Indian Journal of Agronomy **63** (3): 342–349 (September 2018)

Research Paper

Productivity of spring sunflower (*Helianthus annuus*) in response to sowing dates and foliar application of boron and TIBA

BUTA SINGH DHILLON[1], P.K. SHARMA[2] AND VIRENDER SARDANA[3]

Punjab Agricultural University, Ludhiana, Punjab 141 004

Received : April 2017; Revised accepted : February 2018

ABSTRACT

A field experiment was conducted during 2014 and 2015 at Ludhiana, to study growth attributes, physiological parameters, pre- and post-anthesis dry-matter accumulation (DMA), dry-matter translocation (DMT), contribution of pre-anthesis dry-matter assimilates to seed (CDMS), yield-contributing traits and seed yield of sunflower (*Helianthus annuus* L.). The experiment was laid out in a split-plot design by keeping 3 sowing dates (20 January, 10 February and 2 March) in main plots and 8 treatments of foliar applications (control, water spray, boron at 110, 220, 440 ppm, and TIBA at 100, 200, 400 ppm) in subplots in 3 replications. Early-sown crop gave better yield-contributing characters (head diameter, seed weight/head, thalamus weight, number of seeds/head, seed filling percentage, 1,000-seed weight) and higher seed yield (2.01 t/ha) owing to higher post-anthesis DMA (1,908 kg/ha) coupled with better photosynthetic parameters (chlorophyll fluorescence and chlorophyll-content index), growth attributes and root-mass density. Foliar application of boron at 220 and 440 ppm as well as TIBA at 100, 200 and 400 ppm also significantly improved yield-contributing characters and seed yield (by 10.7 to 21.5%) over the control and water spray probably owing to higher post-anthesis DMA (147 to 267 kg/ha higher than the control), DMT (29 to 80 kg/ha higher than the control), DMTE, CDMS and better photosynthetic parameters. Economic analysis indicated that foliar application of B at 110, 220 and 440 ppm and TIBA at 100 ppm can be used to obtain higher profitability from sunflower crop.

Key words : Chlorophyll-content index, Chlorophyll fluorescence, Dry-matter translocation efficiency, Pre–anthesis, Root mass, Sink, Yield attributes

The yield of a crop is the outcome of complex interactions between genetic, environmental and agronomic factors. Genetic potential of a crop notwithstanding, better plant growth and higher productivity require favourable environmental conditions and agronomic management (Sheoran *et al.,* 2014). In north-west India, cultivation of sunflower during spring season gives higher yield. The month of January is the recommended sowing time in the region. However in the intensive cropping systems being followed in the region where sunflower is sown mainly after potato, basmati, peas, sugarcane etc., its sowing gets delayed to end February or early March. Sowing time influences the crop by subjecting it to variable temperatures during growth period by altering various physiological processes. The ideal temperature for sunflower is 15–20^{O}C during the vegetative period and 20–25^{O}C during reproductive period (Prasad, 2003). Higher temperature at flowering stage adversely affects activity of pollinators, inhibits pollen germination and pollen tube growth resulting in lower seed yield (Kakani *et al.,* 2002; Dhillon and Sharma, 2017). The other production constraints are poor seed-filling and seed set, insufficient nutrient supply to the sink and inadequate translocation of photosynthates (Patil and Dhomne, 1997).

Besides environmental factors, several physiological and genetic factors are responsible for poor seed-setting and filling in sunflower (Ram and Davari, 2011). The photosynthetic rate in the leaves declines after the development of reproductive organs due to ageing of leaves and most of the middle leaves as well as a few top leaves start senescing (Srivastava and Sairam, 1983). Application of growth regulators may help in regulating the mobilization of metabolites from stalk during the leaf senescence and consequently in improving the productivity (Kamil and Jobori, 2012). TIBA (2, 3, 5-Tri-iodobenzoic acid), an inhibitor of polar auxin transport, is reported to increase the sink capacity of the head and the movement of metabolites

[1]**Corresponding author's Email:** bsdhillon@pau.edu

[1]Assistant Agronomist, [3]Senior Agronomist, Department of Plant Breeding and Genetics; [2]Senior Agronomist, Directorate of Extension Education

from vegetative organs to the head (Nanja Reddy *et al.,* 2003). Source-sink relationship and photoassimilate-distribution pattern reveals that the supply of assimilates to the capitulum largely depends on the position of sinks in developing inflorescences (head). A higher proportion of empty achenes (up to 60%), especially in the centre of capitulum results due to several factors including poor vascular bundles differentiation and boron (B) deciency (Al-Amery *et al.,* 2011). The main physiological roles of B in plants are translocation of sugars, synthesis of cellular walls, maintaining membrane integrity, IAA metabolism, accelerating flowering and fruit-bearing processes in head (Jabeen and Ahmad, 2011). This study aimed to exploit the role of foliar application of B and TIBA in improving seed yield of sunflower sown on different dates during spring season.

MATERIALS AND METHODS

A field experiment was conducted during the spring seasons of 2014 and 2015 at the Punjab Agricultural University, Ludhiana (30°56' N, 75°52' E, 247 m above mean sea-level) located in the Indo-Gangetic Plains Region (IGPR). 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. After winters, during December–January, temperature starts rising in February and continues till June which may go as high as 45^{O}C. Maximum air temperature varied from 17.5 to 40.6^{O}C and 15.6 to 39.6^{O}C, minimum from 7.0 to 27.1^{O}C and 7.5 to 23.8^{O}C with mean temperature variation from 12.2 to 33.8^{O}C and 11.3 to 31.7°C during spring 2014 and 2015 respectively (Table 1). Total rainfall of 214.6 and 191.2 mm was received during respective crop seasons of 2014 and 2015. Overall, both the seasons were normal crop growing seasons.

The soil was Typic Ustipsamment (Fatehpur sandy-loam), normal in *p*H and electrical conductivity, low in available N (248 and 175 kg/ha) and soil organic carbon (0.39 and 0.36 %). However, high in available P (75.2 and 64.8 kg/ha), medium in available K (179.0 and 184.8 kg/ha) and sufficient in B status (0.9 and 0.7 ppm) during 2014 and 2015 respectively.

The experiment was laid out in a split-plot design with 3 replicates. The main factor consisted of 3 sowing dates, i.e. 20 January, 10 February and 2 March, and subfactor consisted of 8 treatments of foliar spray: control, water spray, B at 110, 220, 440 ppm, and TIBA at 100, 200, 400 ppm. Gross plot size was 25.2 m^2. Sunflower hybrid 'PSH 996' was sown on experimental dates by dibbling 3 seeds/hill at a spacing of 60 cm × 30 cm. One plant/hill was maintained after crop establishment (at 3–4 leaf stage). Nitrogen (60 kg P_2O_5/ha) was applied half as basal and half immediately after thinning followed by irigation, whereas whole phosphorus and potassium (each at 30 kg/ha) were applied as sowing. Irrigations were applied as per crop requirement. Earthing up was done 6–7 weeks after sowing to prevent crop lodging and save irrigation water. Insecticide chlorpyriphos 20 EC @ 2.5 l/ha was sprayed at star-bud initiation and 50% flowering stages to control semi-looper and head-borer. Bird damage was prevented by erecting nylon net over the field at a height of 2.5 m. Borax (B 13.4%) was used as a source of B. The stock solution of TIBA for spray was prepared by dissolving required quantity of TIBA in few drops of ethyl alcohol. Borax was dissolved in distilled water. Foliar application of B and TIBA was made at ray-floret-opening stage using knap-sack sprayer discharging water @ 400 l/ha.

Plant height, number of green leaves/plant and stem girth were recorded from 10 randomly tagged plants in middle 3 rows of each experimental unit. Canopy analyser (Sun Scan Canopy Analyzer Model CI-110/CI- 120) was used to record leaf-area index (LAI). Five plants were uprooted at ray-floret-opening stage and physiological maturity for recording dry-matter partitioning. Plants were separated into leaf, stem and reproductive part (sink) at ray-floret-opening stage and into leaf, stem, thalamus and seed at physiological maturity. The samples were sundried followed by drying in an oven at temperature of 65 ± 2^{O}C till attainment of constant weight for recording dry-matter accumulation (DMA) by various plant parts. Following dry-matter indices were computed:

a) *Post anthesis dry-matter (DM) accumulation:* It was calculated as difference between the DM at physiological maturity and at ray-floret opening stage.
b) *Dry matter translocation (DMT):* It was calculated as per Cox *et al*. (1986):
   DMT = DMA at ray floret – (DMA_{leaf} + DMA_{stem} + $DMA_{Thalamus}$) at physiological maturity
c) *Dry-matter translocation efficiency (DMTE):* It was calculated as:
   DMTE (%) = DMT/dry matter at anthesis × 100
d) *Contribution of pre-anthesis dry-matter assimilates (CDMS):* The CDMS (%) was calculated as:
   CDMS (%) = Dry-matter translocation × 100/Seed yield

Chlorophyll fluorescence and chlorophyll-content index (CCI) were measured periodically (before spray, 3, 7, 15, 21 days after spray- DAS) from fully-expanded apical leaves, using a portable Chlorophyll Fluorometer (Model - OS-30p, Opti-Sciences, Inc.) and portable Chlorophyll Content Meter (Model – CCM-200, Opti-Sciences, Inc.) respectively. For calculating root-mass density at ray-floret-opening stage and physiological maturity, soil core samples were taken layer-wise (0–15, 15–30 and 30–45 cm) with the help of root-sampling pipe having internal diameter of 15 cm by keeping the plant stump in the centre of the core. The soil samples, thus, obtained were washed in thin nylon mesh of 1 mm sieve in running water. The washed roots were picked up and then dried at 65^{O}C in an oven till constant weight. The root density was expressed as weight of roots per unit volume of soil and was calculated:

$$\text{Rooting density (g/cm}^3\text{)} = \frac{\text{Total root weight in particular depth (g)}}{\text{Total soil volume from which roots were collected (cm}^3\text{)}}$$

Data were subjected to analysis of variance (ANOVA) using statistical analysis software (SAS 9.3. North Carolina) to evaluate differences between treatments. Treatment means were compared at P≤ 0.05.

RESULTS AND DISCUSSION

Growth attributes

Plant height increased with delay in sowing, but differences between the consecutive sowing dates were not significant (Table 2). The crop experienced higher temperature under late-sown conditions (Table 1). Sun *et al*. (2012) reported that, biosynthesis of auxin was promoted at higher temperatures, which might have contributed to increased plant height under late sowing. However, leaf-area index (LAI), stem girth and number of green leaves/plant decreased with each delay in sowing (Table 2) due to suppressed vegetative growth, early leaf senescence and early maturity of the late-sown crop because of higher temperature at all pheno-phases. Sheoran *et al*. (2014) and Dhillon and Sharma (2017) also reported similar findings.

Application of B at 220 and 440 ppm increased the plant height over TIBA at 200 and 400 ppm but was at par with the remaining treatments of foliar application (Table 2). Foliar application of B at 220 ppm and 440 ppm, and TIBA at 100, 200 and 400 ppm increased the LAI and number of green leaves/plant over the control and water spray. However, stem girth did not varied due to foliar sprays. Boron maintains cell-wall integrity by lowering K^+ efflux and is also needed for translocation of sugars, carbohydrates, N metabolism and IAA metabolism (Al-Amery *et al*., 2011). These favourable effects of B might have helped the plant to accrue more height, LAI and number of green leaves. Boron also maintains the functionality of leaves by enhancing the photosynthetic oxygen evolution by leaf and thus improves the apparent quantum yield and efficiency of PS II electron transport (Jabeen and Ahmad, 2011).

Pre- and post-anthesis dry matter accumulation and its translocation to seed

The crop sown on 20 January had the highest post-anthesis DMA owing to congenial temperature during reproductive growth phase and longer crop duration, and it decreased with delay in sowing to 10 February and 2 March. However, DMTE and CDMS improved with delay in sowing, but differences between first 2 sowing dates (20 Janaury and 10 February) were not significant (Table 2). Higher CDMS under late sowing can be ascribed to the fact that, temperature stress at reproductive stage might have modified the activity of fructans-catalysing enzymes, which forced the remobilization of assimilates.

Application of TIBA at 200 ppm resulted in significantly higher post-anthesis DMA over the control and water spray, but was statistically similar to all the B and TIBA treatments. Significant improvement in DMT, DMTE and CDMS owing to application of 220 and 440 ppm of B as well as 100, 200 and 400 ppm of TIBA over the control and water spray may be ascribed to the physiological roles of B in translocation of sugars, synthesis of cellular walls, maintaining membrane integrity, IAA metabolism, accelerating flowering and fruit-bearing processes in head (Nanja Reddy *et al.,* 2003; Jabeen and Ahmad, 2011).

Photosynthetic parameters

Each delay in sowing caused progressive reduction in CCI and Fv : Fm ratio at all stages i.e. before spray, 3, 7, 15 and 21 DAS (Fig. 1). The lower CCI and chlorophyll

Table 1. Mean monthly meteorological data during the crop seasons

Month	2014				2015			
	Air temperature (˚C)			Total rainfall	Air temperature (˚C)			Total rainfall
	Max.	Min.	Mean.	(mm)	Max.	Min.	Mean	(mm)
January	17.5	7.0	12.2	55.5	15.6	7.0	11.3	24.6
February	19.4	8.2	13.9	36.7	20.2	10.5	15.3	38.6
March	25.3	12.5	18.9	35.0	25.5	13.3	19.4	84.6
April	32.7	16.7	24.7	31.0	32.6	17.5	25.0	29.4
May	37.6	22.9	30.2	26.2	38.6	23.8	31.2	17.0
June	40.6	27.1	33.8	30.2	37.7	26.1	31.7	17.9

Source: School of Climate Change and Agricultural Meteorology, PAU, Ludhiana

Table 2. Effect of sowing dates and foliar application of boron and TIBA on growth attributes, pre- and post- anthesis dry-matter accumulation (pooled data of 2 years)

Treatment	Growth attributes (at physiological maturity)				DMA and translocation				
	Plant height (cm)	Leaf area index	Leaves/ plant	Stem girth (cm)	Pre-anthesis D MA (kg/ha)	Post-anthesis DMA (kg/ha)	DMT (kg/ha)	DMTE (%)	CDMS (%)
Sowing date									
20 January	139.8	3.41	20.9	2.16	2919	1908	102	3.47	5.06
10 February	146.0	3.04	19.4	1.91	2795	1727	107	3.85	5.96
2 March	153.6	2.79	18.5	1.78	2777	1369	118	4.26	8.09
SEm±	2.9	0.7	0.2	0.04	32	36	3.9	0.19	0.34
CD (P=0.05)	8.3	0.31	0.8	0.12	124	138	NS	0.71	1.40
Foliar spray (ppm)									
Control	147.3	2.88	18.3	1.86	2823	1516	63	2.20	4.18
Water spray	147.6	2.89	18.7	1.88	2807	1543	60	2.11	3.97
Boron 110	149.5	3.06	19.5	1.92	4329	1663	92	3.24	5.35
Boron 220	150.2	3.18	19.8	1.94	2826	1686	133	4.70	7.65
Boron 440	151.4	3.18	19.9	1.94	2836	1689	143	5.02	8.14
TIBA 100	143.4	3.16	20.1	2.01	2839	1749	126	4.45	6.84
TIBA 200	142.0	3.24	20.2	2.04	2845	1783	133	4.73	7.11
TIBA 400	140.5	3.28	20.3	2.01	2837	1670	126	4.45	7.74
SEm±	2.4	0.09	0.4	0.04	47	74	13	0.51	0.71
CD (P=0.05)	7.3	0.25	1.2	NS	NS	194	37	1.37	2.87

DMA, Dry-matter accumulation; DMT, dry-matter translocation; DMTE, dry-matter translocation efficiency; CDMS, contribution of pre-anthesis dry-matter assimilates, NS, non-significant

florescence of the crop sown on 2 March can be ascribed to prevalence of higher air temperature and ageing of leaves, as the crop was more near to maturity because of relatively shorter crop duration.

Application of B and TIBA improved the photosynthetic parameters such as Fv : Fm ratio and CCI at 3, 7, 15 and 21 days after spray over the control and water spray (Fig. 1). The study also revealed that though Fv : Fm ratio and CCI values decreased due to ageing of crop, foliar application of B and TIBA tended to maintain higher values of these photosynthetic parameters even at later stage of crop growth, i.e. 15 and 21 DAS (Fig. 1).

Root-mass density

Root-mass density of sunflower was higher at ray-floret-opening stage than that at maturity stage under all the treatments at all sampling depths (Table 3). There was progressive reduction in root-mass density with delay in sowing at both the stages, viz. ray-floret-opening stage and physiological maturity, at all depths (0–15, 15–30 and 30–45 cm) of sampling. Of the total root dry matter, 86.0% roots of crop sown on 20 January were confined to 0–15 cm soil layer as against 87.7% under 2 March sowing date. However, the proportion of roots confined to 15–30 cm and 30–45 cm soil depths was higher under crop sown on 20 January as compared to that sown on 2 March, thereby indicating higher distribution of roots in sub-soil under early sowing as compared to later sowing dates. However, foliar application of B and TIBA did not influence the root-mass density of sunflower at any stage and at any soil depth.

Yield and yield attributes

Crop sown on 20 January showed the largest heads with the higher number of seeds/head, 1,000-seed weight, hectolitre weight, seed weight/head, thalamus weight and the highest seed-filling percentage (Table 4), leading to significantly higher seed yield (excelling 10 February and 2 March sowing date by a respective margin of 10.4 and 34.9% respectively) (Table 4). Similarly, the highest biological yield obtained under 20 January sowing date was 9.8 and 19.4% higher than 10 February and 2 March sowing dates. The reduction in harvest index due to delay in sowing from 10 February to 2 March was also significant. These results corroborate the earlier findings of Dhillon and Sharma (2017). The superiority of yield-contributing characters in 20 January sowing date can be attributed to prevalence of favourable environmental conditions for crop growth at reproductive phase (Table 1). Higher LAI and post-anthesis DMA (Tables 2) aided in better photosynthetic efficiency of crop sown on early date. Significantly more number of days were available for various pheno-phases under early sowing, that formed the foundations for the sink to efficiently utilize the assimilates.

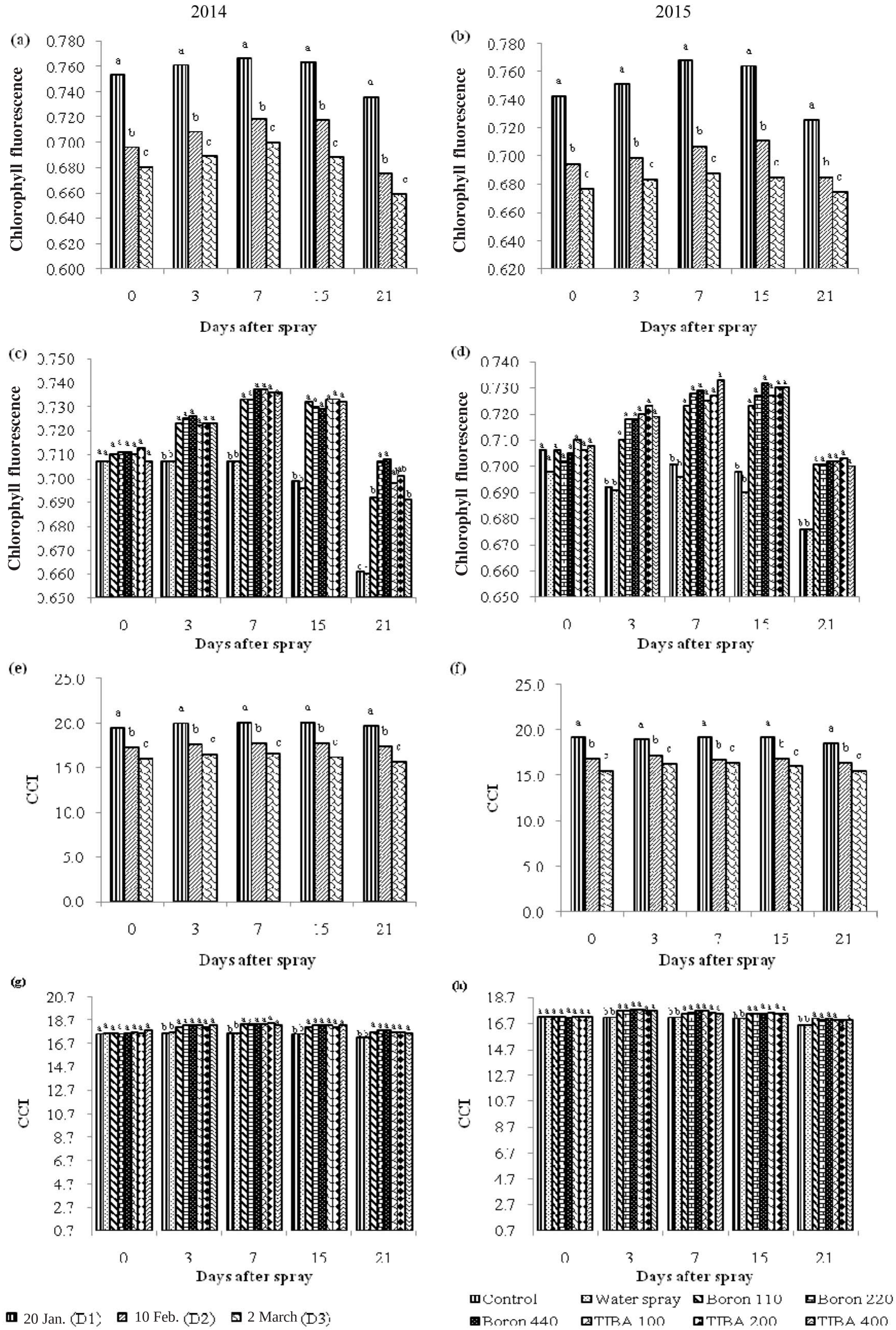

Fig. 1. Effect of sowing dates, boron and TIBA treatments on leaf fluorescence (Fv : Fm) and chlorophyll content index (CCI) of sunflower during 2014 and 2015 (Bars with similar letters did not differ significantly)

Kakani *et al*. (2002) reported that, high temperature at flowering stage inhibits pollen germination and pollen-tube growth, pollen viability, consequently resulting in lower seed set and yield. Astiz and Hernandez (2013) reported that, temperature over 26^{O}C is supra-optimal for pollen production in sunflower even under well-watered conditions. In the present study, canopy temperature of crop sown on 20 January and 10 February up to 50% flowering stage remained below 30^{O}C but crop sown on 2 March experienced a canopy temperature of 34^{O}C during the corresponding period. The higher temperature might be responsible for lower pollen viability and reduced pollen load under late-sown conditions, leading to lower yield.

Foliar application of 110, 220 and 440 ppm B and 100, 200 and 400 ppm TIBA resulted in significantly larger heads with higher seed weight/head than the control and water spray. The number of unfilled seeds/head was the highest under the control, which was at par with water spray. Spray of 220 ppm B resulted in the least number of unfilled seeds/head and the highest seed filling, which was statistically at par with all other concentrations of B and TIBA, except 110 ppm B and 100 ppm TIBA. Unsprayed control registered significantly lowest 1,000-seed weight,

Table 3. Effect of sowing dates and foliar sprays of boron and TIBA on root-mass density (10^{-2} g cc) of sunflower (mean data of 2 years)

Treatment	Ray-floret stage (depth)			Maturity stage (depth)		
	0–15 cm	15–30 cm	30–45 cm	0–15 cm	15–30 cm	30–45 cm
Sowing date						
20 January	1.055	0.135	0.037	0.905	0.127	0.036
10 February	0.905	0.105	0.027	0.840	0.099	0.026
2 March (D_3)	0.720	0.083	0.018	0.660	0.079	0.018
Foliar spray (ppm)						
Control	0.895	0.108	0.028	0.785	0.102	0.027
Water spray	0.895	0.108	0.027	0.790	0.100	0.026
Boron 110	0.905	0.107	0.027	0.785	0.100	0.026
Boron 220	0.900	0.108	0.028	0.795	0.099	0.026
Boron 440	0.880	0.109	0.027	0.785	0.099	0.027
TIBA 100	0.885	0.108	0.027	0.815	0.104	0.026
TIBA 200	0.895	0.107	0.027	0.835	0.104	0.026
TIBA 400	0.890	0.107	0.027	0.835	0.104	0.026

Table 4. Effect of sowing dates and foliar application of boron and TIBA on yield attributes and yield of sunflower (pooled data of 2 years)

Treatment	Head diameter (cm)	Seed weight/ head (g)	Thalamus weight (g)	Seeds/ head	Unfilled seed/head	Seed-filling (%)	1,000-seeds weight (g)	Hectolitre weight (kg)	Biological yield (t/ha)	Seed yield (t/ha)	Harvest index (%)
Sowing date											
20 January	19.7	42.6	12.5	835	59.2	93.3	57.0	45.4	5.04	2.01	39.8
10 February	18.0	37.2	9.8	736	65.5	91.7	53.2	45.8	4.59	1.82	39.8
2 March	16.1	32.5	8.9	606	77.1	88.4	49.0	40.6	4.22	1.49	35.2
SEm±	0.2	0.4	0.2	9	1.0	0.2	1.0	0.4	0.032	0.021	0.7
CD (P=0.05)	0.6	1.3	0.5	29	3.7	0.5	2.1	1.3	0.12	0.08	1.6
Foliar spray (ppm)											
Control	16.8	31.9	9.8	631	85.8	87.6	48.5	44.3	4.21	1.58	37.2
Water spray	16.8	32.7	9.8	642	81.1	88.4	48.8	44.2	4.23	1.60	37.8
Boron 110	17.8	38.8	10.5	751	63.5	92.0	51.9	44.2	4.62	1.75	38.0
Boron 220	18.3	39.0	10.7	787	58.4	92.9	53.6	44.1	4.75	1.82	38.3
Boron 440	18.4	39.4	10.6	785	59.9	92.7	51.8	43.6	4.77	1.83	38.2
TIBA 100	18.5	39.0	10.6	733	65.6	91.5	56.1	43.7	4.77	1.88	39.1
TIBA 200	18.6	39.7	10.7	737	61.1	92.1	57.9	43.6	4.87	1.92	39.2
TIBA 400	18.4	38.8	10.6	736	62.6	92.0	55.9	43.8	4.71	1.80	37.8
SEm±	0.3	1.1	0.3	18	1.9	0.4	1.2	0.8	0.048	0.091	0.8
CD (P=0.05)	0.9	3.1	NS	48	5.0	0.8	3.5	NS	0.20	0.13	NS

NS, non-significant

which was at par with water spray and B treatments except 220 ppm of B. All the TIBA concentrations were statistically at par with each other.

Biological yield and seed yield were also significantly influenced by foliar application treatments (Dhillon *et al*., 2018). The lowest biological yield obtained under the control was statistically at par with water spray. Significantly highest biological yield obtained with spray of 200 ppm TIBA was statistically at par with all the other treatments except B at 110 ppm. Similarly, the lowest seed yield recorded under the control was statistically at par with water spray but significantly lower than all B and TIBA treatments except 100 ppm B. Foliar application of B and TIBA resulted in more rapid transition from vegetative to reproductive phase, resulting in lengthening of reproductive phase, increased the leaf area, delayed leaf senescence (Tables 2 and 3) and increased the CCI and chlorophyll fluorescence (Fig. 1). Foliar application of B improved the cell-wall structure, with transitory increase in elasticity module followed by reduced secondary thickening and increase in the incidence of plasma membrane-bound reductase activity for better partitioning to sink, leading to higher seed yield (Yu *et al*., 2002). The favourable effect of B in increasing pollen viability (Chinnamuthu *et al*., 2000) and enhanced differentiation of vascular bundles might also have contributed towards higher seed yield (Hajiboland *et al.,* 2012). The TIBA, an inhibitor of polar transport of auxins, might have increased the sink capacity and movement of metabolites from vegetative organs to the head. Improved vascularization between the outer and inner parts of the capitulum owing to exogenous spray of TIBA might have increased seed yield by reducing the proportion of empty achenes in the inner portion of the capitulum.

Table 5. Interaction effects of sowing dates and foliar applications on seed-filling (pooled data of 2 years)

Foliar spray	Sowing date		
	20 January	10 February	2 March
Control	90.1	88.9	83.8
Water spray	91.2	90.2	83.7
Boron 110 ppm	94.0	92.6	89.3
Boron 220 ppm	94.7	93.2	90.7
Boron 440 ppm	94.6	92.4	91.0
TIBA 100 ppm	93.4	92.2	89.0
TIBA 200 ppm	94.1	92.7	89.5
TIBA 400 ppm	94.1	91.8	89.8
SEm±		0.5	
CD (P=0.05)		1.5	

Interaction effects of sowing dates and foliar application on seed-filling percentage revealed that foliar application of B to crop sown on 2 March resulted in statistically similar seed filling as obtained in the crop sown on 20 January without spray (Table 5). Crop sown on 10 February produced significantly more number of filled seeds than that sown on 2 March irrespective of foliar application of B and TIBA except B 440 ppm, where the 2 sowing dates were at par.

Economics of foliar application of boron and TIBA

Foliar application of boron and TIBA increased the seed yield of sunflower to the tune of 176 to 339 kg/ha over the control, thereby increasing the gross returns over the control by ₹7,216 to ₹13,899/ha (Table 6). Data further reveals that although the gross returns were higher under TIBA 200 ppm (₹13,899) followed by TIBA 100 ppm (₹12,177), but the net profit was higher in case of foliar application of B 220 ppm (₹9,255) followed by B 440 ppm (₹8,984) because of the reason that cost of production increases under TIBA treatments.

On the basis of results, it can be concluded that early-sown crop gave higher seed yield owing to higher post-anthesis DMA coupled with better photosynthetic parameters, growth attributes and root-mass density. Foliar application of boron at 220 and 440 ppm as well as TIBA at 100, 200 and 400 ppm also caused significant improve-

Table 6. Economics of foliar application of boron and TIBA on sunflower

Treatment	Increase over control			
	Seed yield (kg/ha)	Gross returns (₹/ha)	Cost of production (₹/ha)	Profit (₹/ha)
Boron (110 ppm)	176	7,216	470	6,746
Boron (220 ppm)	245	10,045	790	9,255
Boron (440 ppm)	254	10,414	1,430	8,984
TIBA (100 ppm)	297	12,177	5,350	6,827
TIBA (200 ppm)	339	13,899	10,550	3,349
TIBA (400 ppm)	218	8,938	20,950	-12,012

Price of borax, ₹800/kg (supplied by Merk chemicals); price of TIBA, ₹13,000/100 g (supplied by Labogens chemicals); cost of man power for spray, ₹150/ha; MSP of sunflower, ₹41,000/t.

ment in productivity of sunflower crop owing to improved current photosynthesis during reproductive phase of crop as well as improved accumulation and remobilization of photo-assilmilates, resulting into harmonious source-sink relationship.

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