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Nutrient Content, Uptake and Biochemical Composition in Kharif Sorghum Affected by Soil and Foliar Zinc and Iron in Drought Prone Marathwada Area of Maharashtra

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ABSTRACT: An experiment was carried out during *kharif* 2011 to study the responseof *kharif* sorghum to soil and foliar application of micronutrient zinc and iron at Sorghum Research Station, V.N. Marathwada Krishi Vidyapeeth, Parbhani. The experiment was laid out in Randomized Block Design (RBD) with 10 treatments and three replications. Results revealed that zinc sulphate and ferrous sulphate micronutrient through soil and foliar application along with recommended dose of NPK fertilizers resulted in improvement of *kharif* sorghum grain and fodder yield. Quality parameters like crude protein, crude fiber, crude fat, moisture content, starch, soluble sugar, ash content, approximate calorific value of grain and crude protein, dietary fiber, ash, organic matter, ether extract, nitrogen free extract of fodder were also improved due to soil and foliar application of micronutrients along with RDF. Nitrogen, phosphorus and potassium concentration in sorghum fodder was markedly increased by application of RDF along with micronutrients. The treatment T_7 i.e. RDF + soil application of 15 kg $ZnSO_4$ + 15 kg $FeSO_4$/ha recorded highest % N(0.65), % P (0.49)and % K (0.82)in fodder, whereas highest N, P and K in harvested grainswas noted as1.55, 0.88 and 0.41kg/ha, respectively. Total uptake of major nutrients was also recorded as nitrogen (50.79 kg/ha), phosphorus (31.85 kg/ha) and potassium (32.29 kg/ha).

Key words: Biochemical parameter, chlorophyll, *kharif* sorghum, micronutrient, uptake

In the world, 91% area is under different stress, this includes 25% under drought, 22% shallow depth, 22% mineral stress, 14% freezing stress and 11% water logging. In India, more than half of the cropped area is rainfed and crops in these areas invariably experience droughts of different magnitudes. The abiotic stresses like drought and heat stress are the two most important environmental factors influencing crop growth and yield (Gobain, 2012). The meteorological impacts on crop growth are two-fold, owing to the sensitive stages occurring earlier during the growing season and to the changes in weather patterns with climate change (Gobain, 2012). Further due to climate change, the levels of stresses may further increase and adversely influence the crop yields. The world's population is expected to reach 8.1 billion in 2025 and 9.6 billion in 2050 (Anon, 2014).

Sorghum is the principal dryland cereal crop grown in India and ranks third in the major food grain crops in India after rice and wheat. India has the largest share (32.3%) of world's area under sorghum and ranks second in production after the United States. In addition, the fodder and stover is used to feed millions of animals providing milk and meat. In India during TE 1998-99 to TE 2008-09, the area sown to coarse cereals fell by 8%. while the production increased by about 20% to 38 mt. Within these coarse cereals, the area and yield increases were more conspicuous in case of maize than in case of sorghum and pearl millet which dominate the cropping pattern in the rainfed regions (Raju *et al.,* 2012). At present Maharashtra is the largest producer of sorghum in India accounting for 50% of the total area i.e. 50.10 lakh hectares with a production of 28.90 lakh tonnes and productivity of 657 kg/ha (Awaghad *et al.,* 2010). In the semi-arid region, the kharif crops suffer mainly due to prolonged dry-spells and water scarcity towards the end of the monsoon season. Micronutrients play a vital role in the growth and development of cropsmainly in stress condition. Zinc is essential for several enzymes that regulate various metabolic activities in plants (Krishna and Bhushan, 2004). Zinc is essential for synthesis of tryptophan, an amino acid (precursor of indole acetic acid), which is transported from the endosperm of the seed through the xylem towards coleoptile tips and young leaves. Zink influences N metabolism and uptake, protein quality, photosynthesis, chlorophyll synthesis, carbon anhydrase activity, resistance to abiotic and biotic stresses and protection against oxidative damage (Cakmak, 2002; Pandey *et al.,* 2002). Role of iron is its catalytic function in biological oxidation and reduction in plants like oxidative photophosphorylation during cell respiration.Iron is a constituent of a large number of metabolically active compounds like cytochromes, heme and nonheme enzymes and other functional metalloproteins (Rathod *et al.,* 2005). A sharp increase in extreme heat and drought is projected by the end of the century, with the potential to significantly reduce yields under current technologies (Gobain, 2012). Integrated use of all potential sources of plant nutrients seems to be the only option to maintain soil fertility and crop productivity. With this in view, studies were carried out to find out the effect of micronutrient Fe and Zn on chlorophyll and biochemical growth performance of rainfed sorghum. Availability of micronutrients is influenced by their distribution in soil and other physicochemical properties of soil. From 2009 to 2014, the sowing of *kharif* sorghum in Marathwada shifted from first week of June to July due to aberrant monsoon. Initial dry spell affect germination and crop growth, mainly initial vigour due to non receipt or delayed monsoon.

Materials and Methods

An experiment was carried out during *kharif* 2011 to study the response of *kharif* sorghum to soil and foliar application of micronutrients at Sorghum Research Station, V.N. Marathwada Krishi Vidyapeeth, Parbhani. The experiment was laid out in randomized block design with three replications. Ten treatment combinations involving standard micronutrient fertilizers viz. ferrous sulphate and zinc sulphate were tried through soil and foliar applications. Treatments namely T_1- RDF + Soil application of 25kg $ZnSO_4$/ha, T_2- RDF + Soil application of 25kg $FeSO_4$/ha, T_3- RDF + 0.2% $ZnSO_4$ foliar at 15 & 30 DAS, T_4- RDF + 0.5% $FeSO_4$ foliar at 15 & 30 DAS, T_5- RDF + Soil application of 15 kg $ZnSO_4$ + 0.2% $ZnSO_4$ foliar at 15 & 30 DAS, T_6- RDF + Soil application of 15 kg $FeSO_4$ + 0.5% $FeSO_4$ at 15 & 30 DAS, T_7- RDF + Soil application of 15kg $ZnSO_4$ + 15 kg $FeSO_4$ /ha, T_8- RDF + foliar application (0.2% $ZnSO_4$ + 0.5% $FeSO_4$) at 15 & 30 DAS, T_9- RDF alone and T_{10}- Control (Native fertility). Seeds of sorghum variety PVK-809 were sown in the field at a spacing of 45 x 15 cm. Soil samples were collected before sowing and at harvesting stage of crop treatment wise from 0-15 cm depth from each net plot. The collected soil samples were processed. The soil samples at sowing and after harvest of crops were analyzed for N, P, K, DTPA Zn and Fe availability as per standard procedure.Chlorophyll 'a', chlorophyll 'b' and total chlorophyll in leaves were determined by DMSO method at floweringstage of sorghum as per procedure described by Hiscox and Isaeristan (1979). Moisture per cent in sorghum grain was determined by oven dry method and total minerals in grain was determined by ignition method as described by A.O.A.C. (1965). Crude proteincontent was determined by multiplying per cent nitrogen in grain sample by a constant multiplication factor 6.25. Starch content in grains was determined by Anthrone method. Free sugars content was estimated by phenol sulphuric acid method and dietary fiber in grain was determined by ignition method. Crude fat content in grain was determined by Soxhlet apparatus. All the abovesorghum grain quality parameters were analyzed as described by Sadasivam and Manickam (1992).

Results and Discussion

Chlorophyll a, b, and totalchlorophy ll

The data (Table 1) indicated that chlorophyll content in leaves of *kharif* sorghum was significantly increased due to soil application of micronutrients along with recommended dose of fertilizer. The chlorophyll-a content ranged between 0.11 to 0.20 mg g^{-1} fw. While, the nutrient combination T_6 (RDF + 15 kg $FeSO_4$ + 0.5% $FeSO_4$ at 15 & 30 DAS) recorded maximum chlorophyll-a content (0.20 mg g^{-1} fw). The chlorophyll-b content ranged between 0.36 and 0.54 mg g^{-1} fw. The highest chlorophyll-b content (0.54 mg g^{-1}) was recorded with T_6, which was significantly higher than control, while the treatments T_2, T_4, T_6, T_7 and T_8 are at par with each other. The minimum synthesis of chlorophyll-b observed in control (0.36 mg g^{-1}fw). The total chlorophyll content ranged between 0.47 and 0.74 mg/g fw. The maximum total chlorophyll was also recorded with T_6 (0.74 mg/g fw) significant by superior over control (0.47 mg/g fw). Results clearly indicated that combined soil and foliar application of micronutrients (Fe and Zn) positively influenced the leaf chlorophyll content. This might be due to fact the that iron plays essential role in the metabolism of chlorophylls while Zn helps activation of enzyme and membrane integrity. These results are corroborated with those reported by Bybordiand Mamedov (2010) in canola. Chandrakumar *et al.* (2004) reported higher chlorophyll content in wheat with foliar application of $FeSO_4$ @ 0.5% which was followed by soil application of $ZnSO_4$.

Effect of soil and foliar application of micronutrients on kharif grain sorghum

Moisture content, ash and crude protein in grain

It could be observed that there was no variation due to micronutrient application to sorghum in respect of grain moisture (Table 2). Ash and crude protein content in grain sorghum were significantly influenced due to application of NPK along with micronutrients. As stated by Suha and Babiker (2015) micronutrients fertilization improved the availability of protein and dietary minerals of sorghum. The rate of increment of protein and minerals availability depends on the dose of the fertilizer as well as the season. The treatment (T_7) showed highest ash content (2.54%) andcrude protein content (9.68%) in sorghum grainsand lowest ash content (1.52%) was in control. Crude protein content in sorghum grain ranged between 7.68 and 9.68%. The treatment T_7 was at par with T_1 and T_2 recorded 9.53 and 9.41% crude protein, respectively. Low native fertility of soil with moisture stress condition restricts nutrient uptake, which affects produce quality.

Crude fat, starch,soluble/free sugar and approximate colorific value of grain sorghum

Crude fat in grain sorghum was significantly increased (from 2.52 to 3.50%),% starch (from 70.52 to 73.00) and % soluble sugar (1.92 to 2.30) due toapplication of recommended NPK with 15 kg $ZnSo_4$ and 15 kg $FeSo_4$. Approximate calorific value of *kharif* grain sorghum varied from 342.84 to 371.43 Cal. 100/g. The highest crude fat (3.50%), starch content (73.00%), soluble sugar (2.30%) and calorific value (371.43 Cal. 100/g) was recorded by treatment T_7 whereas lowest crude fat (2.52%), starch (70.52%), soluble sugar (1.92%) and calorific value (342.84 Cal. 100/g) was reported in control. It might be due to balanced nutrition of crop resulting in increased growth, development and photosynthetic activity. NPK with zinc and ferrous also improved calorific value. Kumar *et al.* (2006) reported that the effect of application of micronutrients with soil test based response on starch content was highly significant.

Crude fibre

Crude fibre content (ranged between 2.93 and 2.34%) in grain sorghum significantly influenced due to application of NPK fertilizers with micronutrient. The soil and foliar application of micronutrients to *kharif* sorghum crop could lower down the crude fibre content in grain. The maximum (2.98%) was observed in control, whereas soil and foliar application of micronutrients recorded comparable less crude fibre content. Decreased crude fiber is responsible to raise grain quality.

Effect of soil and foliar application of micronutrient on fodder quality

Crude protein, ether extract, organic matter, dry matter and ash content

It could be observed that% crude protein content in kharif sorghum fodder was varied from 1.45 to 4.10% and organic matter content varied from 90.16 to 94.00%. The dry matter in sorghum was in range of 88.11 to 92.15%. Ash is the prerequisite for total mineral composition in plant sample and it was varied from 7.24 to 10.02%. Significant increase in crude protein content was recorded in different treatments. Higher crude protein (4.10%), ether extract (1.06%), organic matter content (94.00%), dry matter (92.15%) and ash content (10.02%) was obtained in T_7 treatment. Whereas the lowest crude protein content (1.45%), organic matter (90.16%) and dry matter (88.11%) were recorded in T_{10} (control). The treatment T_7 was superior over rest of the treatments. This might be due to higher supply of N which might have increased the protoplasmic constituents and accelerated processes like cell division and elongation thereby resulted in luxuriant growth and higher tonnage of green forage production. Gupta *et al.* (2002) and Verma *et al.* (2005) found that crude protein content increased with combined application of nitrogen and micronutrients. Thakare and Ravankar (2006) reported higher dry matter accumulation by 100% NPK with FYM.

Dietary fibre or crude fibre and nitrogen free extract

Observations revealed that, maximum crude fibre 32.00% and N-free extract (64.87%) in fodder was recorded by treatment T_{10} (control). While, lowest N-free extract value was with T_7 (52.81%). The mineral nutrition helps to improve protein content and declines N free extract.The reduction in NDF content and thereby improvement in fodder quality under optimum organic and inorganic nitrogen sources might be due to the increase in succulence (Yadav *et al.,* 2005).

Effect of soil and foliar application of micronutrients on yield of kharif sorghum

Grain yield, fodder yield and total biomass

The grain yield, fodder yield and total biomass of kharif sorghum was significantly affected due to soil and foliar application of micronutrients (Table 4). Treatment T7 significantly recorded the highest sorghum grain yield (20.58 q/ha), fodder yield (28.69 q/ha) and total biomass (49.27 q/ha). Higher grain yield recorded under micronutrient application could be attributed to early bloom and bold seeds i.e. higher 1000 grain weight. Increase in herbage yield with the increase in N and Zn rate may be combined effect of taller plants, higher leaf area index and dry matter accumulation resulting in better plant growth and ultimately resulted in higher yield of sorghum. Similar results were also reported by Sumeriya and Singh (2008) and Syed Ismail *et al.* (2001). Application of N and Zn gave significantly higher green forage yield (Verma *et al.,* 2005).

Effect of soil and foliar application of micronutrients on nitrogen, phosphorus and potassium content and uptake of kharif sorghum

Nitrogen, phosphorus and potassium content

The % N, P and Kconcentration and uptake in fodder as well as in grain was markedly increased by application of recommended dose of fertilizer along with micronutrients (Table 5). At harvest, grain sorghum N (1.55%), P (0.88%) and Kcontent (0.41%) had recorded significantly superior in treatment T_7. Precise application of fertilizer in right quantity at right time to match with the crop demand might have resulted in higher N content. These findings are in line with those obtained by Dhamak *et al.* (2010) who reported high P concentration in grain sorghum at harvest.

Nitrogen, phosphorus and potassium uptake

The maximum uptake of N, P and K was recorded with treatment T_7 whereas the minimum uptake of N, P and K was recorded with treatment T_{10} (control). The N uptake of fodder ranged between 12.35 and 50.79 kg/ha at harvest.P uptake of fodder was in the range of 7.97 to 31.85 kg/ha whereas K uptake was of 9.33 to 32.29 kg/ha. Maximum P uptake by sorghum grain (31.85 kg/ha) at harvest was recorded by application of Fe and Zn with RDF. The increased K uptake by crop might be due to increased dry matter yield and due to K application through RDF. Higher dry matter accumulation ultimately increased the total uptake of P as compare to control. Zink exerts great influence on basic plant life processes like nitrogen metabolism, uptake of nitrogen and protein quality. Results clearly showed that sorghum is responsive to Zn and Fe with RDF application. Improved N uptake leads to higher biomass and grain yield of sorghum. Micronutrient application protects them from various kind of stress, especially nutrient stress (deficiency) in arid or semi-arid condition. Results confirmed an earlier report of Verma *et al.* (2005) which stated that N uptake increased significantly with application of N and zinc @ 120 and 5 kg/ha, respectively. Nataraja *et al.* (2005) reported that the application of 100% P_2O_5 of RD recorded maximum P uptake. Similar results of K content and uptake were also obtained in groundnut and pearl millet by Hadvani and Gundalia (2003) and Yadav *et al.* (2012).

Zinc and Iron content and uptake

The Zn uptake was in the range of 62.83 to 252.59 g/ha whereas Fe uptake was in the range of 433.30 to 2175.40 g/ha at harvest.Maximum Zn uptake (252.59 g/ha) and Fe uptake (2175.40 g/ha) at harvest was recorded by application of RDF with 15kg $ZnSO_4$ and 15kg $FeSO_4$ /ha (Table 4). The maximum uptake of Zn and Fe was recorded with treatment T_7 whereas the minimum uptake of Zn and Fe was recorded with treatment T_{10} (control). Malakouti (2008) reported that the application of micronutrient enriched NPK fertilizers provides a double benefit by increasing grain yield and improving the nutritional quality of the harvested grains, also increase the concentration of micronutrients in grain (Rathod *et al.,* 2005).

Table 1 : Chlorophyll content (mg g^{-1}fw) in leaves of *kharif* sorghum as influenced by soil and foliar application of micronutrients

Treat. code	Treatments	Chlorophyll a	Chlorophyll b	Total chlorophyll	Fodder yield q/ha
T1	RDF + 25kg$ZnSO_4$ /ha	0.15	0.41	0.56	28.58
T2	RDF + 25kg $FeSO_4$ /ha	0.18	0.49	0.67	27.75
T3	RDF + 0.2% $ZnSO_4$ foliar at 15 &30 DAS	0.14	0.40	0.54	24.12
T4	RDF + 0.5% $FeSO_4$ foliar at 15 &30 DAS	0.19	0.52	0.71	24.76
T5	RDF + 15 kg $ZnSO_4$ + 0.2% $ZnSO_4$ foliar at 15 & 30 DAS	0.16	0.42	0.58	26.37
T6	RDF + 15kg $FeSO_4$ + 0.5% $FeSO_4$ at 15 & 30 DAS	0.20	0.54	0.74	26.31
T7	RDF + 15 kg $ZnSO_4$ + 15 kg $FeSO_4$/ha	0.17	0.49	0.66	28.69
T8	RDF + foliar application (0.2% $ZnSO_4$ + 0.5% $FeSO_4$) at 15 & 30 DAS	0.18	0.49	0.67	24.48
T9	RDF alone	0.12	0.38	0.51	22.52
T10	Control (Native fertility)	0.11	0.36	0.47	12.40
SEm±		0.01	0.03	0.03	1.51
CD (P= 0.05)		0.04	0.10	0.11	4.49

Table 2 : Grain quality parameters of *kharif* sorghum as influenced by soil and foliar application of micronutrients

Tr. code	Treatments	Moisture (%)	Ash (%)	Crude protein (%)	Crude fat (%)	Crude fiber (%)	Starch (%)	Soluble sugar (%)	Approx. calorific value (Cal.100/g)
T1	RDF + 25kg $ZnSO_4$ /ha	9.86	2.42	9.53	3.41	2.45	72.85	2.29	369.42
T2	RDF + 25kg $FeSO_4$ /ha	9.82	2.39	9.41	3.29	2.51	72.59	2.27	366.70
T3	RDF + 0.2% $ZnSO_4$ foliar at 15 &30 DAS	9.42	1.72	8.06	2.82	2.87	71.24	2.06	356.30
T4	RDF + 0.5% $FeSO_4$ foliar at 15 &30 DAS	9.66	1.95	8.74	3.02	2.72	71.80	2.16	358.75
T5	RDF + 15 kg $ZnSO_4$ + 0.2% $ZnSO_4$ foliar at 15 & 30 DAS	9.75	2.35	9.24	3.18	2.57	72.32	2.22	358.44
T6	RDF + 15kg $FeSO_4$ + 0.5% $FeSO_4$ at 15 & 30 DAS	9.70	2.15	8.93	3.09	2.66	71.97	2.20	358.05
T7	RDF + 15 kg $ZnSO_4$ + 15 kg $FeSO_4$/ha	9.95	2.54	9.68	3.50	2.41	73.00	2.30	371.43
T8	RDF + foliar application (0.2% $ZnSO_4$ + 0.5% $FeSO_4$) at 15 & 30 DAS	9.57	1.90	8.39	2.91	2.74	71.65	2.17	352.37
T9	RDF alone	9.25	1.65	7.93	2.69	2.93	70.80	1.97	347.02
T10	Control (Native fertility)	9.12	1.52	7.68	2.52	2.98	70.52	1.92	342.84
SEm$\pm$		0.23	0.10	0.12	0.12	0.04	1.00	0.03	
CD (P= 0.05)		NS	0.29	0.36	0.36	0.12	NS	0.11	

Table 3 : Fodder quality parameters of *kharif* sorghum as influenced by soil and foliar application of micronutrient

Tr. code	Treatments	Dry matter (%)	Organic matter (%)	Ash (%)	Crude protein (%)	Crude fiber (%)	Ether extract (%)	N free extract (%)
T1	RDF + 25kg $ZnSO_4$ /ha	92.00	93.65	9.85	3.91	26.96	0.98	53.44
T2	RDF + 25kg $FeSO_4$ /ha	91.54	93.17	9.47	3.31	27.24	0.96	54.93
T3	RDF + 0.2% $ZnSO_4$ foliar at 15 &30 DAS	89.85	91.42	8.13	1.89	31.32	0.91	61.48
T4	RDF + 0.5% $FeSO_4$ foliar at 15 &30 DAS	90.68	92.15	8.76	2.74	29.12	0.93	58.37
T5	RDF + 15 kg $ZnSO_4$ + 0.2% $ZnSO_4$ foliar at 15 & 30 DAS	91.12	92.94	9.32	3.14	27.90	0.95	56.93
T6	RDF + 15kg $FeSO_4$ + 0.5% $FeSO_4$ at 15 & 30 DAS	90.92	92.85	8.95	2.97	28.52	0.94	58.24
T7	RDF + 15 kg $ZnSO_4$ + 15 kg $FeSO_4$/ha	92.15	94.00	10.02	4.10	27.82	1.06	52.81
T8	RDF + foliar application (0.2% $ZnSO_4$ + 0.5% $FeSO_4$) at 15 & 30 DAS	90.25	91.97	8.42	2.24	29.65	0.92	60.86
T9	RDF alone	89.57	90.72	7.82	1.67	31.81	0.90	63.30
T10	Control (Native fertility)	88.11	90.16	7.24	1.45	32.00	0.89	64.87
SEm±		0.65	0.52	0.65	0.15	0.23	0.08	
CD (P= 0.05)		1.94	1.56	NS	0.46	NS	NS	

Table 4 : Yield, nutrient content and uptake of Zn and Fe in *kharif* sorghum at harvest stage

Treat. Code	Treatments	Nutrient content in sorghum (mg/kg)				Nutrient uptake (g/ha)		Yield (q/ha)		
		Zn		Fe		Zn	Fe	Grain	Fodder	Total Biomass
		Grain	Fodder	Grain	Fodder					
T1	RDF + 25kg $ZnSO_4$ /ha	40.06	49.40	177.07	363.82	221.38	1386.27	19.70	28.58	48.28
T2	RDF + 25kg $FeSO_4$ /ha	32.95	36.40	238.40	554.40	164.79	2000.00	19.36	27.75	47.11
T3	RDF + 0.2% $ZnSO_4$ foliar at 15 &30 DAS	37.06	45.00	168.27	316.60	168.57	1036.22	16.20	24.12	40.32
T4	RDF + 0.5% $FeSO_4$ foliar at 15 &30 DAS	35.33	38.40	202.40	455.40	157.95	1487.84	17.80	24.76	42.56
T5	RDF + 15 kg $ZnSO_4$ + 0.2% $ZnSO_4$ foliar at 15 & 30 DAS	40.00	47.50	168.27	316.60	199.53	1147.34	18.57	26.37	44.94
T6	RDF + 15kg $FeSO_4$ + 0.5 % $FeSO_4$ / ha at 15 & 30 DAS	32.25	36.12	235.80	515.40	154.11	1787.00	18.32	26.31	44.63
T7	RDF + 15 kg $ZnSO_4$ + 15 kg $FeSO_4$ /ha	41.33	58.40	245.80	589.20	252.59	2175.40	20.58	28.69	49.27
T8	RDF + foliar application (0.2% $ZnSO_4$ + 0.5% $FeSO_4$) at 15 & 30 DAS	39.65	46.40	227.07	502.40	182.01	1549.72	17.26	24.48	41.47
T9	RDF alone	31.93	35.80	154.00	286.33	131.06	888.13	15.80	22.52	38.32
T10	Control (Native fertility)	31.40	31.68	102.07	275.60	62.83	433.30	7.50	12.40	19.90
SEm±		0.23	4.92	4.30	26.27	14.51	121.68	0.85	1.51	2.34
CD (P= 0.05)		0.70	14.61	12.76	77.95	43.06	360.99	2.54	4.49	6.20

Table 5 : Nutrient content and uptake of NPK in *kharif* sorghum fodder and grain at harvest stage

Treat. Code	Treatments	Nutrient content of *kharif* sorghum grain and fodder						Nutrient uptake		
		N (%)		P (%)		K (%)		N (kg/ha)	P (kg/ha)	K (kg/ha)
		Grain	fodder	grain	fodder	grain	fodder			
T1	RDF + 25kg $ZnSO_4$ /ha	1.52	0.62	0.74	0.47	0.39	0.80	47.86	28.46	30.78
T2	RDF + 25kg $FeSO_4$ /ha	1.50	0.53	0.72	0.46	0.38	0.78	43.00	26.53	27.90
T3	RDF + 0.2% $ZnSO_4$ foliar at 15 &30 DAS	1.29	0.30	0.65	0.32	0.27	0.67	29.53	19.22	20.52
T4	RDF + 0.5% $FeSO_4$ foliar at 15 &30 DAS	1.40	0.43	0.68	0.34	0.30	0.72	35.35	20.93	23.17
T5	RDF + 15 kg $ZnSO_4$ + 0.2% $ZnSO_4$ foliar at 15 & 30 DAS	1.48	0.50	0.71	0.45	0.35	0.76	39.31	25.50	26.72
T6	RDF + 15 kg $FeSO_4$ + 0.5% $FeSO_4$ at 15 & 30 DAS	1.43	0.44	0.70	0.38	0.32	0.74	37.23	22.61	24.07
T7	RDF + 15 kg $ZnSO_4$ + 15 kg $FeSO_4$ /ha	1.55	0.65	0.88	0.49	0.41	0.82	50.79	31.85	32.29
T8	RDF + foliar appl. (0.2% $ZnSO_4$ + 0.5% $FeSO_4$) at 15 & 30 DAS	1.32	0.43	0.67	0.33	0.29	0.70	34.51	19.98	22.18
T9	RDF alone	1.27	0.25	0.60	0.31	0.24	0.63	25.82	17.50	18.20
T10	Control (Native fertility)	1.23	0.23	0.57	0.28	0.23	0.61	12.35	7.97	9.33
SEm±		0.018	0.02	0.01	0.001	0.004	0.006	1.65	0.931	1.22
CD (P= 0.05)		0.056	0.08	0.04	0.005	0.014	0.017	4.91	2.764	3.64

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Conclusions

Micronutrients are very effective in regulating plant growth as they form a part of the enzyme system and thus regulate plant life. Application methods of micronutrients are very important to attain the best absorption. The results of this study demonstrated that, foliar application of Fe and Zn had positive effect on yield and quality of kharifsorghum and significantly increased the chlorophyll content in leaves. The maximum ash percentage crude protein, crude fat, starch percentage and soluble sugar percentage in sorghum grains was achieved by foliar application of Fe and Zn. So, on the basis of the results, it seems that application of Zn and Fe with recommended fertilizers enhances yield and quality of *kharif* sorghum.

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