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Response of Sunflower - Horse Gram and Sunflower - Avare Rotation to Zinc and Boron Nutrition

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Abstract

A field experiment was conducted at Dryland Agriculture Project, UAS, GKVK, Bengaluru in three years to study the effect of zinc and boron nutrition on sunflower - horse gram and sunflower - avare rotation. The experiments were laid out in randomized complete block design having six treatments and replicated thrice. The hybrid sunflower (KBSH-1), horse gram (PHG-9) and avare (Hebbal avare) is used as test crop. Significantly higher sunflower seed yield (19.44 q ha^{-1} and 18.43 q ha^{-1}) was observed with soil application of NPK+ $ZnSO_4$ @12.5 kg ha^{-1} + Borax @ 10 kg ha^{-1} in sunflower-horse gram and sunflower-avare cropping system, respectively. Soil parameters like pH, EC, DTPA extractable Fe, Mn, Cu, and Mo were non significant in both the cropping systems. Application of NPK + $ZnSO_4$ @12.5 kg ha^{-1} + Borax @ 10 kg ha^{-1} along with microbial inoculants encouraged the activity of all the soil microorganisms to the maximum extent.

Keywords : Avare, boron, cropping system, horse gram, sunflower, zinc

Sunflower (*Helianthus annuus* L.) by virtue of its short duration, wide adaptability, photo period insensitivity and availability of promising hybrids, has stabilized its area and production in India. However, the average productivity of sunflower is very low (550 kg ha^{-1}) from an area of 1.71 m ha (Damodaran and Hegde,2005) largely due to poor nutritional management and lack of scientific based crop rotation. Adoption of hybrids, intensive agriculture, low use of organic manures and increased use of micronutrients free fertilizers, soils has become micronutrient deficient. Micronutrients play a major role in increasing seed setting, and influence growth and yield. Among the micronutrients, boron and zinc play an important role in seed setting and yield of sunflower. Zinc plays multiple roles in activating more than 300 enzymes in plants, involved in auxin synthesis and protein synthesis. Boron deficiency has been reported in 80 countries around the world and in 132 crops. Boron can influence photosynthesis, respiration and activate number of enzymatic systems for protein and nucleic acid metabolism in plants (Chowdhury *et al*., 2010). Boron is involved in the reproduction of plants and germination of pollen spikelet (Bolanos *et al*., 2004). The role of B in stimulating pollen tube growth is well established and positive correlation could be found between B in the plant and the number of flowers, the proportion of flowers not aborted and fruit weight (O'Niell *et al*., 2004). Therefore, applications of micronutrients in addition to essential major elements have gained practical significance.

The beneficial effect of pulse crops in improving soil health and sustaining productivity has long been realized. On account of biological nitrogen fixation, addition of considerable amount of organic matter through root biomass and leaf fall, deep root systems, mobilization of nutrients, protection of soil against erosion and improving microbial biomass, they keep soil productive and alive by bringing qualitative changes in physical, chemical and biological properties. As a result of this, the productivity of cereals following a preceding grain legume often increases and corresponds to 40-60 kg N equivalent. Besides this, the cost of cultivation significantly decreases and returns per rupee investment increase. In the present scenario of degradation of natural resources, the value of pulses is far more important (Singh *et al*., 2014). It is, therefore, imperative that grain legumes are given a preference in cropping systems in dryland areas. With this background, an experiment was carried out during *kharif* to find out the response of boron and zinc on growth and yield parameters of sunflower-horsegram and sunflower – avare cropping system.

Material and Methods

A field experiment was conducted at DLAP, University of Agricultural Sciences, Bengaluru, in three years of crop rotation systems. The experiment was laid out in randomized complete block design having six treatments and replicated thrice in red sandy loam soil with pH ranging from slightly acidic to neutral (4.65 to 5.65), low to medium in organic carbon (0.36-0.59 %), available nitrogen and high in both phosphorus and potassium. The content of sulphur, zinc, boron, and molybdenum were low, where as the soils were high in iron, manganese and copper status. The amount of rainfall received during cropping system is 475.6 mm. The treatment comprised of T_1- Control, T_2 - FYM (only), T_3 - NPK + FYM (Rec), T_4 - NPK + $ZnSO_4$ @12.5 kg ha^{-1} (soil), T_5 - NPK + Borax @ 10 kg ha^{-1} (soil), T_6 - NPK + $ZnSO_4$ @12.5 kg ha^{-1} + Borax @10.0 kg ha^{-1} (soil). The recommended fertilizer dose of N, P_2O_5 and K_2O per hectare was applied in the form of Urea, SSP and MOP as a basal at the time of sowing. Five plants from net plot area were randomly selected and observations on growth and yield parameters were recorded at harvest. Yield and its components were determined at maturity stage. The soil and plant samples were collected after harvest of each crop and were analyzed for macro and micro nutrients by adopting standard procedure. Micronutrient use efficiency and B:C ratio was calculated by using following formulae.

$$\text{Micronutrient use Efficiency} = \frac{\text{Per unit of additional yield produced}}{\text{Per unit of micronutrient applied}}$$

$$\text{B : C ratio} = \frac{\text{Gross returns (Rs. ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs. ha}^{-1}\text{)}}$$

All the data pertaining to the present investigation were statistically analyzed as per the method described by Panse and Sukhatme (1967). The level of significance used in 'F' and 't' test was p= 0.05.

Results and Discussion

Effect of zink and boron on yield parameters

Sunflower-horse gram: The data on the influence of zinc and boron application on growth and yield attributes are presented in Table I. The results found to be significant. Among the treatments, soil application of $ZnSO_4$ @ 12.5 kg ha^{-1} and Borax @ 10 kg ha^{-1} registered significantly higher head diameter (17.06 cm), 1000 seed weight (50.59 g), seed yield (19.44 q/ha) and B:C ratio (2.61) which were significantly on par with the soil application of $ZnSO_4$ @ 12.5 kg ha^{-1} followed by NPK+FYM. Further, it was noticed that 44 per cent increase in yield with the application of $ZnSO_4$ @ 12.5 kg ha^{-1} + Borax @ 10 kg ha^{-1} as compared to control.

It is due to boron which is immobile in plant systems and might have helped to meet the demand for the crop at right time when pollen tubes were to be developed. Moreover, spraying of borax made the boron available directly on the capitulum leading to lower percentage of chaffiness, higher number of filled seeds, higher seed weight and seed yield per plant. Further, spraying of $ZnSO_4$ might have influenced the seed yield synergistically with its favorable effect on chlorophyll (a and b) and auxin synthesis, water uptake and photosynthesis (Siddiqui *et al*., 2009).

Sunflower-avare: Significantly higher seed yield (18.43 q ha^{-1}) was observed with soil application of $ZnSO_4$ @ 12.5 kg ha^{-1} and Borax @ 10 kg ha^{-1} which is mainly due to higher head diameter (17.83 cm), and 1000 seed weight (50.72 g), which were statically on par with the soil application of $ZnSO_4$ @ 12.5 kg ha^{-1} (17.49 q ha^{-1}) and NPK+FYM (17.49 q ha^{-1}). Further, it was noticed that 30.89 per cent increase in yield with the application of $ZnSO_4$ @ 12.5 kg ha^{-1} + Borax @ 10 kg ha^{-1} as compared to control. The combined effect of FYM and micronutrients has resulted in quick germination, uniform and vigorous plant stand as compared to other treatments. The increase in seed yield has attributed to better root growth resulting in higher uptake of nutrients inturn higher yields. Higher B:C ratio (2.38) was obtained with soil application of $ZnSO_4$ @ 12.5 kg ha^{-1} and Borax @ 10 kg ha^{-1}. The results are also in line with those of Khan *et al.* (2010) who displayed that highest seed yields and 1000-seed weight of sunflower in treatment that received combined application of 10 kg zinc and 5 kg iron ha^{-1}. The increase in yield of sunflower may be due to increased growth attributes, leaf area expansion and dry matter accumulation. The combined application of zinc and boron at optimum level helped in fixation

TABLE I

Effect of zinc and boron on yield and yield parameters of sunflower in sunflower – horse gram and sunflower- avare crop rotation

Treatment	Sunflower									
	Sunflower - horse gram					Sunflower - avare				
	Head diameter (cm)	1000 seed weight (g)	Seed yield (q ha^{-1})	MUE (kg kg^{-1})	B : C Ratio	Head diameter (cm)	1000 seed weight (g)	Seed yield (q ha^{-1})	MUE (kg kg^{-1})	B : C Ratio
T_1- Control (only NPK)	12.33	39.00	13.50	-	1.70	12.13	40.00	14.08	-	1.72
T_2- FYM (Rec)	13.83	40.37	15.27	-	1.49	13.24	42.64	15.27	-	1.50
T_3- NPK+FYM (Rec)	14.56	43.47	18.31	-	1.40	14.66	48.00	17.49	-	1.86
T_4- NPK+$ZnSO_4$@12.5 kg ha^{-1}	15.94	44.08	19.42	47.36	2.28	16.37	48.72	17.49	27.28	2.00
T_5- NPK+Borax@10.0 kg ha^{-1} (soil)	14.50	42.38	16.66	31.60	1.91	14.00	44.39	16.32	22.40	1.99
T_6- NPK+$ZnSO_4$@12.5 kg ha^{-1} + Borax @10.0 kg ha^{-1}	17.06	50.59	19.44	26.40	2.61	17.83	50.72	18.43	19.33	2.38
S.Em±	0.33	1.33	0.27	-	-	0.21	0.27	0.45	-	-
CD @ 5 %	1.01	3.99	0.81	-	-	0.63	0.82	1.36	-	-

MUE- Micronutrient Use Efficiency (kg of additional produce of micronutrient applied)

of atmospheric nitrogen due to increased nitrogenous enzyme activity. In addition, boron helps in retention of flower drops and improvement in grains setting (Patil *et al*., 2006).

Nutrient uptake by sunflower as influenced by application of zinc and boron

Soil fertility status and nutrients uptake in sunflower – horse gram : Nutrients status of soil after harvest of sunflower-horse gram was found to be significant with application of zinc, boron and FYM. Results of OC, available N, P, K, S, Zn and B status in soil after harvest of sunflower are presented in Table II. Parameters like pH, EC, DTPA extractable Fe, Mn, Cu, and Mo content of soils were non significant. The content of organic carbon was higher in FYM applied treatments (T_2 and T_3) and lower was in control (T_1). The higher values of Zn (1.33 ppm), B (0.69 ppm) and sulphur (11.9 ppm) were recorded with application of NPK+$ZnSO_4$ @12.5 kg ha^{-1} + Borax @10 kg ha^{-1}.

Significant differences were observed with respect to uptake of all nutrients (Table III). The higher amount of nutrients uptake were observed with application of NPK+$ZnSO_4$ @12.5 kg ha^{-1} + Borax @10 kg ha^{-1}. The combined application of zinc and borax resulted in higher uptake of nutrients compared to individual application.

Soil fertility status and nutrients uptake in sunflower – avare : Application of zinc and boron did not show any significant difference with soil parameters like pH, EC, DTPA extractable Fe, Mn, Cu, and Mo in soils after harvest of sunflower. However, OC, available N, P, K, S, Zn and B found significant in soil after harvest of sunflower are presented in Table IV. The content of organic carbon was higher in FYM applied treatments (T_2 and T_3) and lower was in control (T_1). The higher values of Zn (1.30 ppm), B (0.55 ppm) and sulphur (11.5 ppm) were recorded with application of NPK+$ZnSO_4$ @12.5 kg ha^{-1} + Borax @10 kg ha^{-1}.

The uptake of nutrients by sunflower crop as influenced by application of zinc and borax are presented in Table V. Significant differences were observed with respect to uptake of all nutrients. The higher amount of nutrients uptake were observed with treatment received NPK+$ZnSO_4$ @12.5 kg ha^{-1} + Borax @10 kg ha^{-1}. The combined application of zinc and borax resulted in higher uptake of nutrients compared to individual application.

Influence of micronutrients on the activity of soil microorganisms and soil enzymes in horse gram cropping system

The data on the population of soil microorganisms and soil enzymes as influenced by application of micronutrients at different stages of horse gram is presented in Table VI and VII.

Population of microorganisms found significant with respect to the different treatments. At 50 per cent/g soil), fungi (26.0 X 10^4 cfu/g soil), actinomycetes (12.0 X 10^3 cfu/g soil), PSM's (32.6 X 10^4 cfu/g soil), *Rhizobium* spp (25.0 X 10^4 cfu/g soil) and free living nitrogen fixers (46.0 X 10^4 cfu/g soil) with application of FYM along with recommended dose of NPK compared to control bacteria (23 X 10^5cfu/g soil), fungi (10.0 X 10^4 cfu/g soil), actinomycetes (6.0 X 10^3 cfu/g soil), PSM's (11.0 X 10^4 cfu/g soil), *Rhizobium* spp (9.0 X 10^4 cfu/g soil) and free living nitrogen fixers (22.6 X 10^4 cfu/g soil) (Table VI). However, slightly higher population of micro organisms trend was noticed with other treatments. Similar trend was observed at harvest in soil after harvest of sunflower.

The activity of soil enzymes dehydrogenase (176 µg TPF/g soil), urease (54 µg TPF/g soil), acid and alkaline phosphatase (191 and 59 µg PNP/g soil / h, respectively) enzymes activity were higher with the application of FYM along with the recommended dose of NPK (Table VII). The activity of soil enzymes was higher in the micronutrients applied treatments compared to control at 50 per cent flowering and similar trend was noticed at harvest of sunflower. This might be due to application of FYM which made available in to microbes for multiplication.

From the above experiment, it could be concluded that the application of NPK+ $ZnSO_4$ @12.5 kg ha^{-1} + Borax @ 10 kg ha^{-1} has recorded significantly higher seed yield of sunflower in sunflower-horse gram and sunflower-avare. Soil parameters like pH, EC, DTPA extractable Fe, Mn, Cu, and Mo content were non

TABLE II

Soil fertility status after harvest of sunflower in sunflower-horse gram cropping system in micronutrient management studies

Treatment	pH	EC (dS m^{-1})	OC (%)	Av N	P_2O_5	K_2O	S	Fe	Mn	Cu	Zn	B	Mo
				kg ha^{-1}			ppm						
T_1- Control (only NPK)	5.23	0.07	0.41	189.0	68.0	170.0	8.60	31.0	20.0	0.88	0.88	0.39	0.19
T_2- FYM (Rec)	5.19	0.07	0.52	75.0	55.0	158.0	8.30	33.0	19.0	0.85	0.86	0.35	0.18
T_3- NPK+FYM (Rec)	5.20	0.08	0.53	219.0	68.0	179.0	10.10	32.0	21.0	0.88	1.06	0.41	0.21
T_4- NPK+$ZnSO_4$@12.5 kg ha^{-1}	5.10	0.07	0.43	192.0	67.0	172.0	11.30	31.0	20.0	0.87	1.29	0.39	0.19
T_5- NPK+Borax@10.0 kg ha^{-1} (soil)	5.30	0.08	0.44	188.0	65.0	170.0	9.50	32.0	19.0	0.85	0.89	0.60	0.20
T_6- NPK+$ZnSO_4$@12.5 kg ha^{-1} + Borax @10.0 kg ha^{-1}	5.25	0.08	0.42	190.0	67.0	173.0	11.90	32.0	21.0	0.86	1.33	0.69	0.19
S.Em±	0.14	0.03	0.02	3.64	1.52	2.62	0.27	0.47	0.24	0.02	0.03	0.02	0.02
CD @ 5 %	NS	NS	0.05	10.92	4.56	7.85	0.8	NS	NS	NS	0.09	0.06	NS

TABLE III

Nutrient uptake by sunflower as influenced by application of zinc and boron nutrition in sunflower-horse gram cropping system

Treatments	N	P	K	S	Fe	Mn	Cu	Zn	B	Mo
	kg ha^{-1}		g / ha							
T_1- Control (only NPK)	47.8	14.2	45.6	11.5	915	478	13.5	84.2	40.4	7.5
T_2- FYM (Rec)	48.1	14.4	46.2	11.7	920	483	14	85.3	41.5	7.8
T_3- NPK+FYM (Rec)	49.5	14.9	47.8	12.5	945	496	14.9	86.7	42.3	8.1
T_4- NPK+$ZnSO_4$@12.5 kg ha^{-1}	50.6	15.3	48.3	13	959	510	15.6	87.5	43.6	8.5
T_5- NPK+Borax@10.0 kg ha^{-1} (soil)	49.3	14.6	47.4	11.8	930	492	14.7	86.6	43.1	8.3
T_6- NPK+$ZnSO_4$@12.5 kg ha^{-1} + Borax @10.0 kg ha^{-1}	53.2	15.8	49.8	13.8	966	529	16.3	89.8	45.7	8.8
S.Em±	0.23	0.10	0.41	0.39	11.57	6.84	0.24	0.51	0.91	0.14
CD @ 5 %	0.70	0.30	1.23	1.16	34.68	20.51	0.71	1.54	2.74	0.42

TABLE IV

Soil fertility status after harvest of sunflower in sunflower-avare cropping system in micronutrient management studies

Treatment	pH	EC (dS m^{-1})	OC (%)	Av N	P_2O_5	K_2O	S	Fe	Mn	Cu	Zn	B	Mo
				kg ha^{-1}			ppm						
T_1- Control (only NPK)	5.28	0.07	0.39	211.0	67.0	183.0	8.8	28.0	20.0	0.83	0.88	0.4.0	0.19
T_2- FYM (Rec)	5.10	0.06	0.48	188.0	51.0	165.0	8.2	27.0	19.0	0.81	0.79	0.39	0.18
T_3- NPK+FYM (Rec)	5.15	0.07	0.49	226.0	75.0	189.0	9.3	29.0	19.0	0.90	0.98	0.40	0.20
T_4- NPK+$ZnSO_4$@12.5 kg ha^{-1}	5.20	0.08	0.41	203.0	64.0	185.0	11.9	28.0	19.0	0.88	1.23	0.40	0.19
T_5- NPK+Borax@10.0 kg ha^{-1} (soil)	5.26	0.08	0.39	205.0	68.0	188.0	10.2	28.0	20.0	0.89	0.87	0.51	0.19
T_6- NPK+$ZnSO_4$@12.5 kg ha^{-1} + Borax @10.0 kg ha^{-1}	5.21	7.00	0.40	210.0	70.0	187.0	11.5	29.0	20.0	0.9	1.30	0.55	0.20
S.Em±	0.15	0.03	0.02	4.25	3.11	3.22	0.30	0.6	0.61	0.04	0.07	0.02	0.02
CD @ 5 %	NS	NS	0.06	12.74	9.33	9.67	0.91	NS	NS	NS	0.22	0.08	NS

TABLE VI

Population of soil microorganisms as influenced by application of zinc and boron in horse gram

Treatments	Population of soil microorganisms (x 10 n cfu /g soil) at 50 % flowering						Population of soil microorganisms (x 10 n cfu /g soil) harvest					
	B ($x 10^5$)	F ($x 10^4$)	A ($x 10^3$)	PSM's ($x 10^4$)	Rhi ($x 10^4$)	NF ($x 10^4$)	B ($x 10^5$)	F ($x 10^4$)	A ($x 10^3$)	PSM's ($x 10^4$)	Rhi ($x 10^4$)	NF ($x 10^4$)
T_1- Control (only NPK)	23.0	10.0	6.0	11.0	9.0	22.6	12.0	6.0	3.3	9.0	6.0	13.0
T_2- FYM (Rec)	34.0	20.0	11.0	25.3	18.0	43.0	25.0	15.0	8.0	15.0	15.6	22.3
T_3- NPK+FYM (Rec)	42.0	26.0	12.0	32.6	25.0	46.3	31.3	17.6	8.6	21.3	19.3	30.0
T_4- NPK+$ZnSO_4$@12.5 kg ha^{-1}	21.6	15.3	6.0	20.0	21.3	40.3	11.3	8.0	4.0	11.0	16.0	26.0
T_5- NPK+Borax@10.0 kg ha^{-1} (soil)	30.0	14.0	7.6	25.0	17.3	32.0	22.0	7.0	3.3	12.6	16.6	20.0
T_6- NPK+$ZnSO_4$@12.5 kg ha^{-1} + Borax @10.0 kg ha^{-1}	25.0	22.0	8.0	28.0	23.6	39.0	18.0	10.6	4.3	16.3	17.0	21.6
S.Em±	1.94	1.10	0.62	1.38	0.88	1.33	1.33	0.71	0.67	1.49	1.06	1.11
CD @ 5 %	6.11	3.47	1.96	4.35	2.77	4.20	4.19	2.25	2.13	4.70	3.34	3.51

Note:

- C-Control
- B-Bacteria, F-Fungi, A-Actinomycetes, PSM's-Phosphate solubilizing microorganisms, Rhi- Rhizobium, NF- Free living nitrogen fixers
- Initial populations of microorganisms at the experimental site was B-$6x10^5$, F-$8x10^3$, A-$7x10^3$, PSM's$11x10^4$, Rhi-$12x10^4$ and NF-$19x10^3$

TABLE VII

Effect of zinc and boron on the soil enzymes in horse gram

Treatment	Soil enzyme activity at 50% flowering				Soil enzyme activity at harvest			
	Dehydro genase (µg TPF / F soil / 24h)	Urease (µg NH4 / g soil / 2h)	Phosphatase (µg PNP / g soil / h)		Dehydro genase (µg TPF / F soil / 24h)	Urease (µg NH4 / g soil / 2h)	Phosphatase (µg PNP / g soil / h)	
			Acid	Alkaline			Acid	Alkaline
T_1- Control (only NPK)	80	22	129	36	51	18	105	24
T_2- FYM (Rec)	160	40	186	52	132	29	140	39
T_3- NPK+FYM (Rec)	176	54	191	59	149	32	152	46
T_4- NPK+ZnSO4@12.5 kg ha-1	72	35	160	41	50	26	130	29
T_5- NPK+Borax@10.0 kg ha-1 (soil)	120	30	169	45	110	25	134	34
T_6- NPK+ZnSO4@12.5 kg ha-1 + Borax @10.0 kg ha-1	90	51	165	42	58	30	131	31

significant in both the cropping systems. Application of NPK + $ZnSO_4$ @12.5 kg ha^{-1} + Borax @ 10 kg ha^{-1} encouraged the activity of all the soil microorganisms to the maximum extent

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