Applied Biological Research 19 (2): 156-163; (2017)
DOI: 10.5958/0974-4517.2017.00022.2

OIL YIELD AND FATTY ACID PROFILE OF STAGGERED SOWN *SPRING* SUNFLOWER (*Helianthus annuus* L.) IN RESPONSE TO FOLIAR APPLICATION OF BORON AND TIBA

Buta Singh Dhillon[1], P.K. Sharma[2] and Sanjula Sharma[3]

[1,2]*Department of Agronomy*, [3]*Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana – 141 004, Punjab (India)*
*e-mail: *bsdhillon@pau.edu*

(Received 9 January, 2017; accepted 29 June, 2017)

ABSTRACT

Investigations were conducted at PAU, Ludhiana (India) during 2014 and 2015 to assess the effect of foliar application of boron @ 110, 220 and 440 ppm and 2,3,6-tri-iodo-benzoic acid (TIBA) @ 100, 200 and 400 ppm on oil yield and fatty acid profile of staggered sown (January 20, February 10 and March 2) *spring* sunflower. Studies revealed that delayed sowing reduced oil content and yield with concomitant increase in protein content. Increase in oleic acid with concomitant decrease in palmitic and linoleic acids was also noted as the sowing was delayed. Foliar application of boron and TIBA did not influence the oil content and its fatty acid composition but caused significant improvement in protein content and oil yield. Correlation studies revealed that oil content, oil yield and linoleic acid were highly significant ($p<0.01$) but negatively correlated with canopy temperature. Oleic acid was positively correlated with canopy temperature. It may be concluded that early sowing by 20th January and application of boron 110 ppm or TIBA 100 ppm gavis higher oil yield while maintaining good oil quality.

Key words: Linoleic acid, oil content, oleic acid, protein content, sowing date

INTRODUCTION

Oilseeds occupy an important position in Indian agriculture as food and as an industrial commodity. Among the oilseed crops grown in India, sunflower (*Helianthus annuus* L.), is an all-season crop. The development of short duration, photo-insensitive high yielding varieties and hybrids having wider adaptability have revolutionized the cultivation of sunflower in different agro-climatic regions of country. The sunflower oil is generally considered as a premium oil because of its light colour, high smoke point and ideal combination of saturated and poly-unsaturated fatty acids (PUFA), and its oil cake contains higher amount of protein (40-44%) and balanced amino acids (Kalaiyarasan and Vaiyapuri, 2007). The sunflower oil is also rich in fat soluble vitamins A, D, E and K which are essential for health and its oil have high radical trapping antioxidant activity due to the presence of tocopherols (Reddy and Reddy, 2010).

Yield and quality of any crop is a result of complex set of interactions occurring during growth and development of crop plants as a result of genetic and environmental conditions. Temperature is major environmental factor that determine the rate of plant development and oil yield as well as fatty acid accumulation in sunflower (Ritche and Ne Smith, 1991; Connor and Sadras, 1992). The period of seed development for *spring* sunflower under sub-tropical conditions of Punjab coincides with high daily temperatures. High temperature inhibits ADP-glucose pyro-phosphorylase (AGPase) and starch synthase, the two key enzymes involved in starch synthesis, thereby affecting oil content (Pavithra *et al.*, 2014). Therefore, sowing date is an important determinant of yield and quality in sunflower. Demurin *et al.* (2000) reported that oil concentration in seed depends upon the daily mean temperature in addition to the availability of water during seed filling period. They further indicated a strong negative correlation between oleic and linoleic acid. Similarly, Qadir *et al.* (2007) reported that each 1°C increase in temperature leads to about 2% increase in oleic acid. Hence, the desirable oil content and its quality can be achieved by selecting the most appropriate planting time.

Boron plays a major role in membrane integrity, cell wall development and it is known to alter the oil yield and quality of sunflower oil (Shekhawat and Shivay, 2008). The enhanced oil and protein content in sunflower oil due to application of boron previously been reported (Karthikeyan and Shukla, 2008; Jabeen and Ahmad, 2011). Shekhawat and Shivay (2008) reported that the application of boron improved oil quality resulting in significant and consistent decrease in saturated fatty acids (palmitic and stearic acids). Similarly, increase in oil and protein content of cotton due to application of various growth regulators has been reported by Buttar and Aggarwal (2004). The present study was aimed to assess the oil yield and composition of sunflower oil under different sowing dates vis-à-vis foliar application of boron and 2,3,5-tri-iodo benzoic acid (TIBA).

MATERIALS AND METHODS

A field experiment was conducted for two consecutive seasons (*Spring* 2014 and 2015) at Research Farm, PAU, Ludhiana (India) [30°56' N latitude; 75°52' E longitude; 247 m altitude] located in the Indo-Gangetic plains region (IGPR). The climate of experimental site is characterized as subtropical semi-arid with an annual rainfall of 733 mm, out of which about 80% is received from June to September. Winter season extends from December to January and summer season from April to June. The temperature starts decreasing sharply after November and continues to decrease till January. The lowest temperature during this period may be 1 or 2°C accompanied by frost or foggy conditions. Temperature starts rising by the end of February and continues till June that may go as high as 45°C. During the period under study, rainfall, maximum and minimum temperatures were measured at Agro–meteorological Observatory, PAU, Ludhiana. The maximum air temperature varied from 17.5 to 40.6 and 15.6 to 39.6°C, minimum from 7.0 to 27.1 and 7.5 to 23.8°C with mean temperature varying from 12.2 to 33.8 and 11.3 to 31.7°C during *spring* 2014 and 2015, respectively. Total rainfall of 214.6 and 191.2 mm was received during the respective crop seasons of 2014 and 2015. Overall, both the seasons were normal crop growing season with no major variation in weather parameters between both the years except that rainfall pattern was more uniform during 2014. The soil of experimental site was sandy loam in texture, low in available N (248 and 175 kg ha^{-1}) and soil organic carbon (0.39 and 0.36%). However, high in available-P (75.2 and 64.8 kg ha^{-1}), medium in available-K (179.0 and 184.8 kg ha^{-1}) and sufficient in B-status (0.9 and 0.7 ppm) during 2014 and 2015. The soil pH (7.4 and 7.2) and electrical conductivity (0.24 and 0.25 dSm^{-1}) were within the normal range.

The field experiment was laid out in split-plot design with three replicates. The main factor consisted of three sowing dates i.e. January 20, February 10 and March 2, and sub-factor consisted of eight foliar spray treatments *viz.*, control, water spray, boron @ 110, 220, 440 ppm and TIBA @ 100, 200, 400 ppm. Gross plot size was 25.2 m^2. Sunflower hybrid 'PSH-996' was sown as per treatment by dibbling 3 seeds $hill^{-1}$ at a plant spacing of 60 x 30 cm. One plant $hill^{-1}$ was maintained after crop establishment denoted by 2-4 leaf stage. Nitrogen @ 60 kg ha^{-1} was applied half as basal and half at thinning time (3 weeks after sowing); whereas whole phosphorus and potassium (each

@ 30 kg ha^{-1}) were applied as basal dose. Irrigations were applied as per crop requirement. Borax (B - 13.4%) was used as a source of boron. The stock solutions for sprays were prepared by dissolving required quantity of TIBA in few drops of ethyl alcohol whereas borax was dissolved in distilled water. The final spray solutions were prepared by diluting stock solutions with water. Foliar application of boron and TIBA was done at ray floret opening stage using knap sack sprayer discharging 400 L ha^{-1} water.

The oil content in the intact seeds (moisture content 6-7%) was determined by nuclear magnetic resonance instrument (MQC23, Oxford Instruments, UK), which is a rapid and non-destructive method for oil detection (Alexander *et al*., 1967). For estimating protein content, nitrogen content in seeds was determined by macro-Kjeldahl method (Jackson, 1967)**.** The protein was calculated by multiplying nitrogen with a factor 6.25 (Khalil and Mannan, 1990). Fatty acid composition of sunflower seeds was determined by gas chromatography of fatty acid methyl esters as per Appleqvist (1968) and analyzed on a gas chromatograph (Agilent Technologies; model 7820A) equipped with flame ionization detector with CP-Sil 88 (25 m x 0.25 mm x 0.20 mm) FAME column. Temperatures of oven, detector and injector were maintained at 210, 240 and 230°C, respectively. Two microliters of sample was injected at a split rate of 10:1. Individual fatty acids were expressed as percentages of the total fatty acids.

The data were subjected to analysis of variance using statistical analysis software (CPCS1) to evaluate differences between treatments. Treatment means were compared at $P \leq 0.05$ (Cochran and Cox, 1967).

RESULTS AND DISCUSSION

Canopy temperature

The canopy temperature continued to increase with the advancement of age under all the sowing dates (Table 1). The later sown crop (March 2) experienced significantly higher canopy temperature than the earliest sown (January 20) at all phenological stages. The differences in canopy temperature of January 20 and February 10 sown crops were less but February 10 and March 2 sown crops were more at star bud, ray floret, flower initiation and 50% flowering. However, at later stages the differences between January 20 and February 10 sown crops widened but between February 10 and March 2 narrowed down, except at physiological maturity during 2015. The differences in canopy temperatures between January 20 and March 2 sown crops at star bud stage were 4.5 and 5.0°C, at ray floret stage 7.0 and 6.6°C, at flower initiation 7.4 and 7.7°C, at 50% flowering 6.3 and 5.0°C, at 100% flowering 5.6 and 4.3°C, at seed filling 3.3 and 2.7°C and at physiological maturity 3.0 and 3.9°C, during 2014 and 2015, respectively. All foliar treatments of boron and TIBA significantly lowered canopy temperature at 50 and 100% flowering, seed filling and physiological maturity over control during both the years, except in 2015, when foliar application of 110 ppm boron was also at par with control and water application.

All the reproductive phases of crop sown on January 20 occurred earlier than February 10 and March 2 sown crops, which coincided with lower air temperature. So, relatively lower ambient air temperature (Fig. 1) and higher leaf area/leaf biomass of earlier sown crops resulted in cooler crop canopies as compared to later sown crop (January 20 sown crop recorded a leaf biomass of 1234 and 1214 kg ha^{-1} as compared to 950 and 946 kg ha^{-1} under March 2 sown crop during 2014 and 2015, respectively, at 90 days after sowing). Likewise, the cooler crop canopies under boron and TIBA treatments may be ascribed to the higher leaf area/leaf biomass leading to higher transpiration rate associated with evapo-transpiration, which is an important cooling mechanism of plants.

Oil content, oil yield and protein content

The oil content in sunflower was significantly reduced with delay in sowing during 2014 (Table 2). During the year 2015, though there was progressive reduction in oil content with delayed sowing,

Table 1: Effect of sowing dates and foliar sprays of boron and TIBA on canopy temperature (°C) of sunflower at various phenological stages

Treatments	Canopy temperature (°C)													
	Star bud stage		Ray floret opening		Commencement of flowering		50% flowering		100% flowering		Seed filling		Physiological maturity	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Sowing date														
Jan., 20	25.2	25.5	26.4	27.0	26.8	27.1	27.7	29.2	28.4	30.6	32.3	33.1	34.9	35.1
Feb., 10	26.7	27.2	29.5	30.2	28.1	28.6	30.6	31.0	33.1	33.6	34.4	35.0	36.0	35.9
March, 2	30.2	30.5	33.4	33.6	34.2	34.8	34.0	34.2	34.1	34.9	35.6	35.9	37.9	39.0
$CD_{0.05}$	0.6	0.7	0.3	0.8	0.6	0.3	1.2	0.9	1.0	0.8	0.8	0.9	0.6	0.6
Foliar spray (ppm)														
Control	27.3	27.7	29.8	30.3	29.8	30.2	31.3	32.3	32.6	34.3	34.8	35.6	37.7	38.0
Water spray	27.5	27.7	29.7	30.3	29.7	30.3	31.2	32.4	32.6	34.3	34.8	35.6	37.6	37.9
Boron 110	27.3	27.8	29.8	30.3	29.8	30.2	30.8	31.5	31.9	33.3	34.3	34.8	36.2	37.1
Boron 220	27.4	27.6	29.9	30.3	29.6	30.2	30.8	31.3	31.7	32.7	34.0	34.4	36.1	36.1
Boron 440	27.2	27.7	29.8	30.3	29.7	30.3	30.7	30.9	31.8	32.6	33.7	34.5	35.9	36.2
TIBA 100	27.4	27.6	29.6	30.2	29.7	30.1	30.5	31.3	31.7	32.6	33.9	34.2	35.8	36.0
TIBA 200	27.4	27.8	29.8	30.2	29.7	30.1	30.3	31.0	31.5	32.4	33.7	34.1	35.4	36.0
TIBA 400	27.5	27.8	29.7	30.2	29.5	30.0	30.4	31.0	31.3	32.1	33.7	33.9	35.4	36.0
$CD_{0.05}$	ns	ns	ns	ns	Ns	ns	0.7	0.8	0.8	0.8	0.9	0.9	1.1	1.0

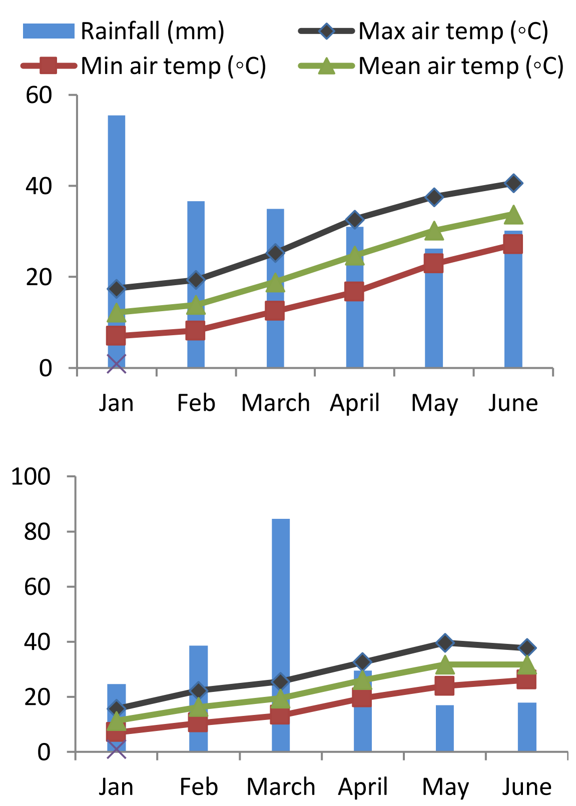

Fig. 1: Mean monthly meteorological data during the crop seasons 2014 (upper) and 2015 (lower)

The differences between consecutive sowing dates were insignificant. Oil yield varied significantly due to differences in sowing dates as indicated by progressive and significant reduction in oil yield with delay in sowing dates from January 20 to March 2 through February 10 (Table 2). Crop sown on January 20 gave 14.3 and 19.2% higher oil yield than February 10 sown crop during 2014 and 2015, respectively. Similarly, such an increase in oil yield of January 20 sown crop over March 2 sown crop was 50.9 and 49.1% during 2014 and 2015, respectively. However, protein content showed increase with successive delay in sowing from January 20 to March 2, though the differences between January 20 and February 10 sowing dates were insignificant in 2014 but significant in 2015 (Table 2). Increase in protein content and decrease in oil content under later sowing conditions may be attributed to high temperature conditions at the time of seed filling (Fig. 1; Table 1) and shorter seed filling period due to late sowing. Pavithra *et al.* (2014) reported a remarkable fall in total sugar content and an upsurge in the starch accumulation during seed maturity. Increase in starch accumulation indicates the role of starch as a carbon source for fatty acid synthesis. In present study, temperature during seed filling stage of the crop sown on March 2 was higher than the corresponding stage

Table 2: Effect of sowing dates and foliar sprays of boron and TIBA on oil content, oil yield and protein content of sunflower

Treatment	Oil content (%)		Oil yield (kg ha^{-1})		Protein content (%)	
	2014	2015	2014	2015	2014	2015
Sowing date						
Jan., 20	46.3	45.6	1004	844	14.5	14.2
Feb.,10	44.2	42.7	878	708	15.2	14.8
March, 2	42.3	40.4	665	566	16.3	16.8
$CD_{0.05}$	1.8	3.0	83	63	0.7	0.4
Foliar spray (ppm)						
Control	44.0	42.7	750	629	14.7	14.5
Water spray	44.0	42.8	764	637	14.8	14.5
Boron 110	44.2	42.6	845	685	15.4	15.4
Boron 220	44.2	42.9	875	724	15.4	15.4
Boron 440	44.5	43.4	887	732	15.4	15.5
TIBA 100	44.4	43.0	901	747	15.4	15.5
TIBA 200	44.6	43.0	924	763	15.6	15.7
TIBA 400	44.2	42.8	845	732	15.9	15.9
$CD_{0.05}$	ns	ns	82	93	0.5	0.9

Table 3: Effect of sowing dates on fatty acid profile of sunflower oil

Sowing date	Palmitic (16:0) + stearic (18:0)		Oleic (18:1) + linoleic (18:2)		Oleic/ linoleic		L/ P+S ratio		O + L/ P + S ratio	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Jan., 20	9.69	10.51	90.31	89.49	0.87	0.86	4.97	4.59	9.32	8.51
Feb.,10	9.72	10.25	90.28	89.75	1.10	1.10	4.43	4.17	9.29	8.76
March, 2	9.47	9.88	90.53	90.12	1.31	1.35	4.13	3.89	9.56	9.12

of January 20 and February 10 sowing dates (Fig. 1), which might have inhibited ADP-glucose pyrophos-phorylase (AGPase) and starch synthase, the two key enzymes involved in starch synthesis which might have caused reduction in oil content under delayed sowings. Arthanari *et al.* (2009) also observed increase in seed protein content and decrease in oil content of sunflower when seed filling occurred under high temperature conditions.

Foliar application of boron and TIBA did not cause any variation in oil content of sunflower but significantly affected oil yield (Table 2). Least oil yield (750 and 629 kg ha^{-1}) was recorded in control which was at par with water spray (764 and 637 kg ha^{-1}) during both the years. The highest oil yield (924 and 763 kg ha^{-1}) was recorded in plots sprayed with TIBA 200 ppm, which was at par with all other foliar treatments, except water spray during both the years. Data revealed significant variation in protein content due to various foliar sprays with least protein content (14.7 and 14.5%) observed in control which was at par with water spray (14.8 and 14.5%) during both the years. The highest protein content (15.9%) was noticed in TIBA 400 ppm treated plots but was at par with all other foliar sprays of TIBA and boron but significantly higher than water spray and control.

Fatty acid profile

The study reveals that linoleic acid decreased but oleic acid increased with progressive delay in sowing from January 20 to March 3 through February 10 during both the years (Fig. 3). However, palmitic and stearic acid content was not influenced by sowing dates (Table 3). The ratio of unsaturated to saturated fatty acids increased under delayed sowing. The data further revealed that O/L ratio increased but L/P + S ratio decreased with progressive delay in sowing. However, staggered sowing of sunflower did not influence the total saturated and total unsaturated fatty acid content (Table 3). Foliar spray of boron and TIBA failed to influence total saturated and total unsaturated fatty acid content during both the years.

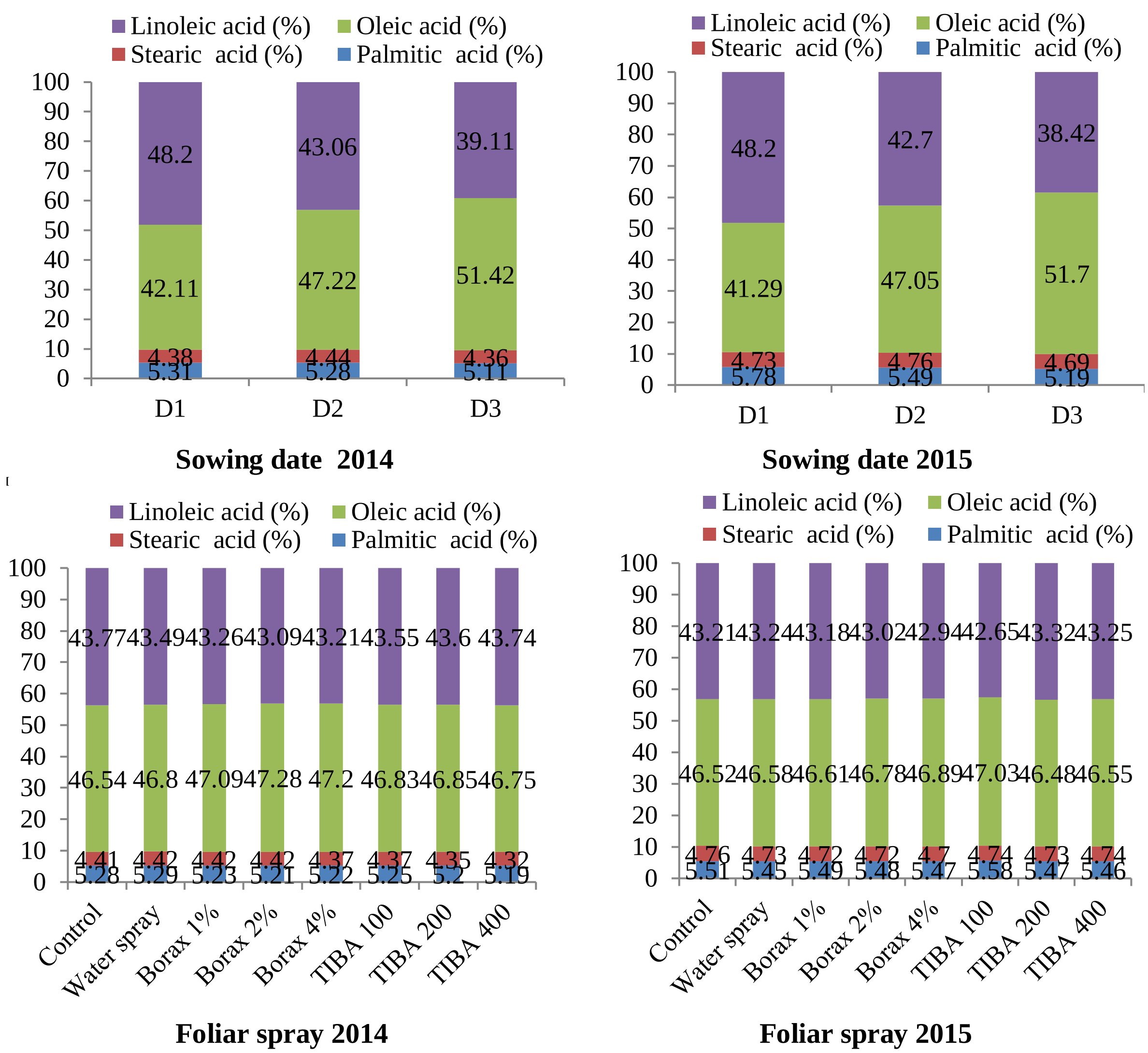

Fig. 3: Effect of sowing dates and foliar sprays on fatty acid profile of sunflower oil

Increased oleic and decreased linoleic acid under later sowing conditions may be attributed to high temperature conditions at seed filling time. Demurin *et al.* (2000) observed that oleic acid content was essentially influenced by temperature during seed development. Robertson and Green (1981) underlined the importance of sunflower oil low in linoleic acid and high in oleic acid for deep frying and for making margarines; hence sowing date is an important cultural tool for production of desired quality of fatty acids.

Correlation and regression studies

Simple Pearson's correlation between canopy temperature at flowering and seed filling stage (Table 4) with various quality attributes of sunflower revealed highly significant ($p < 0.01$) negative correlation of canopy temperature (at both stages) with oil content, oil yield and linoleic acid but highly significant ($p < 0.01$) positive correlation with oleic acid. Similarly, oil content, oil yield, palmitic and linoleic acid was highly significantly ($p < 0.01$) negatively correlated with protein content. Oil content showed highly significant positive correlation with oil yield. Data revealed that oil content decreased by 0.93 and 0.84 units during 2014 and 2015, respectively, with each unit increase in canopy temperature at flowering stages and 0.94 and 0.78 units with each unit increase in canopy temperature at seed filling stages. Similarly, 0.86 to 0.91% variation in oleic and linoleic

Table 4: Correlation matrix showing correlation between canopy temperature and oil quality components of sunflower

Parameters	Year	Canopy temperature (˚C) at Flowering	Canopy temperature (˚C) at Seed filing	Oil Content	Oil yield	Protein content	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid
Canopy temperature (˚C) at flowering	2014	1.00	0.95**	-0.93**	-0.83**	0.48	-0.46	0.23	0.90**	-0.91**
	2015	1.00	0.99**	-0.84**	-0.97**	0.24	-0.77**	-0.07	0.79**	-0.79**
Canopy temperature (^{0}C) at seed filling	2014	0.95**	1.00	-0.94**	-0.93**	0.39	-0.42	0.26	0.86**	-0.87**
	2015	0.99**	1.00	-0.78**	-0.96**	0.17	-0.74**	-0.01	0.74**	-0.74**
Oil content	2014	-0.93**	-0.94**	1.00	0.90**	-0.67*	0.69*	0.06	-0.97**	0.97**
	2015	-0.84**	-0.78**	1.00	0.87**	-0.71*	0.95**	0.30	-0.97**	0.97**
Oil yield	2014	-0.83**	-0.93**	0.90**	1.00	-0.36	0.45	-0.09	-0.77**	0.78**
	2015	-0.97**	-0.96**	0.87**	1.00	-0.35	0.82**	0.20	-0.81**	0.80**
Protein content	2014	0.48	0.39	-0.67*	-0.36	1.00	-0.95**	-0.54	0.78**	-0.71**
	2015	0.24	0.17	-0.71*	-0.35	1.00	-0.75**	-0.61*	0.77**	-0.76**
Palmitic acid	2014	0.46	-0.42	0.69*	0.45	-0.94**	1.00	0.54	-0.78**	0.76**
	2015	0.77**	-0.74**	0.95**	0.82**	-0.75**	1.00	0.47	-0.95**	0.94**
Stearic acid	2014	0.23	0.26	0.01	-0.09	-0.54	0.54	1.00	-0.07	0.04
	2015	0.07	-0.10	0.30	0.20	-0.61*	0.47	1.00	-0.39	0.38
Oleic acid	2014	0.90**	0.86**	-0.97**	-0.77**	0.78**	-0.78**	-0.07	1.00	-1.00**
	2015	0.79**	0.74**	-0.97**	-0.81**	0.77**	-0.95**	-0.39	1.00	-1.00**
Linoleic acid	2014	-0.91**	-0.87**	0.97**	0.78**	-0.76**	0.76**	0.04	-1.00**	1.00
	2015	-0.79**	-0.74**	0.97**	0.80**	-0.76**	0.94**	0.38	-1.00**	1.00

*significant at 5%; **significant at 1% level

Table 5: Regression coefficient (R) and coefficient of determination (r^2) between canopy temperature and oil quality components of sunflower

Parameters	Canopy temperature (°C) at flowering				Canopy temperature (˚C) at seed filing			
	2014		2015		2014		2015	
	R	r^2	R	r^2	R	r^2	R	r^2
Oil content	0.93	0.86	0.84	0.70	0.94	0.88	0.78	0.62
Oil yield	0.83	0.68	0.97	0.93	0.93	0.87	0.96	0.93
Protein content	0.48	0.23	0.24	0.06	0.39	0.15	0.17	0.03
Palmitic acid	0.46	0.21	0.77	0.59	0.42	0.18	0.74	0.54
Stearic acid	0.23	0.05	0.07	0.06	0.26	0.07	0.10	0.09
Oleic acid	0.91	0.81	0.79	0.62	0.86	0.73	0.74	0.54
Linoleic acid	0.91	0.83	0.78	0.61	0.87	0.75	0.74	0.54

acid is attributable to each unit variation in canopy temperature at flowering and seed filling stages.

On the basis of present study, it may be concluded that early sowing of *spring* sunflower by 20th January and foliar application of boron 110 ppm or TIBA 100 ppm at ray floret opening stage gives higher oil yield while maintaining good quality of sunflower oil in Indo-Gangetic plains.

REFERENCES

Appleqvist, L. 1969. Lipid in cruciferae: IV fatty acid composition of single seeds and seed populations of various cruciferae and in different tissue of *Brassica napus* L. *Heriditas,* **61**: 9-44.

Arthanari, P., Balasubramanian, T.N. and Mohamed, A.M. 2009. Impact of climate and nutrient management on yield components and yield of sunflower (*Helianthus annuus* L.). *American-Eurasian Journal of Sustainable Agriculture*, **3**: 13-16.

Buttar, G.S. and Aggarwal, N. 2004. Growth retardants in cotton – A review. *Journal of Cotton Research and Development*, **18**: 61-69.

Cochran, W.G. and Cox, G.M. 1967. *Experimental Designs*. Asia Publishing House, New Delhi, India.

Connor, D.J. and Sadras, V.A. 1992. Physiology of yield expression in sunflower. *Field Crops Research*, **30**: 373-389.

Demurin, Y., Skoric, D., Veresbaranji, I. and Jocic, S. 2000. Inheritance of increased oleic acid content in sunflower seed oil. *Helia*, **23**: 87-92.

Jabeen, N. and Ahmad, R. 2011. Effect of foliar applied boron and manganese on growth and biochemical activities in sunflower under saline conditions. *Pakistan Journal of Botany*, **43**: 1271-1282.

Jackson, M.L. 1967. *Soil Chemical Analysis.* Constable and Co. Ltd., London, UK.

Kalaiyarasan, C. and Vaiyapuri, V. 2007. Effect of integrated nutrient management practices on growth and yield attributes and quality characters of sunflower (*Helianthus annuus* L.). *International Journal of Tropical Agriculture*, **25**: 15-18.

Karthikeyan, K. and Shukla, L.M. 2008. Effect of boron–sulphur interaction on their uptake and quality parameters of mustard (*Brassica juncea* L.) and sunflower (*Helianthus annuus* L.). *Journal of Indian Society of Soil Science*, **56**: 225-230.

Khalil, I.A. and Mannan, F. 1990. Colorimetry and flame photometry. pp. 131-157. **In**: *Chemistry One - Bioanalytical Chemistry* (2nd edn.). Taj Printing Press, Peshawar, Pakistan.

Pavithra, H.R., Gowda, B. and Shivanna, M.B. 2014. Biochemical changes in the composition of developing seeds of *Pongamia pinnata* (L.) Pierre. *Industrial Crops and Products*, **53**: 199-208.

Qadir, G., Cheema, M, A., Hassan, F.U., Ashraf, M. and Wahid, M.A. 2007. Relationship of heat units accumulation and fatty acid composition in sunflower. *Pakistan Journal of Agricultural Sciences*,**44**: 24-29.

Reddy, T.Y. and Reddy, G.H.S. 2010. *Principles of Agronomy* (4th edn.). Kalyani Publishers, New Delhi, India.

Ritche, J.T. and Ne Smith, D.S. 1991. Temperature and crop development. *Agronomy Journal*, **31**: 5-29.

Robertson, J.A. and Green, V.E. 1981. Effect of sowing date on sunflower seed oil content, fatty acid composition and yield in Florida. *Journal of American Oil Chemists Society*, **58**: 698-701.

Shekhawat, K. and Shivay, Y.S. 2008. Effect of nitrogen sources, sulphur and boron levels on productivity, nutrient uptake and quality of sunflower (*Helianthus annuus*). *Indian Journal of Agronomy*, **53**: 129-134.