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Yield, Yield Attributes and Economics of Sunflower (*Helianthus annuus* L.) as Influenced by Boron Fertilization in Boron Deficient Alfisols of Karnataka Region

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Abstract Field experiment conducted during *kharif* 2014 sandy caly loam soils low in boron (0.33 ppm) using RCBD design with three replications and 11 treatments to study the influence of boron fertilization on yield, yield parameters and economics of sunflower. The results revealed that significantly higher seed yield (2176 kg ha^{-1}), oil yield (858.5 kg ha^{-1}), harvest index (0.37), capitulum diameter (15.97 cm), test weight (5.22 g), volume weight (43.87 g 100 ml^{-1}), number of filled seeds (1195 capitulum^{-1}), total number of seeds (1233 capitulum^{-1}), and lower number of unfilled seeds (37.88 capitulum^{-1}) and per cent chaffiness (3.07) were recorded with the application of RDF + borax @ 0.4% spray to capitulum at ray floret opening stage. Significantly lesser seed yield (1385 kg ha^{-1}), oil yield (536.3 kg ha^{-1}), capitulum diameter (12.80 cm), test weight (4.38 g), number of filled seeds (830.6 capitulum^{-1}), and highest number of unfilled seeds (135.3 capitulum^{-1}) and per cent chaffiness (13.99) were recorded with the application of RDF + borax seed treatment @ 6 g kg of seeds^{-1}. Highest B: C ratio (3.37) was recorded in RDF + borax @ 0.4% spray to capitulum at ray floret opening stage over all other treatments.

Keywords Sunflower, Boron fertilization, Chaffiness.

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Introduction

Oil seeds play an important role in Indian agriculture as food and industrial commodity. India is the largest producer of oilseeds in the world in terms of output and in terms of area. Among the oilseed crops, sunflower (*Helianthus annuus* L.) is one of the major oilseed crop and widely cultivated. This crop has gained importance because of its wider adaptability to different agro-climatic regions and cropping pattern, shorter duration of maturity, photo insensitive, drought tolerance and excellent quality oil. The oil accounts for 80% of the value of sunflower crop and it is a wealthy source of vitamin A and D. Its oil is called premium oil due to the presence of oleic acid

Table 1. Capitulum diameter (cm), test weight (g 100 seeds^{-1}), volume weight (g 100 ml^{-1}), seed yield (g plant^{-1}), number of seeds (capitulum^{-1}) and chaffiness (%) as influenced by different levels and methods of borax application.

Treatments	Capitulum diameter	Test weight	Volume weight	Seed yield	Number of seeds capitulum^{-1} Filled	Unfilled	Total	% Chaffiness
T_1: RDF (90:90:60 kg NPK ha^{-1} and FYM 7.5 t ha^{-1})	14.40	4.58	41.12	38.47	953.4	87.71	1041	8.43
T_2: Borax @ 2 g kg^{-1} seed as ST	14.67	4.73	41.93	40.20	991.7	64.35	1056	6.10
T_3: Borax @ 4 g kg^{-1} seed as ST	13.87	4.41	39.65	34.20	881.5	93.99	975.4	9.65
T_4: Borax @ 6 g kg^{-1} seed as ST	12.80	4.38	38.86	31.83	830.5	135.3	965.8	13.99
T_5: T_1 + Soil application of borax @ 11 kg ha^{-1}	15.00	4.78	43.37	40.77	1016	56.09	1073	5.23
$^{T}{}_{6}$: T_1 + Borax at 0.2% spray to capitulum at RFO stage	15.83	4.92	43.63	47.47	1122	50.97	1173	4.35
T_7: T_1 + Borax at 0.4% spray to capitulum at RFO stage	15.97	5.22	43.87	48.87	1195	37.88	1233	3.07
T_8: T_1 + Borax at 0.6% spray to capitulum at RFO stage	15.03	4.75	42.09	40.73	998.6	59.51	1058	5.62
T_9: T_1 + Dusting of borax @ 2 kg ha^{-1} on capitulum at RFO stage	15.43	4.94	43.36	41.80	1069	56.21	1125	5.10
T_{10}: T_1 + Dusting of borax @ 3 kg ha^{-1} on sapitulum at RFO stage	14.97	4.70	41.82	39.33	986.1	63.29	1049	6.05
T_{11}: T_1 + Dusting of borax @ 4 kg ha^{-1} on sapitulum at RFO stage	14.77	4.56	41.83	38.67	966.1	77.60	1043	7.48
SEm ±	0.23	0.13	0.77	2.48	38.50	5.62	40.67	0.52
CD (p=0.05)	0.68	0.38	2.27	7.31	113.58	13.27	119.9	1.52
CV (%)	6.9	7.4	8.1	10.67	6.9	9.67	6.57	9.60

(16.2%) and linoleic acid (72.5%) with higher (60%) polyunsaturated fatty acid.

Though the crop has the yield potential of 2.3 to 2.5 tonnes ha^{-1} under favorable conditions but the average productivity level is India is only 0.79 tonnes ha^{-1}, the productivity of sunflower in India is much lower than the world's average. One of the main reasons for low productivity of sunflower is poor seed setting and high per cent of chaffy seeds in the centre of capitulum. The reasons for poor seed setting are self-incompatibility, absence of pollen vectors, nutrient inbalance, less irrigation. Among these factors, imbalanced fertilization is one of the aspect of crop production that can be regulated by the farmer to effect increased yields. But as yields increase and the major nutrient requirements are more efficiently met through macronutrient fertilization, micronutrient deficiencies are more likely to become limiting for production. Boron is one such element in sunflower production since sunflowers have an apparently high boron requirement. At flowering, B deficiency can affect pollen viability and abortion of stamens and pistils which contribute to poor seed set due to malformed capitulum and consequently low seed yield. Hence the application of boron in sunflower crop helps to increase growth, pollen germination, pollen viability, stigmatic receptivity and translocation of photosynthates from source to sink, resulting in higher seed set and yield.

B deficiency can be treated by application of soluble B fertilizer such as borax [($Na_2B_4O_7$. $10H_2O$), 11% B] at the time of sowing or foliar application at ray floret opening stage. Inspite of different methods of boron application, seed treatment with boron helps in improving germination percentage and early seedling vigor hence helps in better early crop growth. The amount of fertilizers required is also less in this method. Being an easy and cost effective method, seed treatment offers an alternate option for resource poor farmers. But information available on these methods is limited. Therefore, this investigation on boron nutrition in sunflower (*Helianthus annuus* L.) at dif-

Table 2. Seed yield (kg ha^{-1}), stalk yield (kg ha^{-1}), oil content (%), oil yield (kg ha^{-1}) and harvest index of sunflower as influenced by different levels and methods of borax application. DAS: Days after sowing, RDF: Recommended dose of fertilizer, ST: Seed treatment, RFO: Ray floret opening.

	Treatments	Seed yield	Stalk yield	Oil content	Oil yield	Harvest index
T_1:	RDF (90:90:60 kg NPK ha^{-1} and FYM 7.5 t ha^{-1})	1662	4110	39.06	649.4	0.30
T_2:	T_1 + Borax @ 2 g kg^{-1} seed as ST	1725	4202	38.85	670.0	0.31
T_3:	T_1 + Borax @ 4 g kg^{-1} seed as ST	1425	3861	38.74	551.9	0.25
T_4:	T_1 + Borax @ 6 g kg^{-1} seed as ST	1385	3705	38.76	536.3	0.22
T_5:	T_1 + Soil application of borax @ 11 kg ha^{-1}	1827	4471	39.33	712.7	0.31
T_6:	T_1 + Borax @ 0.2% spray to capitulum at RFO stage	1958	4446	38.53	754.3	0.33
T_7:	T_1 + Borax @ 0.4% spray to capitulum at RFO stage	2176	4538	39.44	858.5	0.37
T_8:	T_1 + Borax @ 0.6% spray to capitulum at RFO stage	1802	4235	38.69	701.0	0.28
T_9:	T_1+ Dusting of borax @ 2 kg ha^{-1} on capitulum at RFO stags	1842	4267	38.92	718.7	0.31
T_{10}:	T_1+ Dusting of borax @ 3 kg ha^{-1} on capitulum at RFO stags	1709	4189	39.27	671.9	0.28
T_{11}:	T_1+ Dusting of borax @ 4 kg ha^{-1} on capitulum at RFO stags	1692	4120	38.86	657.5	0.27
	SEm ±	76.58	60.98	0.40	34.36	0.01
	CD (p=0.05)	225.9	179.9	NS	96.56	0.04
	CV (%)	7.60	6.19	3.1	7.99	8.6

ferent levels and with different methods of application was carried out at Zonal Agricultural Research Station. AICRP on sunflower, GKVK, University of Agricultural Sciences, Bengaluru.

Materials and Methods

A field experiment was carried out to study the boron nutrition in sunflower (*Helianthus annuus* L.) during *kharif* 2014 at Zonal Agricultural Research Station, University of Agricultural Sciences, Bengaluru. Soil texture of the experimental site was red sandy loam with neutral pH (6.7), medium in organic carbon (0.57), nitrogen (285 kg ha^{-1}), potassium (262.5 kg ha^{-1}) and low in available boron (0.3 ppm).

KBSH-53 hybrid was used for the present experiment. These were 11 treatments combinations included for the study viz., T_1: Control (RDF- 90:90:60 kg NPK ha^{-1} and FYM 7.5 t ha^{-1}), T_2: T_1 + Borax @ 2 g kg^{-1} of seed as seed treatment, T_3: T_1 + Borax @ 4 g kg^{-1} of seed as seed treatment, T_4: T_1 + Borax @ 6 g kg^{-1} of seed as seed treatment, T_5: T_1 + Soil application of borax @ 11 kg ha^{-1}, T_6: T_1 + Borax @ 0.2% spray to capitulum at ray floret opening stage, T_7: T_1 + Borax @ 0.4% spray to capitulum at ray floret opening stage, T_8: T_1 + Borax @ 0.6% spray to capitulum at ray floret opening stage, T_9: T_1 + Dusting of borax @ 2 kg ha^{-1} on capitulum at ray floret opening stage, T_{10}: T_1 + Dusting of borax @ 3 kg ha^{-1} on capitulum at ray floret opening stage and T_{11}: T_1 + Dusting of borex @ 4 kg ha^{-1} on capitulum at ray floret opening stage.

Recommended dose of fertilizers (90:90:60 kg NPK ha^{-1} and FYM 7.5 t ha^{-1}) were applied through Urea, Single Super Phosphate and Muriate of Potash and Borax (11% B) is used as source of boron. FYM was applied at the rate of 7.5 t ha^{-1} before two weeks of sowing. According to the treatments, manually seeds were treated at 2, 4, 6 g borax kg^{-1} seeds with the help of 2% gum acasia solution @ 10 ml kg^{-1} seed and seeds were allowed to dry for 4 h at room temperature. Foliar application of borax spray @ 0.2%, 0.4% and 0.6% was carried out by taking calculated quantity of borax sprayed to capitulum according to the treatments. Dusting of borax @ 2, 3 and 4 kg ha^{-1} was done by taking calculated quantity of well ground borax in a muslin cloth and dusted on capitulum as per treatments. The yield and yield parameters were recorded at the time of harvest and B:C ratio was calculated by using cost of cultivation and gross returns. The experimental data collected on various yield components of plant was subjected to Fisher's method of analysis of variance (ANOVA) [1]. Per cent chaffiness and oil yield, harvest index, B:C ratio were

Table 3. Economics of sunflower as influenced by different levels and methods of borax application. DAS: Days after sowing, RDF: Recommended dose of fertilizer, ST: Seed treatment, RFO: Ray floret opening.

Treatments	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio	Marginal return (Rs ha^{-1})	Marginal cost (Rs ha^{-1})	MR/MC
T_1: RDF (90:90:60 kg NPK ha^{-1} and FYM 7.5 t ha^{-1})	18272	49847	31575	2.73	–	–	–
T_2: T_1 + Borax @ 2 g kg^{-1} seed as ST	18283	51743	33460	2.83	1895	11	172.3
T_3: T_1 + Borax @ 4 g kg^{-1} seed as ST	18294	42749	24455	2.34	-7097	22	-322.6
T_4: T_1 + Borax @ 6 g kg^{-1} seed as ST	18305	41545	23240	2.27	-8301	33	-251.6
T_5: T_1 + Soil application of Borax @ 11 kg ha^{-1}	19372	54796	35424	2.83	4949	1100	4.5
T_6: T_1 + Borax @ 0.2% spray to capitulum at RFO stage	18612	58730	40118	3.16	8883	340	26.1
T_7: T_1 + Borax @ 0.4% spray to capitulum at RFO stage	18752	63279	44527	3.37	15432	480	32.1
T_8: T_1 + Borax @ 0.6% spray to capitulum at RFO stage	18892	54065	35173	2.86	4218	620	6.8
T_9: T_1+ Dusting of borax @ 2 kg ha^{-1} on capitulum at RFO stags	18872	55261	36389	2.93	5414	600	9.0
T_{10}: T_1+ Dusting of borax @ 3 kg ha^{-1} on capitulum at RFO stags	18972	51276	32304	2.70	1429	700	2.0
T_{11}: T_1+ Dusting of borax @ 4 kg ha^{-1} on capitulum at RFO stags	19072	50781	31709	2.66	924.0	800	1.0

calculated by using following formulas.

$$\text{Per cent chaffiness} = \frac{\text{Number of unfilled seeds per capitulum}}{\text{Total number of seeds per capitulum}} \times 100$$

$$\text{Oil yield (kg ha}^{-1}\text{)} = \frac{\text{Oil percent in seed} \times \text{Seed yield (kg ha}^{-1}\text{)}}{100}$$

$$\text{Harvest index} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}}$$

$$\text{Benefit cost ratio} = \frac{\text{Gross returns (Rs ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs ha}^{-1}\text{)}}$$

Results and Discussion

The results pertaining to yield, yield parameters and economics as influenced by boron nutrition in sunflower (*Helianthus annuus* L.) are discussed as follows.

Yield and yield attributes were significantly influenced by different levels and methods of borax application in sunflower. Among the different treatments, seed yield was significantly higher (2,176 kg ha^{-1}) with the application of RDF + borax @ 0.4% spray to capitulum at ray floret opening stage. However RDF + borax @ 0.2% spray to capitulum at ray floret opening stage was also found to be on par with (1,958 kg ha^{-1}) compared to control (1,662 kg ha^{-1}). Higher seed yield might be associated with spraying of borax met the crop demand for boron at right time when pollen tubes were to be developed, which may result in increased pollen germination and pollen viability and also boron role in translocation of photosynthates towards sink that due improved the seed setting percentage in the capitulum. Foliar spraying helps to meet the crop nutrient requirement quickly compared to other methods of application because boron is applied in the dissolved form, which resulted in better absorption by the plant.

Higher seed yield was due to higher yield parameters like capitulum diameter (15.97 cm), higher capitulum diameter facilitates more number of seed in turn increases the yield. So, RDF + borax @ 0.4% spray to capitulum at ray floret opening stage produced significantly higher number of seed, number of filled seeds, test weight, seed yield plant^{-1} (1,233 capitulum^{-1}, 1,195 capitulum^{-1}, 5.22g and 48.87 g plant^{-1}, respectively) which was on par with RDF + borax @ 0.2% spray to capitulum at ray floret opening stage (1,173 capitulum^{-1}, 1122 capitulum^{-1}, 4.92 g and 47.47 g plant^{-1} respectively). This was mainly due to boron role in translocation of photosynthates from source to sink which resulted in more accumulation of photosynthates. The results are in conformity with the findings of Patil et al. [2].

RDF + borax @ 0.4% spray to capitulum at ray floret opening stage resulted proper seed filling due to boron role in translocation of sugars from source to sink resulted in higher pollen germination and fertilization, hence resulted in lower number of unfilled seeds and chaffiness percentage (37.88 capitulum^{-1}, 3.07% respectively) followed by application of RDF + borax @ 0.2% spray to capitulum at ray floret opening stage (50.97 capitulum^{-1} and 4.35%, respectively). The similar result was also reported by Arvindakumar et al. [3].

Among different treatments higher oil yield (858.5 kg ha^{-1}) was recorded with the application of RDF + borax @ 0.4% spray to capitulum at ray floret opening stage and which was on par with application of RDF + borax @ 0.2% spray to capitulum at ray floret opening stage (754.3 kg ha^{-1}). This was mainly due to higher seed yield (2,176 kg ha^{-1} and 1958 kg ha^{-1}, respectively) and oil percentage (39.44% and 38.53%, respectively). The oil content is the varietal feature which did not influenced by these treatments. The similar result was reported by Muhammad et al. [4].

Application of RDF (90:90:60 kg NPK ha^{-1} and FYM 7.5 t ha^{-1}) along with seed treatment with borax at 6 g kg^{-1} of seed produced significantly lowest seed yield (1,385 kg ha^{-1}), compared to all other treatments. Yield components such as capitulum diameter (12.80 cm), number of seeds capitulum^{-1} (965.8), number of filled seeds capitulum^{-1} (830.4), 100 seed weight (4.38 g) and seed yield plant^{-1} (31.83 g) are all low with seed treatment with borax @ 6 g kg^{-1} of seed. All these might have contributed for lower seed yield. Further it had highest chaffiness (13.99%) indicating more number of unfilled seed capitulum^{-1} (135.3). This was mainly due to the seed treatment at higher level causing toxicity to seed and resulted in reduction of growth and development, photosynthetic activity and translocation of photosynthates to sink further resulted in decreased yield and yield attributes.

Among different treatments, application of RDF + borax @ 0.4% spray to capitulum at ray floret opening stage recorded significantly higher stalk yield (4,538 kg ha^{-1}) and harvest index (0.37) which was on par RDF + borax @ 0.2% spray to capitulum at ray floret opening stage (4,446 kg ha^{-1}, 0.33 respectively). The increase in stalk yield mainly due to boron role in increasing photosynthesis which resulted in higher growth and development. Same results were also reported by Ayad Shaker et al. [5]. The increase in harvest index may be attributed to better utilization of photo-assimilates for seed formation. However, RDF + seed treatment with borax @ 6 g kg^{-1} of seed recorded significantly lower stalk yield (3,705 kg ha^{-1}) and harvest index (0.22), owing to toxicity of borax at the time of sowing reduced growth and development which hindered the production of photosynthates and transolocation of photosynthates to economic portion.

Effect of different levels and methods of borax application on economics of sunflower cultivation

Spraying of borax @ 0.4% to capitulum at ray floret opening stage along with RDF (90:90:60 kg NPK ha^{-1} and FYM 7.5 t ha^{-1}) recorded higher B: C ratio (3.37) and net returns (Rs 43,527 ha^{-1}) followed by RDF + borax @ 0.2% spray to capitulum at ray floret opening stage (3.16 and Rs 39,118 ha^{-1} respectively). Higher net return and B: C ratio was achieved due to higher seed yield resulted in high amount of gross returns (Rs 63,279 ha^{-1} and Rs 58,730 ha^{-1}, respectively).

Higher marginal return to marginal cost ratio (32.1) was obtained with application of RDF + borax @ 0.4% spray to capitulum at ray floret opening stage followed by the application of RDF + borax @ 0.2% spray to capitulum at ray floret opening stage (26.1).

Important feature associated with sunflower, the yield and yield parameters mainly depends on boron nutrition at the time of ray floret initiation stage which significantly improves the seed setting percentage, test weight, number of filled seed capitulum^{-1} and chaffiness percentage. By proper fertilization, filling of seeds contributes a lot towards economic yield compared to other growth parameters. This result was in conformity with the findings of Patil et al. [2].

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