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Effect of Long-term Application of Graded Levels of Boron on Growth, Yield and Oil Content of Sunflower (*Helianthus annuus* L.)

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P. G. Greena : Carried out the experiment, drafted the manuscript;
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Abstract

A field experiment was conducted to study the levels of boron application on growth, yield and oil content of sunflower (*Var*- KBSH-78) during *kharif*-2020 at Zonal Agricultural Research Station, Gandhi KrishiVignana Kendra, Bengaluru. The experiment was laid out in a RCBD with eight treatments, replicated thrice. Treatments consisting of the application of recommended dose of fertilizer (POP-90:90:62.5 kg N: P_2O_5: K_2O ha^{-1} and 7.5 t ha^{-1} FYM), POP along with soil application of graded levels of boron. The results revealed that due to the application of higher dose of boron, germination of sunflower was completely affected from 2 kg B ha^{-1} to 16 kg B ha^{-1} applied plots even at 13th DAS. But, after gap filling with the seedlings grown in polythene pockets, crop stand was good however, crop growth and yield was affected as the boron level increased. The sunflower yield data indicated that continuous application of boron from 2 kg ha^{-1} to 16 kg ha^{-1} has drastically reduced the seed yield as compared to no boron applied plots. Stalk yield and other growth and yield attributes of sunflower also followed the same trend. Significantly higher seed yield (20.47 q ha^{-1}) and stalk (30.88 q ha^{-1}) in FYM+ RDF to 16 kg B ha^{-1} (13.28 q ha^{-1}) has considerably lowered the seed yield of sunflower.

Keywords: Sunflower, Long term application of boron, Growth, Yield

Sunflower (*Helianthus annuus* L.), one of the major oilseed crops, is widely cultivated in the world. This crop has gained importance because of its short duration of maturity, excellent quality oil, photo insensitivity, wide adaptability in different agro-climatic regions, kind of cropping patterns and drought tolerance. Sunflower production is about 50.22 million tons from 27.87 million ha of global coverage India accounts for about 15-20 per cent of global oilseeds area (32 lakh ha) with seed production of 21.3 lakh tons (FAO. 2020). Karnataka, Maharashtra and Odisha are the major states, which accounts for about 75 per cent of the total area under sunflower cultivation in India. In Karnataka it is grown in an area of 1.29 lakh ha with production of 1.03 lakh tons and productivity of 802 kg ha^{-1}, which is lower than national (931 kg ha^{-1}) and much lower than world's (2048 kg ha^{-1}) average productivity (APEDA. 2020).

Sunflower requires a high amount of B as compared to other crops and has been used as a good indicator of B deficiency. It is one of the most sensitive crop to low boron (B) supply, showing B-deficiency symptoms on leaves, stems and reproductive organs. Yield reduction due to B deficiency is frequent, even if typical visual symptoms on leaves and heads are not evident. Furthermore, an increase in the incidence of B deficiency can be expected with continued cropping and increased yields because very little B is supplemented as fertilizer.

For many plant species there is a very narrow range in critical tissue concentrations of boron between deficiency and toxicity. Boron toxicity exerts different effects on vascular plants, such as reduced root cell division, lower photosynthetic rates and decreased lignin and suberin levels. Accordingly, a reduced growth of shoots and roots is typical of plants exposed to higher levels of boron. Boron toxicity in the sunflower is indicated first by a mottling of the tips and edges of the lowest leaves. Later these mottled areas die. In severe cases of injury practically the entire leaf may be affected. However, the exact tissue concentration or soil boron level showing the boron toxicity symptoms is rarely known specially in sunflower crop. Hence, a study was taken on boron dynamics with the objective to know the effect of long term application of different levels of boron on growth, yield and oil content of sunflower.

Material and Methods

A long term field experiment has been in progress since 2016 on *Afisols* belonging to *Vijaypura* soil series at 'F' block, STCR field unit, Zonal Agriculture Research Station, University of Agricultural Sciences, Gandhi KrishiVignyan Kendra, Bengaluru located in Eastern Dry Zone of Karnataka at 13° 04' 55.2" N latitude, 77° 34' 10.0" E longitude with an altitude of 930 meters above mean sea level (MSL). The experiment consists of eight treatments with graded levels of boron application and replicated thrice. The different crops raised during different years are sunflower-maize-sunflower-ragi. In the present study, sunflower as a test crop was taken up during *kharif* 2020.

A germination study was conducted prior to the long-term study at various levels of B and found germination at 40 mg kg^{-1} B also. From the results obtained, a pot experiment was conducted till 45 DAS from 1, 2, 4, 8, 10, 20 kg B ha^{-1} upto 80 kg B ha^{-1}. In that particular pot study also there were no toxicity symptoms till 20 kg B ha^{-1} application. Hence the experiment was designed with regard to the results since 2016 and the treatment details are as follows below.

Treatment details :

T_1 : Absolute control
T_2 : POP + without boron
T_3 : POP + 2 kg B ha^{-1}
T_4 : POP + 4 kg B ha^{-1}
T_5 : POP + 6 kg B ha^{-1}
T_6 : POP + 8 kg B ha^{-1}
T_7 : POP + 12 kg B ha^{-1}
T_8 : POP + 16 kg B ha^{-1}

Note: POP - UAS-B Package of practice for sunflower is 90:90:62.5 (N, P_2O_5, K_2O kg ha^{-1}) + FYM 7.5 t ha^{-1}

A composite soil sample was taken from 0-15 cm depth from each plot after laying out the field plan before start of experiment during 2016. The soil was air dried, pounded and then passed through 2 mm sieve and was analyzed for physical and chemical properties following standard procedure. The analytical techniques followed for the estimation of physical and chemical properties of soil and the results are presented in Table 1.

The germination of sunflower seeds was observed till 13 DAS and the failure in germination was compensated with gap filling with the seedlings grown in pockets, crop stand was found good after that.

The sunflower was raised as per the treatment details. Borax was used as boron source. The biometric observations like growth (at 30 DAS, 60 DAS and at harvest) and yield parameters of sunflower were recorded. The oil content in seeds was assessed using nuclear magnetic resonance spectrophotometer (NMR, model Minispec 20 pi).

Results and Discussion

Boron Concentration in Soil with Long Term Boron Fertilization

With the continuous application of graded levels of B from 2 to 16 kg ha^{-1} resulted in an increase in available boron content in soil over a period of five years in all treatments except control and POP treatments where boron was not applied. Both before and after the sunflower crop *kharif* 2020, the available

TABLE 1

Initial physico-chemical properties of the experimental site (2016)

Particulars	Values	Methodology
Physical properties of soil		
Sand (%)	65.60	International pipette method(Piper, 1966)
Silt (%)	16.60	
Clay (%)	17.80	
Texture	Sandy loam	
Bulk density (Mg m^{-3})	1.52	Keen Raezkowski cup method (Piper,1966)
Chemical properties of soil		
pH (1:2.5)	5.45	Potentiometry (Jackson, 1973)
Electrical conductivity (dS m^{-1})	0.04	Conductometry (Jackson, 1973)
Organic carbon (g kg^{-1})	4.0	Wet oxidation method (Walkley and Black, 1934)
Available N (kg ha^{-1})	231.37	Alkaline peramanganate method(Subbiah and Asija, 1956)
Available P_2O_5 (kg ha^{-1})	176.84	Bray's method (Jackson, 1973)
Available K_2O (kg ha^{-1})	250.26	Flame photometry method(Page *et al*., 1982)
Available S (mg kg^{-1})	27.30	Turbidometry method (Jackson, 1973)
Exchangeable calcium [c mol (p^+) kg^{-1}]	0.60	Versenate titration method(Jackson, 1973)
Exchangeable magnesium [c mol (p^+) kg^{-1}]	1.85	
DTPA iron (mg kg^{-1})	8.66	DTPA extraction method(Lindsay and Norvell, 1978)
DTPA manganese (mg kg^{-1})	3.91	
DTPA copper (mg kg^{-1})	1.36	
DTPA zinc (mg kg^{-1})	1.03	
Hot watersoluble boron(mg kg^{-1})	0.64	Extracted with hot water (Berger andTruog, 1939)

soil boron was found to be statistically significant. In the intial stage (*kharif* 2020) of the experiment soil boron increase was from 3.05 to 5.51 mg kg^{-1} with application of B from 2 to 16 kg ha^{-1}, respectively.

The available boron content after the harvest was also increased due to the continuous application of boron to a higher concentration (3.46 to 5.57 mg kg^{-1}) from 2 to 16 kg ha^{-1}, respectively. Higher doses of B at 12 and 16 g ha^{-1} showed on par results at the end of this experiment. The application of higher levels of boron to previous crop increased the hot water soluble B in the soils at harvest of residual crop. This might be due to slow release of B in to soil pool (Priyanka 2018). Similarly, in a study conducted by Bhatacharya *et al.* (2015) soil B was increased from 33.33 to 70.37 per cent after sunflower harvest with graded levels of B application.

TABLE 2

Effect of long-term application of graded levels of boron on available B of soil initial (*kharif* 2020) and after harvest of sunflower

Treatment details		Initial (*kharif* 2020) Soil available B (mg kg^{-1})	After harvest Soil available B (mg kg^{-1})
T_1	Control	0.46	0.54
T_2	POP without Boron	0.58	0.56
T_3	POP+ 2 kg B ha^{-1}	3.05	3.46
T_4	POP+ 4 kg B ha^{-1}	3.56	3.69
T_5	POP+ 6 kg B ha^{-1}	3.56	3.88
T_6	POP+ 8 kg B ha^{-1}	3.81	4.45
T_7	POP+ 12 kg B ha^{-1}	4.07	5.54
T_8	POP+ 16 kg B ha^{-1}	5.51	5.70
S Em ±		0.39	0.35
C D @ 5%		1.19	1.06

Status of Post-harvest Soil Available N, P and K

As shown in Table 3, the varying quantities of boron application had no discernible effect on the post-harvest soil available N, P and K status.

After the sunflower crop was harvested, the available nitrogen content of the soil did not significantly differ across different boron treatments. However, in the treatments the available N increased compared to initial nitrogen level of soil. The soil available N content (Table 3) was numerically increased compared to control (252.97 kg ha^{-1}) and as the boron level increased from 2 kg (257.15) to with 16 kg B ha^{-1} (270.92 kg ha^{-1}). The available phosphorus was quite high in all of the treatments but, compared to initial phosphorous, it was increased. After the sunflower crop was harvested, there was no significant variation in the available phosphorus level of the soil between the various treatments. But, the available P_2O_5 level increased numerically as the boron level increased. The 16 kg B ha^{-1} along with the POP-treated plot (T_8) had the numerically higher available phosphorus content (189.49 kg P_2O_5 ha^{-1}). Wherein absolute control (T_1) had numerically lower amount of available phosphorus (102.73 kg P_2O_5 ha^{-1}).

TABLE 3

Effect of long-term application of graded levels of boron on available N, P_2O_5 and K_2O of soil after harvest of sunflower

Treatment details		N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
T_1	Control	252.97	102.73	131.25
T_2	POP without Boron	258.86	159.24	147.84
T_3	POP+ 2 kg B ha^{-1}	257.15	169.53	151.93
T_4	POP+ 4 kg B ha^{-1}	260.03	172.84	154.71
T_5	POP+ 6 kg B ha^{-1}	265.06	176.82	157.45
T_6	POP+ 8 kg B ha^{-1}	261.33	179.28	161.00
T_7	POP+ 12 kg B ha^{-1}	268.86	184.37	162.33
T_8	POP+ 16 kg B ha^{-1}	270.92	189.49	163.51
S Em ±		13.72	18.94	10.79
C D @ 5%		NS	NS	NS

Due to differing levels of boron application, the soil available potassium concentration did not significantly differ between the treatments either but, the K status of soil after post-harvest has increased in the different levels of boron application compared to control. However, with 16 kg B ha^{-1} combined with POP (T_8), a numerically larger amount of available potassium (163.51 kg K_2O ha^{-1}). From 2 kg to 16 kg B there was slight increase in available potassium. While in the absolute control (T_1), had lower potassium levels (131.25 kg K_2O ha^{-1}).

Different boron application levels had no significant effect on the amount of available nitrogen, phosphorous and potassium in the soil. However numerically higher nitrogen and phosphorus availability were seen in the treatment receiving 16 kg B ha^{-1}, also potassium concentration in the soil increased up to the same level of B. These results concur with those of Banasode and Channakeshava (2021), who noted an increase in available nitrogen due to the mineralization of additional FYM along with Borax application. Higher dose of boron in the soil induces the desorption of $H_2PO_4^-$ and NO_3^- from the adsorption sites by $H_3BO_3^-$ makes them available in the soil. Higher amounts of boron may interact favourably with an increase in K, balancing cations and anion in the soil (Sathi Babu *et al*., 2017). Similar to this, Das *et al.* (2014) found that a high B concentration in the soil enhances the availability of potassium to plants.

Boron Fertilization and Sunflower Crop Growth

The observations relating to selected growth attributing characteristics (e.g., plant height and no. of leaves) as influenced by graded levels of B fertilization at different growth stages *viz.,* 30 DAS, 60 DAS and at harvest have been recorded and data are given in Table 4. Significantly highest mean plant height (27.07, 113.73 and 124.07 cm) at 30, 60 DAS and at harvest, respectively were recorded in treatment T_2 where POP was applied without boron. However, gradual decrease in the plant height and no of leaves at all the intervals of growth period was observed due to the application of boron from 2 kg ha^{-1} to

TABLE 4

Influence of graded levels of boron application on plant height and no. of leaves of sunflower crop at different stages

Treatment details		Plant height (cm)			No. of leaves		
		30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest
T_1	Control	18.20	66.67	75.07	10.40	17.27	25.00
T_2	POP without Boron	27.07	113.73	124.07	13.53	24.47	30.40
T_3	POP+ 2 kg B ha^{-1}	23.73	111.00	120.87	12.93	24.00	27.60
T_4	POP+ 4 kg B ha^{-1}	22.73	92.07	96.20	12.07	21.27	27.27
T_5	POP+ 6 kg B ha^{-1}	18.53	76.67	83.33	10.27	20.00	25.67
T_6	POP+ 8 kg B ha^{-1}	17.87	76.60	87.47	10.07	19.67	25.13
T_7	POP+ 12 kg B ha^{-1}	16.87	73.27	85.60	9.67	19.53	24.93
T_8	POP+ 16 kg B ha^{-1}	14.93	68.13	77.93	9.00	19.40	24.87
S.Em. ±		2.12	7.60	6.97	0.37	0.80	0.88
C.D. @ 5%		6.43	23.06	21.15	1.11	2.44	2.66

16 kg ha^{-1}. But, the plant height in treatment T_3 treated with POP + 2 kg B ha^{-1} (23.73,111.11 and 120.87 cm) was found on par with POP + without boron (T_2) throughout the growth period. Significantly lower plant height was recorded in absolute control (T_1) (66.67 and 75.07 cm) followed by T_8 where POP + 16 kg B ha^{-1} (68.13 and 77.93 cm) was applied at 60 DAS and at harvest, respectively, whereas at 30 DAS lower plant height was recorded in T_8 where POP + 16 kg B ha^{-1} (14.93 cm) followed by T_7 (POP + 12 kg B ha^{-1}).

There was a significant differences in number of leaves per plant at all intervals with application of different levels of boron. Significantly higher number of leaves (13.53, 24.47 and 30.40) at 30, 60 DAS and at harvest, respectively were recorded with the application of POP without boron (T_2), whereas at 30 DAS and harvest number of leaves was significantly lower (9.00 and 24.87, respectively) in T_8 (POP + 16 kg B ha^{-1}) followed by T_7 (POP + 12 kg B ha^{-1}). At 60 DAS, lowest number of leaves was recorded in absolute control (T_1) (17.27) followed by T_8 where POP + 16 kg B ha^{-1} (19.4) was applied. Continuous application of B increased the level of boron in the soil and toxic conditions began to set in, thereby exerting adverse effects on plant metabolic activities that consequently affect plant height negatively. Regular application of more than 2 kg ha^{-1} B fertilizer annually or application of irrigation water high in B leads to B toxicity in plants and reduced crop yields (Singh *et al.,* 2005). Lower boron levels undergo rapid cells division and differentiate hence increase in plant height and photosynthetic rate (Bonilla *et al*., 2004). The significant increase in growth parameters at low concentration of boron could be due to its involvement in cell elongation or cell division and meristematic growth (Khan *et al*., 2006).

Increase in different levels of boron up to 16 kg B ha^{-1} along with POP, decreased all the growth and yield attributes beyond 2 kg B ha^{-1} along with POP. It was due to excessive amount of boron appears to inhibit the formation of starch from sugars in turn results in the formation of carbohydrates complexes, and thus fails to increase growth and yield attributes (Soad Soliman EI- Feky *et al.,* 2012).

Boron Fertilization and Sunflower Yield Attributes and Oil Content

The initial soil boron content shows that, the continuous application of boron increased the boron content to a toxic level with increasing dose of application (Table 3). The highest initial boron content was observed in T_8 (5.51 mg kg^{-1}) where, 16 kg B ha^{-1} with POP was applied and lowest soil boron status was found in absolute control (0.46 mg kg^{-1}) followed by treatment (T_2) no boron with POP (0.58 mg kg^{-1}). Due to the application of heavy dose of boron, the germination was affected from 2 kg B ha^{-1} to 16 kg B ha^{-1} applied plots at 7 and 13 DAS (Table 6). The per cent germination of sunflower recorded at 7 and 13 DAS indicates, that significantly higher germination was observed in absolute control treatment (73.3 and 93.33%, respectively) and it was on par with treatment (T_2) no boron with POP (85%) at 13 DAS. But, after gap filling with the seedlings grown in pockets, crop stand was good however, crop growth and yield was affected as the boron levels increased.

The long-term application of boron on sunflower crop recorded a decrease in test weight, number of seeds per head, head weight and head diameter with increase in levels of boron (Table 5). A significant higher test weight (75.19g), number of filled seeds per head (586.6) and head diameter (18.8cm) in treatment T_2 (POP without Boron) were recorded whereas the lowest test weight (47.13g) was recorded in higher dose of boron applied treatment (T_8: POP + 16 kg B ha^{-1}) but, absolute control treatment recorded lowest in number of filled seeds (298.2) and head diameter (51.17 cm) in T_7 (POP+ 12 kg B ha^{-1}). The capitulum was often mal-formed with poor seed set due to the toxicity effect on continuous application of boron over the years. Similarly, Ceyhan *et al.* (2008) reported that B application as average of years, decreased diameter of head and 1000 seed weight with increasing B dose.

The number of chaffy and total seeds as well as head weight of sunflower crop after harvest was showing non significant results with the application of graded levels of boron. However, highest number of chaffy seeds per head (486.1) was recorded in treatment of (T_7) POP+ 12 kg B ha^{-1} and number of total seeds per head (963.1) and head weight (17.8 kg) were recorded in the treatment of POP without Boron (T_2). Lowest number of chaffy seeds per head (337.0), number of total seed per head (612.8) and head weight (11.7kg) were recorded at absolute control, (T_5) POP + 6 kg B ha^{-1} and (T_8) POP + 16 kg B ha^{-1}, respectively. Shirur *et al.* (2021) observed, significantly higher number of tubers per plant, tuber weight and tuber yield per hectare were recorded in potato with the application of 150 kg Gypsum ha^{-1} + Foliar spray of 0.5 per cent Boron along with RDF +FYM.

TABLE 5

Effect of long-term application of graded levels of boron on sunflower seeds test weight, number of chaffy, filled and total seeds per head, head weight and diameter after harvest

	Treatment details	Test weight (g)	Number of seeds per head			Head weight (kg)	Head diameter (cm)
			Chaffy seeds	Filled seeds	Total		
T_1	Control	47.13	337.0	298.2	635.2	5.2	12.4
T_2	POP without Boron	75.19	343.1	586.6	963.1	12.0	17.8
T_3	POP+ 2 kg B ha^{-1}	70.10	218.7	361.4	580.1	10.1	13.5
T_4	POP+ 4 kg B ha^{-1}	62.69	207.7	358.7	566.3	10.2	14.3
T_5	POP+ 6 kg B ha^{-1}	51.72	260.8	352.0	612.8	7.3	12.4
T_6	POP+ 8 kg B ha^{-1}	48.02	375.5	347.9	723.3	7.2	11.8
T_7	POP+ 12 kg B ha^{-1}	39.61	486.1	342.9	829.0	6.3	12.0
T_8	POP+ 16 kg B ha^{-1}	35.53	482.6	338.2	820.9	5.8	11.7
S.Em. ±		0.39	55.7	47.4	86.8	1.20	1.3
C.D. @ 5%		1.19	NS	145.0	NS	3.62	NS

TABLE 6

Effect of long-term application of graded levels of boron on germination percentage, seed yield, stalk yield and oil content of sunflower crop with initial soil B concentration

Treatment details		Germination per cent		Seed yield (q ha^{-1})	Stalk yield (q ha^{-1})	Oil content (%)
		7 DAS	13 DAS			
T_1	Control	73.33	93.33	11.64	12.91	32.98
T_2	POP without Boron	57.50	85.00	20.47	30.88	34.22
T_3	POP+ 2 kg B ha^{-1}	39.17	56.67	18.71	27.17	35.72
T_4	POP+ 4 kg B ha^{-1}	20.83	32.50	17.76	26.96	36.69
T_5	POP+ 6 kg B ha^{-1}	13.33	21.67	16.34	24.32	35.64
T_6	POP+ 8 kg B ha^{-1}	10.00	15.00	15.14	22.32	33.51
T_7	POP+ 12 kg B ha^{-1}	2.50	4.17	14.98	21.45	32.38
T_8	POP+ 16 kg B ha^{-1}	0.83	0.83	13.28	15.44	31.81
S.Em. ±		2.79	3.49	0.77	8.42	8.42
C.D. @ 5%		5.98	10.60	2.34	2.78	2.78

The perusal of the data in (Table 6) related to seed yield indicated that there was a significant difference due to application of different levels of boron. Among the different levels of boron application to sunflower crop the treatment POP without boron application (T_2) recorded significantly higher grain yield (20.47 q ha^{-1}) compared to other treatments. However, it was found to be on par with T_3 (POP + 2 kg B ha^{-1}) (18.71 q ha^{-1}) was applied. Among boron treatments, significantly lower grain yield (11.64 q ha^{-1}) was observed in absolute control where no POP and no boron was applied. The yield reduction was to the tune of 8.6 to 35.1 per cent from 2 kg B to 16 kg B ha^{-1}. Statistically stalk yield was significantly higher (30.88 q ha^{-1}) in treatment (T_2) without boron + POP and was decreasing with increased application of boron in the soil. The significantly lower stover yield (73.72 q ha^{-1}) was recorded in absolute control (T_1) when compared to other treatments. Even though the available N, P_2O_5 and K_2O increased after harvest of sunflower with increasing dose of B, the results showed that the toxicity effect of B was prominent in retarding the growth and yield of sun flower due to higher levels of B in soil.

The oil content in sunflower seeds significantly increased with application of POP + 4 kg B ha^{-1} (T_4) (36.69%) followed by T_3, where 2 kg B ha^{-1} with POP (35.72%) and (T_2) no boron with POP (34.22). The oil content was significantly reduced with application of higher dose of boron (T_8) @ 16 kg B ha^{-1} (31.81%) compared to absolute control (32.98%).

The Fig. 1. showing effect of long-term application of graded levels of boron on seed yield, stalk yield and oil content of sunflower crop with initial soil B content illustrated the adverse effect of toxicity of B in soil on sunflower seed and stalk yield. Excess of B deteriorated the quality of sunflower seeds by lowering the plant height, number of leaves, head diameter number of filled grains and test weight. The B toxicity might be due to direct effect of B on pollen viability, fertility and seed set in plant (Fang *et al.,* 2016). High B concentration in leaves can cause

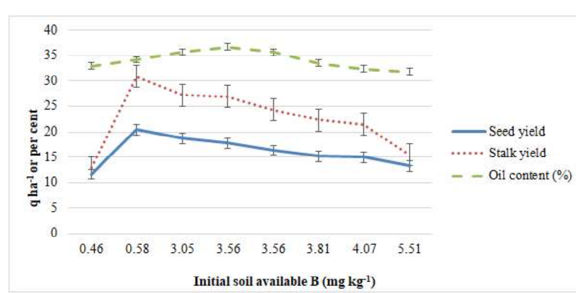

Fig. 1 : Effect of long-term application of graded levels of boron on seed yield, stalk yield and oil content of sunflower crop with initial soil B concentration

a decrease in photosynthesis as reported for olives (Chatzissavvidis and Therios, 2010). A reason for this decline could be the reduction of N concentration in leaves because most of this element in green tissues is utilized in the photosynthetic machinery (Simon *et al*., 2013). Residual effects of B on yield was reported by Dongale and Zende (1977) in wheat, while Ratna Kalyani *et al.* (1993) reported that the application of B to the pigeon pea crop played a critical role in reducing flower and pod drop by preventing the formation of an abscission layer. At lower dose of boron, the application Zn and B along with NPK and FYM increased growth and yield of paddy as well as residual crop cowpea (Banasode and Channakeshava, 2021). The increase in oil content may be due to the positive influence of B on bio-synthesis of oil and fatty acids (Malewar *et al.* 2001 and Mallick & Raj 2015). The increase in oil content of mustard due to B application have also been reported by Mandal and Das (2014) and Jaiswal *et al.* (2015) Yadav *et al*. (2016).

The essential tissue boron concentrations for many plant species fall within a very small range between deficiency and toxicity. Boron toxicity has a variety of consequences on vascular plants, including lowered photosynthetic rates and impaired root cell division. As a result, plants exposed to increased levels of boron typically exhibit lower development of shoots and roots. A mottling of the lowest leaves tips and edges is the earliest sign of boron toxicity in sunflower and these spotted regions eventually perish. The entire plant growth is hampered in cases of severe injury, which leads to low yields and poor quality oil. Due to continued application of boron for five years, POP along without boron practise, showed initial soil boron status at its ideal level, which led to good plant growth at various phases and a high yield of sunflowers. In the intial stage (*kharif* 2020) of the experiment soil boron increase was from 3.05 to 5.51 mg kg^{-1} and after the harvest was also increased to a higher concentration (3.46 to 5.57 mg kg^{-1}) from 2 to 16 kg ha^{-1}, respectively. Thus, toxicity was more severe at the higher dose of boron where, the test weight, number of filled seeds per head, head weight, and head diameter per plant was decreased finally, yield was lowered by 8.6 to 35.1 per cent from 2 kg B to 16 kg B ha^{-1}. Also with treatment of a greater dose of boron the oil content was significantly decreased (T8) @ 16 kg B ha^{-1} (31.81%) compared to the absolute control (32.98%). Different boron application levels had no significant effect on the amount of available nitrogen, phosphorous and potassium in the soil. However numerically higher nitrogen, phosphorus and potassium availability were seen in the treatment receiving 16 kg B ha^{-1}. But, higher B treatments partially hindered a variety of cellular processes, which could prevent roots from absorbing nutrients. Hence the treatment where POP without B showed the highest seed production (20.47 q ha^{-1}) and stalk yield (30.88 q ha^{-1}) whereas it considerably decreased with an increase in B application rate. This makes it quite evident that not even the recommended 2 kg B ha^{-1}, should be administered consistently without first assessing the soil, since this could lead to boron accumulation, toxicity and decreased crop yield. The B toxicity might be due to direct effect of B on germination, pollen viability, fertility and seed set which reduced the sunflower seed yield and oil content also the plant growth of sunflower crop.

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