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Effect of soil and foliar application of zinc on sorghum (*Sorghum bicolor* (L.) *Moench)* yield, agronomic efficiency and apparent recovery efficiency

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Abstract
A field investigation was conducted during *kharif* season 2015-16 to study the yield of sorghum [*Sorghum bicolor* (L.) Moench] grains, leaves, stem and root with soil and foliar application of zinc. Significantly highest grain (32.54 q ha^{-1}), leaves (38.73 q ha^{-1}), stem (79.20 q ha^{-1}) and root (26.90 q ha^{-1}) yield was recorded with soil application of 5 kg Zn ha^{-1} through $ZnSO_4$ with two foliar sprays before flowering and at dough stage of $ZnSO_4$ @ 0.5% as compared to soil application of 5 kg Zn ha^{-1} through $ZnSO_4$ and control. Among the eight sorghum genotypes, the genotype CSH-35 recorded significantly highest grain yield (39.87 q ha^{-1}) as compared to the PVK-809, CSV-20, AKSV-181, AKSV-161, AKSV-313, AKSV-314, AKSV-318. The highest agronomic efficiency (AE), apparent recovery efficiency (RE) of nitrogen, phosphorus and potassium with soil application of 5 kg Zn ha^{-1} and two foliar application of $ZnSO_4$ @ 0.5% followed by soil application of 5 kg Zn ha^{-1}. It is inferred that increased Zn level resulted in increased yield of grain, leaves, stem and root of sorghum genotypes.

Keyword: Sorghum yield, Agronomic efficiency, Apparent recovery efficiency, Zinc sulphate, *Sorghum bicolor*

Introduction

Sorghum is a tolerant to drought, well adapted to the semi-arid and arid climate condition of Africa and Asia. Sorghum is high light the importance in the human diets. It is the third most important cereal food crop in India after rice, wheat and sorghum is an important staple food for millions of poor people in. It is the staple for large tribal populations across the country. The poor and vulnerable groups in the society depend upon sorghum for their calories and micronutrient requirement. The absence of access and affordability to nutrient-rich foods and fortification of sorghum help in enhancing in nutritional security. Sorghum grain contains 10-12% protein, 70% carbohydrates, 3% fats, vitamins, mineral and salts which are essential for vigorous growth. Zinc is essential for several enzymes system that regulates vital metabolic reaction in the plant body. It is the constituent of carbonic anhydrides and is also essential for auxin production. It is also required for synthesis of tryptophan which is precursor of IAA. It is helpful in reproduction of certain plants and required for normal plant growth. Sorghum is an exhaustive crop and its requirement for nutrients especially for nitrogen as essential constituent of chlorophyll, protoplasm and enzymes. It is important factor for boosting up the yield of cereals and it is very important for vegetative growth and yield.

Material and Methods

The experiment was conducted in split plot design with three replications during *kharif season* 2015-16 at AICRP on Micronutrient, Dr. PDKV, Akola. Eight sorghum genotypes were selected to study the Zn application on yield and uptake by sorghum in black soil. The experiment was laid in split plot design with three replication with main plot treatment sorghum genotypes and sub plot treatment zinc levels. The selected genotypes of sorghum were G_1: CSH-35, G_2: PVK-809, G_3: CSV-20, G_4: AKSV-181, G_5: AKSV-161, G_6: AKSV-313, G_7: AKSV-314 and G_8: AKSV-318. The zinc treatments comprised of Z_1- Control (No Zn application), Z_2- Soil application of 5 kg Zn ha^{-1} through $ZnSO_4$ at the time of sowing,

Z_3- Soil application of 5 kg Zn ha^{-1} through $ZnSO_4$ with two foliar sprays before flowering and at dough stage of $ZnSO_4$ @ 0.5%. Recommended dose of NPK (80:40:40 kg ha^{-1} N, P_2O_5 and K_2O) was applied in all treatments. Full dose of P and K and half dose of N was applied at the sowing and half dose of N was applied at 30 DAS. The soil was low in available nitrogen (219.78 kg ha^{-1}) medium available in phosphorus (22.25 kg ha^{-1}) high in available potassium (392.00 kg ha^{-1}) and deficient in DTPA- Zn (0.58 mg kg^{-1}). Recommended agronomic practices were followed during crop growth period. After harvesting of sorghum, yield data was recorded and grain-straw samples were collected. The agronomic efficiency (AE), apparent recovery efficiency (RE) was calculated using formulae.

$$\text{AE (kg ha}^{-1}\text{)} = \frac{\text{Grain yield in fertilized plot (kg/ha) - Grain yield in unfertilized plot (kg/ha)}}{\text{Amount of applied nutrient (kg/ha)}}$$

$$\text{AR (\%)} = \frac{\text{Total uptake in fertilized plot (kg/ha) - Total uptake in unfertilized plot (kg/ha) x100}}{\text{Amount of applied nutrient (kg/ha)}}$$

Results and Discussion

Grain, leaves, stem and root dry matter yield

Genotypes

The sorghum genotype CSH-35 recorded significantly highest grain yield (39.87 q ha^{-1}) as compared to all genotypes and followed by AKSV-181 (31.13 q ha^{-1}). The yield of sorghum leaves was significantly highest in AKSV-161(38.96 q ha^{-1}) than rest of genotypes but on par with that of AKSV-181 and PVK-809. Stem dry matter yield was noticed significantly highest in AKSV-161 (80.06 q ha^{-1}) while lowest stem dry yield (62.35 q ha^{-1}) was recorded in CSH-35. The genotypes AKSV-161 recorded significantly highest root dry matter yield (27.15 q ha^{-1}) as compared to the other genotypes. AKSV-161 recorded significantly highest total dry matter yield (176.66 q ha^{-1}) as compared to rest of the genotypes and found at par with AKSV-181 (176.54 q ha^{-1}), PVK-809 (169.10 q ha^{-1}), and AKSV-313 (165.82 q ha^{-1}). The lowest total dry matter was recorded in CSH-35 (152.53 q ha^{-1}). Reddy *et al.* (2006) found grain yield superiority of two hybrid genotypes (ICSR 24010 and ICSR 24006) as compared to control, CSV-4 (4.4 t ha^{-1}), which has a similar maturity period.

Zinc levels

The significantly highest grain yield (32.54 q ha^{-1}) was recorded with soil application of 5 kg Zn ha^{-1} through $ZnSO_4$ along with two foliar sprays before flowering and at dough stage of $ZnSO_4$ @ 0.5% and followed by soil application of 5 kg Zn ha^{-1} through $ZnSO_4$ (31.52 q ha^{-1}). The soil application of 5 kg Zn ha^{-1} and two foliar spray of $ZnSO_4$ @ 0.5% increased grain yield by 3.24 per cent over soil application of 5 kg Zn ha^{-1} and 7.32%) (Fig.1). Zinc is required in relatively very small quantities for adequate plant growth and production, physiological and metabolic processes in the sorghum plant (Table 1). Rajput *et al.* (1997) [6] reported that grain and straw yield of wheat significantly increased by 5 kg ha^{-1} Zn as a foliar spray and 20 kg ha^{-1} as basal over control. Shukla *et al.* (1976) [7] registered response of zinc to higher yielding wheat and rice varieties by foliar application of @ 0.5% $ZnSO_4$. Cakmak (2008) [3] the highest increase in grain yield was obtained with soil and soil + foliar.

Significantly highest leaves dry matter yield (38.73 q ha^{-1}) was recorded with soil application of 5 kg Zn ha^{-1} through $ZnSO_4$ with two foliar sprays before flowering and at dough stage of $ZnSO_4$ @ 0.5% followed by soil application of 5 kg Zn ha^{-1} through $ZnSO_4$ (Fig.2). The soil application of 5 kg Zn ha^{-1} with two foliar sprays before flowering and at dough stage of $ZnSO_4$ @ 0.5% recorded significantly highest stem dry matter (79.20 q ha^{-1}) which showed 16.07 per cent higher over the control while only soil application of 5 kg Zn ha^{-1} increased by 8.91 per cent over control (Fig.3). Haslett *et al.* (2001) [5] stated that the increased in biomass by Zn application through soil without or with foliar sprays in wheat. Soleymani and Shahrajabian (2012) [8] noticed foliar application of Zn increased of leaves and stem dry yield of sorghum. Significantly highest root dry matter yield (26.90 q ha^{-1}) was also recorded with soil application of 5 kg Zn ha^{-1} with two foliar sprays before flowering and at dough stage of $ZnSO_4$ @ 0.5% which was 22.88 per cent and soil application of 5 kg Zn ha^{-1} recorded higher root dry matter yield by 12.42 per cent as compared to control (Fig. 4). Metabolically active root and coleoptiles tissues use zinc most probably used for protein synthesis, membrane function, cell elongation (Cakmak 2000) [3] and Haslett *et al.* (2001) [5] noticed increase biomass by Zn application through soil without or with foliar sprays in wheat. The significantly highest total dry matter yield (177.76 q ha^{-1}) was observed with Soil + Foliar application which improved the total dry matter yield of sorghum genotypes by 15.21 per cent over control but only soil application of 5 kg Zn ha^{-1} recorded total dry matter yield by 8.46 per cent over control.

Interaction

Significantly highest grain yield (40.48q ha^{-1}) was recorded in CSH-35 in combination with soil application of 5 kg Zn ha^{-1} and two foliar sprays before flowering and at dough stage of $ZnSO_4$ @ 0.5% (Table 2). This could be attributed to high yield potential and application of zinc in soil and foliar application. Similar results were observed by Haslett *et al.* (2001) [5].

Agronomic efficiency, apparent recovery efficiency of N, P and K by sorghum

Highest agronomic efficiency (AE_N), apparent recovery efficiency (RE_N) of nitrogen, phosphorus and potassium with soil application of 5 kg Zn ha^{-1} and two foliar application of $ZnSO_4$ @ 0.5% followed by soil application of 5 kg Zn ha^{-1}(Table 3).

The similar result was noted by Bandara *et al.* (2008) [1] observed that the soil analysis revealed that soil was deficient in zinc and application of zinc sulphate @ 0.5 kg ha^{-1} influence that increased nitrogen recovery from 31-41% in rice. Highest agronomic efficiency (AE), apparent recovery efficiency (RE) of phosphorus and potassium with soil application of 5 kg Zn ha^{-1} and two foliar application of $ZnSO_4$ @ 0.5% followed by soil application of 5 kg Zn ha^{-1}.

Table 1: Yield of various sorghum genotypes as influenced by zinc levels

Treatment	Yield (q ha^{-1})				
	Grain	Leaves	Stem	Root	Total dry matter
A) Main plot (Genotypes)					
G_1 : CSH-35	39.87	31.07	62.35	19.25	152.53
G_2 : PVK-809	30.49	37.02	75.81	25.78	169.10
G_3 : CSV-20	30.42	36.30	73.75	24.14	164.60
G_4 : AKSV-181	31.13	38.89	79.52	27.00	176.54
G_5 : AKSV-161	30.49	38.96	80.06	27.15	176.66
G_6 : AKSV-313	29.76	36.47	74.86	24.73	165.82
G_7 : AKSV-314	29.36	36.55	73.21	24.43	163.56
G_8 : AKSV-318	30.17	34.76	71.74	23.25	159.91
SE(m)$\pm$	0.62	0.74	2.10	0.88	3.59
CD at 5%	1.90	2.24	6.36	2.66	10.88
B) Sub-plot (Zinc levels)					
Z_0 - Control	30.32	33.50	68.23	21.89	153.94
Z_1 - SA	31.52	36.53	74.31	24.61	166.97
Z_2 - FS	32.54	38.73	79.20	26.90	177.36
SE(m)$\pm$	0.15	0.33	0.82	0.34	1.38
CD at 5%	0.42	0.96	2.36	0.99	3.98
C) Interaction (A x B)					
SE(m)$\pm$	0.41	0.94	2.31	0.97	3.91
CD at 5%	1.18	NS	NS	NS	NS

Z_0 :Control, Z_1 :SA of 5 kg Zn ha^{-1} through $ZnSO_4$, Z_2 :SA of 5 kg Zn ha^{-1} through $ZnSO_4$ + Two FS before flowering and at dough stage of $ZnSO_4$ @ 0.5%

Table 2: Interaction effect between sorghum genotypes and zinc levels of grain yield in Vertisols

Genotypes	Zinc levels			
	(Z_0) Control	**(Z_1) SA of 5 kg Zn ha^{-1}**	**(Z_2) SA of 5 kg Zn ha^{-1} and two F.S $ZnSO_4$ of @0.5%.**	**Mean**
G_1 : CSH-35	39.21	39.92	40.48	39.87
G_2 : PVK-809	29.04	30.26	32.16	30.49
G_3 : CSV-20	29.27	29.98	32.01	30.42
G_4 : AKSV-181	29.09	31.79	32.51	31.13
G_5 : AKSV-161	29.92	30.52	31.04	30.49
G_6 : AKSV-313	28.86	30.44	29.97	29.76
G_7 : AKSV-314	28.24	29.51	30.34	29.36
G_8 : AKSV-318	28.95	29.77	31.79	30.17
Mean	30.32	31.52	32.54	31.46
SE(m)$\pm$	0.41			
CD at 5%	1.18			

Table 3: Agronomic efficiency, apparent recovery efficiency of nitrogen, phosphorus and potassium as influenced by zinc levels

Treatment	Agronomic efficiency (AE_N) (kg ha^{-1})			Apparent recovery efficiency (RE_N) (%)		
	N	P	K	N	P	K
Z_0 - Control	-	-	-	-	-	-
Z_1 - SA	1.5	3.01	3.01	23.06	11.09	46.7
Z_2 - FS	2.77	5.54	5.54	41.75	12.35	80.53

Z_0 :Control, Z_1 :SA of 5 kg Zn ha^{-1} through $ZnSO_4$, Z_2 :SA of 5 kg Zn ha^{-1} through $ZnSO_4$ + Two FS before flowering and at dough stage of $ZnSO_4$ @ 0.5%

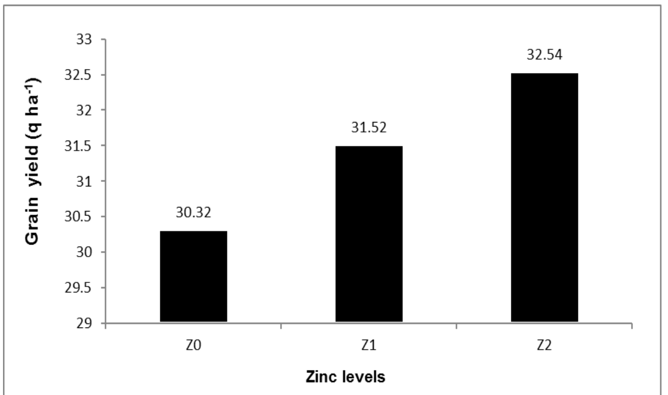

Fig 1. Grain yield of sorghum as influenced by zinc levels

Z_0:Control, Z_1 :SA of 5 kg Zn ha^{-1} through $ZnSO_4$, Z_2 :SA of 5 kg Zn ha^{-1} through $ZnSO_4$ + Two FS before flowering and at dough stage of $ZnSO_4$ @ 0.5%

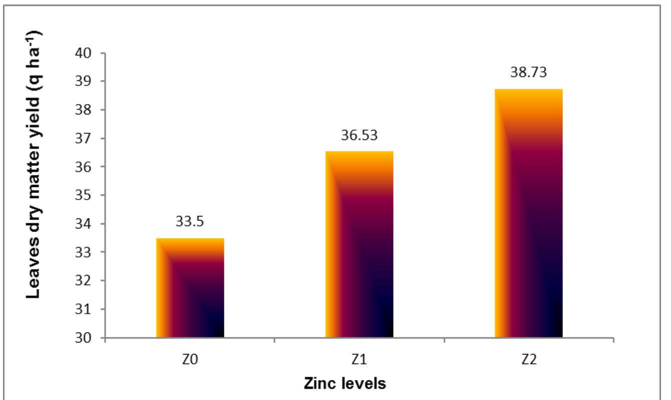

Fig 2. Leaves dry matter yield of sorghum as influenced by zinc levels

Z_0:Control, Z_1 :SA of 5 kg Zn ha^{-1} through $ZnSO_4$, Z_2 :SA of 5 kg Zn ha^{-1} through $ZnSO_4$ + Two FS before flowering and at dough stage of $ZnSO_4$ @ 0.5%

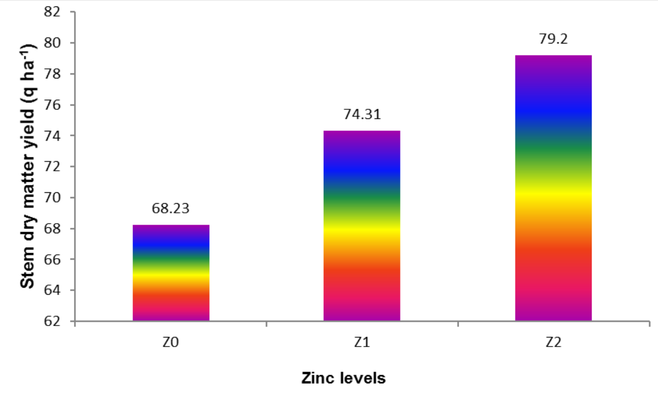

Fig 3. Stem dry matter yield of sorghum as influenced by zinc levels

Z_0:Control, Z_1 :SA of 5 kg Zn ha^{-1} through $ZnSO_4$, Z_2 :SA of 5 kg Zn ha^{-1} through $ZnSO_4$ + Two FS before flowering and at dough stage of $ZnSO_4$ @ 0.5%

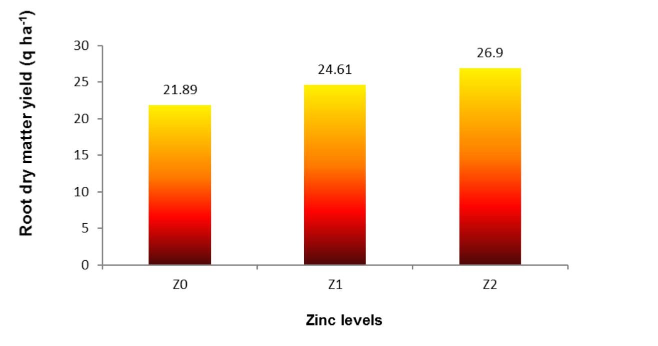

Fig 4. Root dry matter yield of sorghum as influenced by zinc levels

Z0: Control, Z1: SA of 5 kg Zn ha-1 through ZnSO4, Z2: SA of 5 kg Zn ha-1 through ZnSO4 + Two FS before flowering and at dough stage of ZnSO4 @ 0.5%

Conclusions

It can be concluded that sorghum genotype CSH-35 recorded higher grain yield, while AKSV-161 proved better in leaves, stem and root dry matter yield of sorghum. Soil application of 5 kg Zn ha^{-1} with two foliar sprays before flowering and at dough stage of $ZnSO_4$ @ 0.5% found to be higher in grain, leaves, stem, root dry matter yield.

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