41.0±0.8 (39.8)	36.7±0.5 (37.3)	37.0±2.2 (37.5)	34.0±0.2 (35.7)	41.9±0.3 (40.3)	37.5±0.5 (37.7)	37.8±2.3 (37.9)	37.0±1.2 (37.4)	
	60	32.0±0.4 (34.4)	40.8±0.2 (39.7)	36.4±0.3 (37.1)	36.4±2.5 (37.0)	34.5±0.1 (35.9)	43.9±0.4 (41.5)	38.1±0.2 (38.1)	38.8±2.7 (38.5)	34.9±0.3 (36.2)	44.8±0.4 (42.0)	38.4±0.6 (38.3)	39.4±2.9 (38.8)	38.2±1.4 (38.1)	
	75	31.6±0.2 (34.2)	40.6±0.4 (39.6)	36.2±0.3 (37.0)	36.1±2.6 (36.9)	34.1±0.3 (35.7)	43.9±0.6 (41.5)	37.7±0.8 (37.9)	38.6±2.9 (38.4)	34.6±0.4 (36.0)	44.6±0.2 (41.9)	38.3±0.1 (38.2)	39.2±2.9 (38.7)	38.0±1.5 (38.0)	
	Mean	31.8±0.1 (34.3)	40.6±0.2 (39.6)	36.3±0.1 (37.1)	36.2±2.6 (37.0)	34.0±0.4 (35.6)	42.9±1.0 (40.9)	37.5±0.4 (37.7)	38.1±2.6 (38.1)	34.5±0.2 (36.0)	43.8±1.0 (41.5)	38.1±0.3 (38.1)	38.8±2.7 (38.4)	37.7±1.4 (37.8)[d]	

Table 3: Effect of weather factors and nitrogen doses on diurnal floral nectar-sugar concentration after various weeks of blooming initiation in *Helianthus annuus* hybrid PSH 996 (Pooled data of 2014 & 2015)

Mean	45	30.5±0.4 (33.5)	39.0±0.5 (38.6)	34.9±0.5 (36.2)	34.8±2.4 (36.1)	32.1±0.4 (34.5)	39.7±0.3 (39.4)	35.6±0.3 (36.6)	35.8±2.2 (36.7)	33.0±0.4 (35.0)	40.8±0.4 (39.7)	36.7±0.6 (37.3)	36.8±2.2 (37.4)
	60	30.8±0.4 (33.8)	39.5±0.4 (38.9)	35.2±0.4 (36.4)	35.1±2.5 (36.3)	33.2±0.4 (35.2)	42.7±0.4 (40.8)	36.9±0.2 (37.4)	37.6±2.8 (37.8)	33.7±0.5 (35.5)	43.5±0.5 (41.2)	37.4±0.4 (37.6)	38.2±2.9 (38.1)
	75	30.4±0.3 (33.4)	39.3±0.5 (39.8)	34.9±0.4 (36.2)	34.9±2.6 (36.3)	33.0±0.4 (35.0)	42.7±0.5 (40.8)	36.5±0.4 (37.2)	37.4±2.8 (37.7)	33.5±0.6 (35.4)	43.3±0.3 (41.1)	37.1±0.5 (37.4)	37.9±2.9 (38.0)
Grand mean		30.6±0.1 (33.5)	39.3±0.2 (38.8)	35.0±0.1 (36.2)	34.9±2.5 (36.2)	32.8±0.4 (34.9)	41.7±0.5 (40.2)	36.3±0.1 (37.1)	36.9±2.6 (37.4)	33.4±0.3 (35.3)	42.5±0.9 (40.7)	37.1±0.2 (37.4)	37.7±2.7 (37.8)
Grand mean for time		32.3±0.9 (34.6)	41.2±1.0 (39.9)	36.1±0.6 (36.9)									

Data values: Mean±S.Em; *Figures in parentheses are the means of arc sine $\sqrt{\text{percentage}}$ transformations

LSD (p=0.05) for:

A	(0.1)	C	(0.1)	ABC	(NS)	BD	(0.1)	ACD	(NS)
B	(0.1)	AC	(0.2)	D	(0.1)	ABD	(NS)	BCD	(0.2)
AB	(NS)	BC	(0.1)	AD	(NS)	CD	(0.1)	ABCD	(NS)

A= Date of sowing; B= Nitrogen dose; C= Week, and D= Time of the day

Table 4: Effect of weather factors and nitrogen doses on diurnal floral nectar-sugar concentration after various weeks of blooming initiation in *Helianthus annuus* hybrid PSH 1962(Pooled data of 2014 & 2015)

Date of sowing	Nitrogen dose (kg ha^{-1})	Mean nectar-sugar concentration (TSS%)*													
		Week I				Week II				Week III				Overall mean	Grand for mean nitrogen
		0900-1000 h	1200-1300 h	1500-1600 h	Mean	0900-1000 h	1200-1300 h	1500-1600 h	Mean	0900-1000 h	1200-1300 h	1500-1600 h	Mean		
Jan. 31	45	29.7±0.4 -33	36.6±0.4 -37.2	33.4±0.4 -35.3	33.2±2.0 -35.1	30.7±0.1 -33.6	38.0±0.6 -38	34.7±0.1 -36.1	34.4±2.1 -35.8	31.4±0.2 -34.1	38.7±0.6 -38.5	36.6±0.6 -37.2	35.6±2.2 -36.6	34.4±1.1 -35.9	35.2±1.0 (36.4)[a]
	60	30.7±0.4 -33.6	37.2±0.2 -37.6	33.9±0.5 -35.6	33.9±1.9 -35.6	31.4±0.5 -34.1	38.7±0.3 -38.4	34.9±0.2 -36.2	35.0±2.1 -36.3	32.2±0.2 -34.6	39.4±0.5 -38.9	37.4±0.6 -37.7	36.3±2.1 -37	35.1±1.1 -36.4	35.9±1.1 (36.8)[b]
	75	30.1±0.1 -33.2	37.1±0.8 -37.5	33.5±0.3 -35.3	33.6±2.0 -35.4	31.3±0.3 -34	38.1±0.5 -38.1	34.3±0.3 -35.9	34.6±2.0 -35.9	31.9±0.2 -34.3	38.8±0.3 -38.5	36.7±0.3 -37.3	35.8±2.1 -36.7	34.6±1.0 -36	35.5±1.2 (36.5)[a]
	Mean	30.2±0.3 -33.2	37.0±0.2 -37.4	33.6±0.1 -35.3	33.6±2.0 -35.3	31.1±0.2 -33.9	38.2±0.2 -38.1	34.6±0.2 -36	34.7±2.1 -36.1	31.8±0.2 -34.2	39.0±0.2 -38.7	36.9±0.2 -37.4	35.9±2.1 -36.8	34.7±0.2 (36.1)[a]	
Feb. 10	45	29.7±0.2 -33	36.7±0.2 -37.3	33.5±0.2 -35.4	33.3±2.0 -35.2	30.4±0.1 -33.5	38.2±0.3 -38.2	34.4±0.4 -35.9	34.3±2.2 -35.9	31.5±0.0 -34.2	38.9±0.4 -38.6	36.7±0.3 -37.3	35.7±2.2 -36.7	34.5±1.1 -36	
	60	31.0±0.1 -33.8	37.6±0.4 -37.8	34.4±0.2 -35.9	34.3±1.9 -35.9	31.2±0.1 -34	38.8±0.4 -38.5	35.2±0.3 -36.4	35.1±2.2 -36.3	32.3±0.0 -34.6	39.6±0.3 -39	37.5±0.3 -37.8	36.5±2.2 -37.1	35.3±1.0 -36.5	
	75	30.3±0.2 -33.4	36.9±0.3 -37.4	34.3±0.1 -35.8	33.9±1.9 -35.6	30.6±0.2 -33.6	38.3±0.4 -38.2	34.7±0.3 -36.1	34.5±2.2 -35.9	31.7±0.1 -34.3	39.0±0.3 -38.7	36.9±0.4 -37.4	35.9±2.2 -36.8	34.8±0.9 -36.1	
	Mean	30.3±0.4 -33.4	37.1±0.3 -37.6	34.1±0.3 -35.7	33.8±1.9 -35.4	30.8±0.2 -33.7	38.4±0.1 -38.2	34.8±0.5 -36.2	34.7±2.2 -36.1	31.9±0.4 -34.3	39.2±0.6 -38.8	37.0±0.3 -37.4	36.0±2.2 -36.9	34.8±1.1 (36.1)[a]	
Feb. 20	45	30.6±0.3 -33.5	37.5±0.1 -37.8	34.5±0.1 -36	34.2±2.0 -35.8	31.9±0.1 -34.4	39.7±0.1 -39	35.8±0.5 -36.7	35.8±2.2 -36.7	32.8±0.2 -34.9	40.1±0.7 -39.3	37.9±0.6 -38	37.0±2.2 -37.5	35.7±1.1 -36.7	
	60	32.0±0.1 -34.4	38.6±0.1 -38.4	35.3±0.1 -36.5	35.3±1.9 -36.5	32.7±0.6 -34.9	40.2±0.3 -39.4	36.7±0.5 -37.3	36.6±2.2 -37.3	33.6±0.1 -35.4	40.8±0.4 -39.7	38.7±0.6 -38.5	37.7±2.2 -37.9	36.5±1.2 -37.2	
	75	31.3±0.1 -34	37.9±0.3 -38	35.3±0.5 -36.4	34.8±1.9 -36.1	32.0±0.5 -34.4	39.7±0.7 -39.1	36.2±0.4 -37	36.0±2.2 -36.8	32.8±0.4 -34.9	40.3±0.6 -39.4	38.2±0.6 -38.2	37.1±2.2 -37.6	36.0±1.0 -36.8	
	Mean	31.3±0.4 -34	38.0±0.3 -38	35.0±0.3 -36.2	34.8±2.0 -36.2	32.2±0.2 -34.6	39.9±0.2 -39.2	36.3±0.3 -37.1	36.1±2.2 -37	33.1±0.4 -35.1	40.4±0.2 -39.4	38.3±0.3 -38.3	37.2±2.2 -37.6	36.0±1.2 (36.9)[b]	
Mar. 2	45	31.4±0.3 -34.1	38.2±0.4 -38.1	36.0±0.1 -36.8	35.2±2.0 -36.3	32.7±0.1 -34.9	39.8±0.4 -39.1	36.3±0.5 -37	36.3±2.0 -37	33.4±0.2 -35.3	40.9±0.6 -39.8	38.6±0.5 -38.4	37.7±2.2 -37.9	36.4±1.0 -37.1	
	60	32.7±0.2 -34.9	39.1±0.4 -38.7	36.3±0.2 -37	36.0±1.8 -36.8	33.9±0.2 -35.6	40.4±0.2 -39.4	37.3±0.3 -37.6	37.2±1.9 -37.6	33.3±0.1 -35.4	40.7±0.4 -39.8	38.5±0.6 -38.5	37.5±2.2 -37.8	36.9±0.8 -37.4	
	75	32.3±0.2 -34.6	38.9±0.3 -38.6	36.1±0.0 -36.9	35.7±1.9 -36.7	32.4±0.2 -34.7	40.3±0.8 -39.4	36.5±0.3 -37.2	36.4±2.3 -37	33.2±0.3 -35.2	41.1±0.8 -39.8	39.1±1.0 -38.7	37.8±2.4 -37.9	36.6±1.1 -37.2	
	Mean	32.1±0.4 -34.5	38.7±0.3 -38.5	36.1±0.1 -36.9	35.6±1.9 -36.5	33.0±0.5 -35.1	40.1±0.2 -39.3	36.7±0.3 -37.3	36.6±2.1 -37.2	33.3±0.1 -35.4	40.9±0.3 -39.8	38.8±0.4 -38.6	37.6±2.3 -37.8	36.6±1.0 (37.2)[c]	

Table 4: Effect of weather factors and nitrogen doses on diurnal floral nectar-sugar concentration after various weeks of blooming initiation in *Helianthus annuus* hybrid PSH 1962(Pooled data of 2014 & 2015)

Mean	45	30.3±0.4	37.2±0.4	34.3±0.6	34.0±2.0	31.4±0.5	38.9±0.5	35.3±0.5	35.2±2.2	32.3±0.5	39.7±0.5	37.5±0.5	36.5±2.2
		-33.3	-37.5	-35.8	-35.6	-34.1	-38.7	-36.4	-36.3	-34.7	-39	-37.7	-37.1
	60	31.6±0.5	38.1±0.4	35.0±0.5	34.9±1.9	32.3±0.6	39.5±0.5	36.0±0.6	36.0±2.1	32.8±0.3	40.1±0.4	38.0±0.3	37.0±2.2
		-34.2	-38.1	-36.2	-36.2	-34.7	-38.9	-36.8	-36.8	-34.9	-39.3	-38	-37.5
	75	31.0±0.5	37.7±0.4	34.8±0.6	34.5±1.9	31.6±0.4	39.1±0.5	35.5±0.5	35.4±2.2	32.4±0.4	39.8±0.5	37.7±0.6	36.6±2.2
		-33.8	-37.9	-36.1	-35.9	-34.2	-38.7	-36.5	-36.5	-34.7	-39.1	-37.9	-37.1
Grand mean		31.0±0.4	37.7±0.3	34.7±0.2	34.5±1.9	31.8±0.3	39.2±0.2	35.6±0.2	35.5±2.1	32.5±0.5	39.9±0.4	37.7±0.3	36.7±2.2
		-33.8	-37.9	-36.1	-35.9	-34.3	-38.7	-36.5	-36.5	-34.8	-39.2	-37.9	-37.3
Grand mean for time		31.8±0.4	38.9±0.6	36.0±0.9									
		-34.3	-38.6	-36.9									

Data values: Mean±S.E.mean; *Figures in parentheses are the means of arc sine transformations

LSD (p=0.05) for:

A	-0.2	C	-0.1	ABC	(NS)	BD	(NS)	ACD	(NS)
B	-0.1	AC	(NS)	D	-0.1	ABD	(NS)	BCD	(NS)
AB	(NS)	BC	(NS)	AD	(NS)	CD	-0.2	ABCD	(NS)

A= Date of sowing; B= Nitrogen dose; C= Week, and D= Time of the day

also reported that the application of Nitrogen 'fytovit' (9.4 % N, 3.9 % Mg, 3.1 % S, 1.0 % Na, 0.5 % B, 0.75 % Cu, 0.3 % Mo) to *Trifolium pretense* produced 8.4 per cent more nectar and a slight increase in sugar contents than in unfertilized plots. Singh (1991) reported an increase in nectar-sugar concentration (41.6 %) over control (32.0 %) at 60 kg ha^{-1} nitrogen dose and then a decrease (39.1 %) at 80 kg ha^{-1} of nitrogen.

Effect of weather factors and nitrogen doses on honey production potential

Honey production potential of PSH 996 was 18.5 kg ha^{-1} in timely sown crop and it decreased to 17.0 kg ha^{-1} with delay in sowing date by one month (Fig. 6). Similarly in PSH 1962, honey production potential decreased from 20.9 to 19.1 kg ha^{-1}. This was due to lesssecretion of nectar coupled with high TSS in late sown crop under the influence of high temperature and low relative humidity. Honey production potential was the lowest at nitrogen dose of 45 kg ha^{-1}(25% less than recommended N dose) in both the genotypes, PSH 996 (16.9 kgha^{-1}) and PSH 1962 (19.1 kg ha^{-1}). The honey production potential at 60 and 75 kg ha^{-1} nitrogen dose was 18.4 and 18.6 kg ha^{-1} in PSH 996 and 20.7 and 20.9 kg ha^{-1} in PSH 1962, respectively. Increase in honey potential of from 19.03 to 30.8 kg $ha^{-1}$was reported by Singh (1991) with increase in nitrogen doses**.**

CONCLUSIONS

Floral nectar secretion decreased and sugar-concentration increased significantly with delay in sowing of sunflower because such crops were exposed to higher mean maximum temperature and lower relative humidity. Nectar secretion and its TSS increased significantly at 60 kg ha^{-1} nitrogen dose as compared to 45 kg ha^{-1}. Delay in sowing date by a month resulted in reduction in honey production potential by 1.5 and 1.8 kg ha^{-1} in PSH 996 and PSH 1962, respectively.The effect of weather parameters was more pronounced on nectar sugar concentration in the crop which received lesser nitrogen application (45 kg ha^{-1}).The decrease may result in lower number of foragers visiting the crop due to whichthe crop may lose the potential benefit of pollination. Besides this, there will be less honey production. Thus, the situation may affect all the three components i.e. the bees, the plants and the beekeepers. Hence, farmers must not delay the sowing of sunflower or apply lower dose of nitrogen fertilizer.

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REFERENCES

Anonymous. (2019). "Package of Practices for Crops of Punjab: *Rabi*".Punjab Agricultural University, Ludhiana, India.

Atlagic, J., Joksimovic, J., Sakac, Z., Miklic, V. and Dusanic, N. (2003).Mode of inheritance and heritability of disc flower corolla length and nectar content in sunflower.*Genetika*,35: 59-65.

Dhillon, B.S., Sharma, P.K. and Kingra, P.K. (2017). Agronomicmeasures to improve thermal energy utilization by spring sunflower.*J. Agrometeorol*., 19 (1): 34-38.

FAO(2017). Production data of crops.Internetdownload http:/ /www.fao.org/faostat/en/#data/QC

Fota, G., Grosu, E. and Stoenescu, F. (1977). Influence of different factors on the rhythum of vegetation and nectar secretion in sunflower (*Helianthus annuus*L.). *Proc. 26th Int. Apic.Congr.*,pp. 397-399. Apimondia Publishing House, Adelaide, Bucharest, Romania.

Goluboviæ, M., Balana, I. and Stanojeviæ, D. (1992).Melliferous value ofsunûower cultivars and hybrids.*Savetovanje o unapreð enjuuljarstva Jugoslavije*, 34–40 (in Serbian).

Gowda, J., Bhat, N.S. and Kusuma, B.K. (2003). Honey bee activity and forage yield of selected parental lines of sunflower hybrids. *Indian Bee J.*,65: 36-43.

Jociæ S. (2000). The degree of fertilization in sunflower hybrids in1999.*Zbornik Radova Institutazara tarstvoipovr tarstvo* 33: 81–90.

Kaziev, I.T. (1967). Some agrotechnical measures expending increased nectar productivity of cotton. *XXI Int. Beekeep.Congr.Summ.*,160: 164-169.

Neff, J.L. and Simpson, B.B. (1990). The roles of phenology and reward structure in the pollination biology of wild sunflower (*H. annuus*). *Isr. J. Bot.*,36: 197-216.

Oertel, E. (1946). Effect of temperature and relative humidity on sugar concentration of nectar.*J. Econ.Ent.*,39**:** 513-515.

Park, O.W. (1929). The influence of humidity upon sugar concentration in the nectar of various plants.*J. Econ.Ent.*,22**:** 534-544.

Popovic, I. (1987). Stimulation of nectar production of red clover by means of microelements.*Vcelarskeho V. Dole.*,9: 167-177.

Roy, A. and Bhat, N.S. (2005).Effect of planting geometry on disruption of floral fidelity of honey bees in CMS and maintainer lines of sunflower hybrid.*Indian Bee J.*,67: 103-112.

Satyanarayana, A.R. and Seetharam, A. (1982). Role and activity of insect visitors in pollination and seed set. *Seed Sci. Tech.*,10: 13-17.

Shashibala and Singh, A.K. (2013). Relative abundance of *Apismellifera* and *Apisflorea* and sugar concentration in *Rabi* season sunflower bloom. *Envion. Ecol.*,31: 1116-1120.

Shuel, R.W. (1964). Effect of external factors on nectar production.*Ann.Abeil.*,7**:** 5-12.

Singh, B. (1991)."Phenological studies for the estimation of apicultural value of major nectar secreting plants". M.Sc. thesis, Punjab Agricultural University, Ludhiana, India.

Singh, P.B. and Sinha, S.N. (1997).Evaluation of different methods of pollination on seed setting and yield of hybrid sunflower seed.*Indian Bee J.*,59: 161-163.

Suryanarayana, M.C. (1985). Nectar secretion in sunflower. In:*29th Int.Apic.Congr.Apimondia,* Budapest.

Swaminathan, R. and Bharadwaj, S.C. (1998).Role of insect pollinators in seed setting of sunflower (*Helianthus annuus* L.) at Udaipur, Rajasthan, India.*Indian Bee J.*,60: 155-56.

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