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Effect of Zinc Sulphate and Boron Nutrition for Enhancing the Productivity of Castor-Finger Millet Rotation System

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Abstract

A field experiment was conducted to studay the effect of zinc sulphate and boron nutrition for enhancing the productivity of castor and finger millet based cropping system during *kharif* season at DLAP, University of Agricultural Sciences, Bengaluru. The experiment was laid out in randomized complete block design having ten treatments replicated thrice with castor (DCH-9) genotype and (GPU-28) finger millet. The rainfall received during cropping system is 537. 7 (castor) and 566.2 mm (finger millet). The treatment comprised of recommended NPK with different levels of Zn and B with and without FYM. Among the treatments, soil application of Zn sSO_4 @12.5 kg / ha and Borax @ 10.0 kg / ha recorded significantly higher plant height (82.20 and 84 cm, respectively), higher no. of tillers/plant (3.98 and 4.10, respectively), no. of leaves / plant (26.8 and 33.50, respectively), number of fingers / earhead (7.8 and 8.67, respectively), grain yield (32.6 and 25.10 q / ha, respectively) and straw yield (43.96 and 33.14 q / ha, respectively) compared to control in finger millet- castor and finger millet- finger millet cropping system. Whereas, in castor- castor and castor-finger-millet system significantly higher plant height (181 and 166 cm, respectively), number of spikes / plant (5.93 and 5.44, respectively), spike length (27.21 and 26.11 cm, respectively), grain yield (11.38 and 11.56 q / ha, respectively) in castor was observed in the same treatment as compared to control.

In India, micronutrient deficiencies have been reported as one of the main causes for yield plateau or even yield decline, especially in irrigated intensified systems (Takkar *et al*., 1989). While, soil and plant testing for diagnostic purposes have been more frequently employed in intensive, irrigated systems and micronutrient deficiencies have been reported with increasing frequencies (Takkar, 1996), little attention, however, has been paid to diagnose the deficiencies of micronutrients in the field under dryland farming in the semi-arid tropical (SAT) regions of India.

Minor millets are claimed to be the future foods for better health and nutrition security. Small millets comprising finger millet, kodo millet, foxtail millet, little millet, barnyard millet and proso millet are crops of antiquity known for their suitability under dry lands and contribution towards food security at farm and regional level. Among small millets, finger millet has gained a wide importance due to its high nutritional value, high fiber with proteins, minerals and essential amino acids and particularly micronutrients. Zinc has emerged as the most widespread micronutrient deficiency in soils and crops worldwide, resulting in severe yield losses and deterioration in nutritional quality (Sillanpaa, 1982).

Zinc is one of the 17 essential elements necessary for the normal growth and development of plants. It is among eight micronutrients essential for plants. Zinc plays a key role in plants with enzymes and proteins involved in carbohydrate metabolism, protein synthesis, gene expression, auxin (growth regulator) metabolism, pollen formation, maintenance of biological membranes, protection against photo-oxidative damage and heat stress, and resistance to infection by certain pathogens (Alloway, 2008). Zinc deficiency in plants retards photosynthesis and nitrogen metabolism, reduces flowering and fruit development, prolongs growth periods (resulting in delayed maturity), decreases yield and quality, and results in sub-optimal nutrient-use efficiency. The results from a large number of on-farm follow-up trials comparing soil test-based balanced nutrition with farmers' inputs showed that balanced plant nutrient management significantly increases crop productivity (Sahrawat and Wani, 2013) and enhances grain and straw quality of crops (Sahrawat *et al*., 2008). Currently farmers use only sub-optimal amounts of major nutrients. Castor is another drought resistant candidate for arid region. Intercropping castor with finger millet or rotation of castor with finger millet or castor monocropping in

providing in dry track of southern Karnataka. Keeping these aspects in mind, investigation was carried out to study the impact of micronutrients on productivity of castor-finger millet rotation system in comparision with monocropping of castor and finger millet.

Material and Methods

A field experiment was conducted at DLAP, University of Agricultural Sciences, Bengaluru, during *Kharif* in three years crop rotation systems. The experiment was laid out in randomized complete block design having ten treatments and replicated thrice. The treatment comprised of T_1- Control, T_2- NPK + FYM (Rec), T_3-NPK + $ZnSO_4$ @12.5 kg / ha (soil), T_4-NPK + $ZnSO_4$ @ 25 kg / ha (soil), T_5-NPK + Borax @5 kg / ha (soil), T_6-NPK + Borax @10 kg/ha (soil), T_7- NPK + $ZnSO_4$ @12.5 kg / ha + Borax @ 5 kg / ha (soil), T_8- NPK + $ZnSO_4$ @12.5 kg / ha + Borax @10.0 kg / ha (soil), T_9- NPK + $ZnSO_4$ @ 25 kg / ha + Borax @5 kg / ha (soil), T_{10}- NPK + $ZnSO_4$ @ 25 kg / ha + Borax @10 kg / ha (soil). Recommended dose of N, P_2O_5 and K_2O (50:40:25 in finger millet and 38:38:25kg / ha in castor) was adopted as per UAS package. 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. 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

The influence of Zinc sulphate and boron application on growth, yield and yield parameters in castor and fingermillet in fingermillet – castor, castor-castor, castor-fingermillet and fingermillet – fingermillet are presented under the following headings.

Cropping system: Finger millet – Castor

Crop : Finger millet : Higher grain yield of finger millet (32.60 q ha^{-1}) was obtained with soil application of $ZnSO_4$ @12.5 kg / ha and Borax @ 10.0 kg / ha and was higher to an extent 28.24 per cent compared to control (25.42 q ha^{-1}) (Table I). The higher seed yield was mainly due to positive association between yield attributing characters *viz.,* plant height (82.20 cm), higher no. of tillers/plant (3.98), no. of leaves/plant (26.8), number of fingers/earhead (7.80) (Table I), which were significantly higher with soil application of $ZnSO_4$ @12.5 kg/ha and Borax @ 10.0 kg/ha compared to control (63.70.cm. 3.74, 18.54 & 5.20, respectively).

Significantly higher dry weight of shoot and root (13.13 mg), germination (97 %) and vigour index (1273.61) were recorded Table-III with soil application of $ZnSO_4$ @12.5 kg / ha and Borax @ 10.0 kg / ha to control (6.30 mg, 88 %, and 554.4, respectively).

The B: C ratio was significantly influenced by soil application of zinc sulphate and boron Table-I. Soil application of $ZnSO_4$ @12.5 kg/ha recorded significantly higher B: C (2.40) compared to rest of the treatments and control (1.90). However, it was followed by soil application of $ZnSO_4$ @ 12.5 kg/ha and Borax @ 10.0 kg/ha (2.34). The increase in grain yield may be attributed to combined application of Zinc sulphate and boron, the positive response of finger millet to zinc sulphate application may be due to increased growth and yield components produced due to increased availability and better uptake of nutrients.

Finger millet –finger millet

Finger millet: Significantly higher gain yield (25.10 q ha^{-1}) and straw yield (33.14 q ha^{-1}) was obtained with soil application of $ZnSO_4$ @12.5 kg / ha and Borax @ 10.0 kg ha^{-1} and was higher to an extent 33.51 per cent compared to control (18.8, & 26.95 q ha^{-1} gain and straw yield, respectively) (Table II). The significantly higher seed yield was mainly due to positive association between yield attributing characters *viz.,* plant height (84.00 cm), higher no. of tillers / plant (4.10), no. of leaves / plant (33.50), number of fingers / ear head (8.67) with soil application of $ZnSO_4$ @12.5 kg / ha and Borax @ 10.0 kg ha^{-1} compared to control (67.42 cm, 3.24, 25.80 & 5.00, respectively). Soil application of $ZnSO_4$ @12.5 kg ha^{-1} recorded higher B:C (2.30) compared to rest of the treatments, however higher MUE (93.10 kg kg^{-1}) was noticed with Borax @ 10.0 kg ha^{-1} compared to all other treatments. Lowest MUE (9.20 kg kg^{-1}) was noticed with $ZnSO_4$ @25 kg ha^{-1}.

TABLE I

Effect of zinc and boron on growth, yield and yield parameters of Finger millet and castor at harvest in finger millet and castor based cropping system

Treatment	Finger millet-castor								Castor - castor						
	Finger millet								Castor						
	Plant height (cm)	No. of Tillers / Plants	No. of Leaves / Plants	No. of finger / ear head	Grain Yield (q / ha)	Straw Yield (q / ha)	MUE	B:C Ratio	Plant height (cm)	No. of spikes / Plants	Spike length (cm)	No. of capsules/ spike	Seed Yield (q / ha)	MUE	B:C Ratio
T1- Control,	63.70	3.74	18.54	5.20	25.42	32.58	-	1.90	126.00	3.81	19.60	21.45	9.12	-	1.40
T2- NPK + FYM (Rec),	74.32	3.65	23.10	6.10	29.05	36.17	-	1.67	149.00	4.31	22.98	26.94	9.78	-	1.10
T3- NPK + ZnSO4 @12.5 kg ha-1 (soil),	65.00	3.30	24.18	6.60	30.03	37.62	36.88	2.40	157.00	4.68	23.90	27.88	10.12	8.00	1.46
T4- NPK + ZnSO4 @25.5 kg ha-1 (soil),	66.40	3.80	19.70	5.55	25.96	32.89	21.60	1.92	129.00	3.88	19.91	22.16	9.22	0.40	1.25
T5- NPK + Borax @5 kg ha-1 (soil),	67.80	3.88	21.00	5.80	26.52	33.46	22.00	2.25	135.00	3.92	20.36	22.85	9.30	3.60	1.40
T6- NPK + Borax @10 kg ha-1 (soil),	69.00	3.46	21.86	6.20	27.41	34.24	19.90	2.26	140.00	4.00	21.26	23.59	9.46	3.40	1.44
T7- NPK + ZnSO4 @12.5 kg ha-1 + Borax @5 kg ha-1 (soil),	81.60	3.94	25.00	7.00	31.82	39.32	36.57	2.30	162.00	4.85	24.58	28.14	11.32	12.57	1.47
T8- NPK + ZnSO4 @12.5 kg ha-1 + Borax @10.0 kg ha-1 (soil),	82.20	3.98	26.80	7.80	32.60	43.96	31.90	2.34	166.00	5.44	26.11	30.68	11.56	10.84	1.50
T9- NPK + ZnSO4 @25 kg ha-1 + Borax @5 kg ha-1 (soil),	71.70	3.15	22.50	6.75	30.94	38.30	18.40	2.05	144.00	4.05	21.59	24.88	9.58	1.53	1.3
T10- NPK + ZnSO4 @25 kg ha-1 + Borax @10 kg ha-1 (soil)	77.50	3.21	22.78	5.91	27.96	35.56	7.25	2.08	152.00	4.50	23.52	27.52	10.47	3.88	1.25
S.Em+		0.71	0.11	0.65	0.30	0.46	1.11	-	5.53	0.18	0.63	0.73	0.15	-	-
CD at 5%		2.13	0.33	1.94	0.91	1.40	3.39	-	16.58	0.54	1.9	2.2	0.47	-	-

TABLE II

Effect of zinc and boron on growth, yield and yield parameters of castor and finger millet at harvest in castor –castor and finger millet – finger millet based cropping system.

Treatment	Castor Finger millet						Finger millet-Finger millet						
	Castor						Finger millet						
	Plant height (cm)	No. of Spikes / Plant	Spike length (cm)	Seed yield (q/ha)	MUE	B:C Ratio	Plant height (cm)	No. of tillers / Plant	No. of leaves / Plant	No. of finger ear head	Grain yield (q/ha)	Straw Yield (q / ha)	MUE	B:C Ratio
T1- Control,	137.00	4.74	23.15	9.42	-	0.99	67.42	3.24	25.80	5.00	18.80	26.95	-	1.95
T2- NPK + FYM (Rec),	149.00	4.96	24.65	11.23	-	0.85	79.40	3.78	31.66	5.82	23.75	31.35	-	1.58
T3- NPK + ZnSO4 @12.5 kg ha-1 (soil),	169.00	5.34	25.86	11.47	16.40	1.10	80.70	3.85	32.20	6.00	24.46	32.68	45.28	2.30
T4- NPK + ZnSO4 @25.5 kg ha- (soil),	1144.00	4.84	23.82	9.92	2.00	0.92	70.50	3.32	26.58	5.12	21.10	27.00	9.20	1.90
T5- NPK + Borax @5 kg ha-1 (soil),	140.00	4.77	23.54	9.84	8.40	1.07	71.16	3.39	27.44	5.28	21.74	27.53	58.80	1.92
T6- NPK + Borax @10 kg ha-1 (soil),	147.00	4.92	24.11	11.05	16.30	1.10	72.53	3.46	28.00	5.50	22.71	32.00	93.10	1.76
T7- NPK + ZnSO4 @12.5 kg ha-1 + Borax @5 kg ha-1 (soil),	175.00	5.36	26.54	11.66	12.80	1.16	82.20	3.98	32.70	7.64	24.76	32.75	34.06	2.10
T8- NPK + ZnSO4 @12.5 kg ha -1+ Borax @10.0 kg ha-1 (soil),	181.00	5.93	27.21	11.79	10.53	1.20	84.00	4.10	33.50	8.67	25.10	33.14	28.00	2.13
T9- NPK + ZnSO4 @25 kg ha-1 + Borax @5 kg ha-1 (soil),	155.00	5.21	25.54	11.38	6.53	1.00	77.33	3.65	30.96	5.70	23.13	29.64	14.43	1.80
T10- NPK + ZnSO4 @25 kg ha-1+ Borax @10 kg ha-1 (soil)	151.00	5.12	25.00	11.31	5.40	0.98	74.65	3.55	28.75	5.90	24.27	32.25	15.63	1.70
S.Em+	6.990.18	1.04	0.20	-	-	6.99	0.02	0.23	0.27	0.55	1.27	-	-	
CD at 5%	20.98	0.56	-	0.60	-	-	20.98	0.08	0.69	0.82	1.66	3.81	-	-

TABLE III

Effect of zinc and boron on seed quality parameter of castor based cropping system

Treatment	Castor- Finger millet			Castor- Castor			Finger millet-Castor		
		Finger millet			Castor			Finger millet	
	Dry weight of shoot & root (mg)	Germination (%)	Vigourindex	Dry weight of shoot & root (mg)	Germination (%)	Vigourindex	Dry weight of shoot & root (mg)	Germination (%)	Vigourindex
T1- Control,	6.30	88	554.4	6.30	89	560.70	1.42	92	130.64
T2- NPK + FYM (Rec),	10.01	92	920.92	9.94	94	934.36	1.60	94	150.40
T3- NPK + ZnSO4 @12.5 kg ha-1 (soil),	11.86	94	1114.84	11.72	95	1113.40	1.68	95	159.60
T4- NPK + ZnSO4 @25.5 kg ha-1 (soil),	8.60	93	799.80	8.62	93	801.66	1.55	93	144.15
T5- NPK + Borax @5 kg ha-1 (soil)	8.22	92	759.24	8.16	92	750.72	1.50	93	139.50
T6- NPK + Borax @10 kg ha-1 (soil),	9.65	94	907.10	9.77	93	908.61	1.61	94	151.34
T7- NPK + ZnSO4 @12.5 kg ha-1 + Borax @5 kg ha-1 (soil),	11.81	95	1121.95	12.37	96	1187.52	1.72	95	163.40
T8- NPK + ZnSO4 @12.5 kg ha-1 + Borax @10.0 kg ha-1 (soil),	13.13	97	1273.61	13.85	97	1343.45	1.88	97	182.36
T9- NPK + ZnSO4 @25 kg ha-1 + Borax @5 kg ha-1 (soil),	11.35	95	1078.25	12.33	95	1171.35	1.80	94	169.20
T10- NPK + ZnSO4 @25 kg ha-1+ Borax @10 kg ha-1 (soil)	11.90	93	1106.70	11.71	93	1089.03	1.74	95	165.30
S.Em+	0.34	1.12	4.04	0.16	1.12	1.21	0.06	0.96	0.95
CD at 5%	1.02	3.38	12.11	0.49	3.36	3.63	0.18	-	2.85

TABLE IV

Effect of zinc and boron on seed quality parameter of castor based cropping system

Cropping System	Castor Finger millet			Castor-castor			Finger millet-castor		
Crop	Finger millet			Castor			Finger millet		
Treatments	Dry weight of shoot and root (mg)	Germina - tion (%)	Vigour index	Dry weight of shoot and root (mg)	Germina - tion (%)	Vigour index	Dry weight of shoot and root (mg)	Germina - tion (%)	Vigour index
Control,	6.30	88	554.4	6.30	89	560.70	1.42	92	130.64
NPK + FYM (Rec),	10.01	92	920.92	9.94	94	934.36	1.60	94	150.40
NPK + $ZnSO_4$ @12.5 kg/ha (soil),	11.86	94	1114.84	11.72	95	1113.40	1.68	95	159.60
NPK + $ZnSO_4$ @25 kg/ha (soil),	8.60	93	799.80	8.62	93	801.66	1.55	93	144.15
NPK + Borax @5 kg/ha (soil),	8.22	92	759.24	8.16	92	750.72	1.50	93	139.50
NPK + Borax @10 kg/ha (soil),	9.65	94	907.10	9.77	93	908.61	1.61	94	151.34
NPK + $ZnSO_4$ @12.5 kg/ha + Borax @5 kg/ha (soil),	11.81	95	1121.95	12.37	96	1187.52	1.72	95	163.40
NPK + $ZnSO_4$ @12.5 kg/ha + Borax @10.0 kg/ha (soil),	13.13	97	1273.61	13.85	97	1343.45	1.88	97	182.36
NPK + $ZnSO_4$ @25 kg/ha + Borax @5 kg/ha (soil)	11.35	95	1078.25	12.33	95	1171.35	1.80	94	169.20
NPK + $ZnSO_4$ @25 kg/ha + Borax @10 kg/ha (soil)	11.90	93	1106.70	11.71	93	1089.03	1.74	95	165.30
S.Em+	0.34	1.12	4.04	0.16	1.12	1.21	0.06	0.96	0.95
CD at 5%	1.02	3.38	12.11	0.49	3.36	3.63	0.18	-	2.85

TABLE V

Effect of zinc and boron on micronutrient use efficiency (MUE) and castor in castor based cropping system and finger millet monocropping

Cropping System	Castor Finger millet		Finger millet Finger millet	
Crop	Castor		Finger millet	
Treatments	MUE	B : C Ratio	MUE	B : C Ratio
Control	-	1.40	-	1.95
NPK + FYM (Rec),	-	1.10	-	1.58
NPK + $ZnSO_4$ @12.5 kg/ha (soil),	8.00	1.46	45.28	2.30
NPK + $ZnSO_4$ @25kg/ha (soil),	0.40	1.25	9.20	1.90
NPK + Borax @5 kg/ha (soil),	3.60	1.40	58.80	1.92
NPK + Borax @10 kg/ha (soil),	3.40	1.44	93.10	1.76
NPK + $ZnSO_4$ @12.5 kg/ha + Borax @5 kg/ha (soil),	12.57	1.47	34.06	2.10
NPK + $ZnSO_4$ @12.5 kg/ha + Borax @10.0 kg/ha (soil),	10.84	1.50	28.00	2.13
NPK + $ZnSO_4$ @25 kg/ha + Borax @5 kg/ha (soil),	1.53	1.32	14.43	1.80
NPK + $ZnSO_4$ @25 kg/ha + Borax @10 kg/ha (soil)	3.88	1.25	15.63	1.70

Cropping system : Castor – Castor and Castor-Finger millet

Crop : Castor : The effect of zinc sulphate and boron application on growth, yield attributes and seed yield are presented in Table I and II. The results were found to be significant (except spike length and number of capsules in castor –castor cropping system). Among the treatments, soil application of $ZnSO_4$ @ 12.5 kg / ha and borax @ 10 kg / ha has registered significantly higher plant height (181 and 166 cm), no. of spikes per plant (5.93 and 5.44) and seed yield (11.79 and 11.56 q/ha) with higher B: C ratio (1.20 and 1.50) under castor – castor and castor – finger millet cropping systems respectively. Which were statistically on par with the soil application $ZnSO_4$ @ 12.5 kg / ha and borax @ 5 kg / ha. While higher micronutrients use efficiency of 16.4 and 12.57 kg additional yield / kg of micronutrient applied was observed with the soil application of $ZnSO_4$ @ 12.5 kg / ha and $ZnSO_4$ @ 12.5 kg / ha and $ZnSO_4$ @ 12.5 kg / ha and borax @ 5 kg/ha respectively. Further. It was noticed that, 20 and 15 per cent increase in yield with the application of $ZnSO_4$ @ 12.5 kg / ha and borax @ 10 kg / ha under castor-castor and castor-finger millet cropping systems, respectively as compared to only NPK. In spite of dry spell the crop performed well under micronutrient applied plots and proved the drought tolerance capacity due to application of micronutrients. Similar findings reported earlier by Alloway (2008). The results showed that balanced nutrition significantly increased Zn concentration in grain and straw for castor and pigeonpea crops.

Significantly higher dry weight of shoot and root (13.85 mg), germination (97%) and vigour index (1343.45) were recorded with soil application of $ZnSO_4$ @12.5 kg / ha and Borax @ 10.0 kg / ha to control (6.30 mg, 89 %, and 560.70, respectively) in castor crop in castor-castor cropping system. Whereas, significantly higher germination (97 %) and vigour index (1273.61) were recorded with soil application of $ZnSO_4$ @12.5 kg / ha and Borax @ 10.0 kg / ha to control (88 % and 554.4, respectively) in finger millet crop in castor-finger millet cropping system.

The B:C ratio was varied with soil application of zinc sulphate and boron. Soil application of $ZnSO_4$ @12.5kg / ha + and Borax @ 10.0 kg / ha recorded higher B: C ratio (1.20, 1.50 and 2.13) compared to rest of the treatments and control (0.99, 1.40 and 1.95, respectively) (Table I & II). However, it was followed by soil application of $ZnSO_4$ @12.5 kg / ha and Borax @ 5 kg / ha in castor-castor, castor-finger millet and finger millet- finger millet cropping system. The increase in grain yield may be attributed to combined application of zinc sulphate and boron, the positive response of finger millet to zinc sulphate application may be due to increased growth and yield components produced due to increased availability and better uptake of nutrients.

From the above investigations it can be concluded that Soil application of $ZnSO_4$ @12.5 + and Borax @ 10.0 kg / ha proved effective in significantly enhancing the growth and yield of both castor and finger millet basedcropping system.

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