International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(3): 90-94

Received: 19-03-2019
Accepted: 23-04-2019

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Response of zinc and iron to *Rabi* sorghum grown on an inceptisol

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Abstract
A field experiment was conducted on "Response of zinc and iron to *rabi* sorghum grown on an Inceptisol" at Micronutrient Research Farm, Department of Soil Science and Agril. Chemistry, MPKV, Rahuri for three years during 2013 to 2015. The experimental soil was slightly alkaline in reaction (pH 7.94), normal in electrical conductivity (0.28 dSm-1), moderately high in organic carbon content, deficient in available iron and zinc. Soil order was Inceptisol with taxonomically classified as fine Montmorillonite isohyperthermic family of Vertic Haplustept. The results revealed that, the application of Zinc Sulphate @ 20 kg ha^{-1} incubated with cow dung water slurry (1:4 ratio) @ 500 L ha^{-1} at 30 and 45 days after sowing with the general recommended dose of nutrient (80:40:40 kg ha^{-1} N:P_2O_5:K_2O + 5 t ha^{-1} FYM) found beneficial for increase in leaf area, chlorophyll content in fresh leaves, uptake of Fe, Zn, availability of zinc and iron in soil, nutrient use efficiency, grain and stover yield of *rabi* sorghum, however this treatment was at par with treatment of single time application of same slurry at 30 DAS with the benefit of higher B:C ratio (1.74).

Keywords: micronutrient, *rabi* sorghum, slurry application, effect of zinc and Iron

Introduction
Sorghum (*Sorghum bicolar* (L) Moench) is one of the worlds most important nutritional cereal crop and also the major staple food and fodder crop for millions of people in semi-arid tropics. The area under *kharif* sorghum is less compared to *rabi* sorghum. *Rabi* sorghum is the major dry land crop currently grown over an area of 3.89 million hectares with a production of 3.14 million tones and productivity of 808 kg ha^{-1} (Anonymous, 2014) [2]. Insufficient micronutrient availability in soils not only causes low crop productivity but also poor nutritional quality of the crops and consequently contributes to malnutrition in the human population (Kumssa *et al*., 2015) [7]. The micronutrient enrichment of staple food crops in general and *rabi* sorghum in particular has been considered as a sustainable strategy for immediate solution to tackle the problems of micronutrient deficiencies in human beings. Fortification is a potential cost–effective and sustainable agronomic way to enrich the micronutrient content in food grains and fodder. It is an upcoming strategy for dealing the deficiencies of micronutrients in the developing world. Post-rainy (*rabi*) sorghum that are predominantly grown for food and fodder has lower zinc and iron content than that of rainy season sorghum (Kumar *et al*., 2013) [6]. Usually the farmers do not apply recommended dose of fertilizer including micronutrients to *rabi* sorghum. Some farmers do not apply any fertilizer leading to deficiency of nutrients in soil and further resulted in lower yield with low nutritional quality of grain and fodder. Hence, the present experiment had planned to study response of iron and zinc application to *rabi* sorghum on Inceptisol to enrich the grain and fodder with micronutrient especially iron and zinc.

Material and Method
A field experiment was conducted in *rabi* season during 2013 to 2015 at Micronutrient Research Farm, Department of Soil Science and Agril. Chemistry, MPKV, Rahuri. *Rabi* sorghum (cv. Phule Revati) was grown on an Inceptisol. The experimental field was Vertic Haplustepts, clay and pH 7.69, EC 0.28 dSm^{-1}, $CaCO_3$ 4.87%, organic carbon 0.74%, available N 198, P 6.18 and K 274 kg ha^{-1}, DTPA Fe 3.87, Zn 0.51, Mn 4.66, Cu 0.97 ppm. The treatments comprised of T_1: Control (RDF), T_2: GRDF (80:40:40 N:P_2O_5:K_2O kg ha^{-1} + FYM @ 5 t ha^{-1}), T_3: T_2 + soil application of $FeSO_4$ @ 25 kg ha^{-1} at sowing, T_4: T_2 + soil application of $ZnSO_4$ @ 20 kg ha^{-1} at sowing, T_5: T_2 + $FeSO_4$ @ 25 kg ha^{-1} + cow dung slurry

(1:4) @ 500 L ha^{-1} through irrigation at 30 DAS, T_6: T_2 + $FeSO_4$ @ 25 kg ha^{-1} + cow dung slurry (1:4) @ 500 L ha^{-1} through irrigation at 30 and 45 DAS, T_7: T_2 + $ZnSO_4$ @ 20 kg ha^{-1} + cow dung slurry (1:4) @ 500 L ha^{-1} through irrigation at 30 DAS, T_8: T_2 + $FeSO_4$ @ 25 kg ha^{-1} + cow dung slurry (1:4) @ 500 L ha^{-1} through irrigation at 30 and 45 DAS, T_9: T_2 + $ZnSO_4$ @ 20 kg ha^{-1} + cow dung slurry (1:4) @ 500 L ha^{-1} through irrigation at 30 DAS, T_{10}: T_2 + $ZnSO_4$ @ 20 kg ha^{-1} + cow dung slurry (1:4) @ 500 L ha^{-1} through irrigation at 30 and 45 DAS, T_{11}: T_2 + foliar application of chelated Fe (0.1%) at two critical growth stages, T_{12}: T_2 + foliar application of chelated Zn (0.1%) at two critical growth stages. The treatments were replicated thrice in a randomized block design. Cow dung slurry was prepared as (Cow dung: Water ratio 1:4) @ 500 L incubated for 1 week. Foliar spray was given at panicle (30 DAS) and boot stage (45 DAS). Half dose of N, full dose of P and K at sowing and half dose of N were given at 30 DAS. Cow dung slurry 1:4 ratio (125 kg fresh cow dung + water) @ 500 L ha^{-1} incubated for 1 week and applied after 30 DAS and 45 DAS with irrigation.

Results

The chemical composition of cow dung slurry after incubated for one weeks showed slightly acidic (pH 5.80) with high electrolyte concentration of soluble salts (EC 5.50 dSm^{-1}). However very little quantity of nutrients total N, P and K were present in slurry (0.08, 0.02 and 0.3%, respectively). It also content very little amount of Fe followed by Cu, Zn and Mn (3.4, 16.20, 50.3, 2.08 ppm, respectively).

Yield and yield contributing characteristics

The pooled mean data of three years of leaf area chlorophyll content of fresh tissue and yield of *rabi* sorghum are presented in table 1. The pooled mean data of leaf area showed significantly higher value 372 cm^2 in treatment of T_8 over all the treatment. The total chlorophyll content in fresh leaves of sorghum was also significantly increased in treatment of T_8 (3.18 mg g^{-1}) over all the treatments under study. Increased in chlorophyll content and leaf area of sorghum might be due to iron and zinc enriched organics were applied through incubated slurry to the soil, the photosynthetic and metabolic rates may increased in plant along with increase in cell division and cell elongation (Hossian *et al.*, 2011) [4].

The mean pooled data of grain yield of sorghum showed significantly higher grain and stover yield (41.95 and 104.5 q ha^{-1}, respectively) in treatment of T_8 (GRDF + $ZnSO_4$ @ 20 kg ha^{-1} + cow dung slury (1:4) @ 500 L ha^{-1} through irrigation at 30 and 45 DAS) over all the treatments except treatment T_7 (41.30 and 99.90 q ha^{-1} respectively) and treatment T_4 (38.68 q ha^{-1}) in respect of grain yield of sorghum. The increase in the yield could be due to continuous supply of organically chelated iron and zinc through incubated slurry to the crop. Iron and zinc are part of the photosynthesis, assimilation and translocation of photosynthates from source (leaves) to sink (earhead). Nalina (2013) [9] observed the higher test weight (35.83 g) and grain weight (21.57 g $plant^{-1}$) in *rabi* sorghum with foliar application of $ZnSO_4$ (0.5%) over RDF alone. Similar observations were also recorded by Adsul *et al.* (2016) [1] who reported the higher grain yield (20.58 q ha^{-1}) and fodder yield (28.69 q ha^{-1}) in *kharif* sorghum with soil application of RDF + 15 kg $ZnSO_4$ ha^{-1} + $FeSO_4$ ha^{-1} over other treatments. Increased in yield might be due to improved availability of iron and zinc which could be attributed to the formation of stable organometalic complexes with organic matter, especially during the enrichment process to last for a longer time and release the nutrients slowly in the soil system in such a way that the nutrients are protected from fixation and made available to the plant root system throughout the crop growth (Meena *et al*., 2006) [8].

Soil properties at harvest

The pooled mean three years data of soil properties of soil pH, EC, organic carbon and calcium carbonate content in soil at harvest of *rabi* sorghum are presented in table 2. The pooled mean of soil pH showed significantly decreased (7.72) in treatment of T_8 (GRDF + $ZnSO_4$ @ 20 kg ha^{-1} with cow dung slurry at 30 and 45 DAS) over T_1 to T_4, T_9 and T_{10} however, treatment T_8 was at par with application of incubated cow dung slurry in treatments of T_5, T_6, T_7, T_{11} and T_{12} treatment. In respect of soil EC, the significant higher value recorded in treatment of T_6 (0.36 dSm^{-1}) over all the treatments except T_5, T_6, T_7 and T_{12} treatment.

The pooled mean data of organic carbon content in soil at harvest was significantly increased (0.90%) in treatment of T_8 over T_1, T_2, T_3 and T_9 however, treatment T_8 was at par with treatments of T_7, T_{11} (0.88%), T_5, T_6, T_{10} and T_{12}. The pooled mean data of calcium carbonate content in soil was decreased (4.06%) in treatment of T_8 however, it was at par with T_5, T_6, T_7, T_{11} and T_{12} this might be due to application of cow dung slurry treatment may effect on reduction of $CaCO_3$ content in soil through leaching with organic acid produced in the decomposition of organic cow dung slurry.

Soil available nutrient at harvest

The pooled three years mean data on soil available N, P and K are presented in table 3, which revealed that, the available N and K at harvest showed non significant. However, pooled mean data of available P in soil at harvest showed significantly increased (14.37 kg ha^{-1}) in treatment of T_8 over all the treatments except treatments T_5, T_6, T_7, T_9 and T_{10} which were at par. Higher agronomic efficiency was observed in treatments of T_8 (9.84 kg kg^{-1}) followed by T_7 (9.43 kg kg^{-1}).

The pooled three years mean data of soil available DTPA Fe, Zn, Mn and Cu are presented in table 4. The pooled mean of status of available Fe was significantly increased and sufficient in treatment of T_5, T_6 and T_3 (5.61, 5.33 and 4.89 ppm respectively) where the application of $FeSO_4$ @ 25 kg ha^{-1} was applied with cow dung slurry and also in alone with GRDF. However rest of the treatments were showed deficient in available Fe in soil as the critical limit of DTPA Fe is 4.5 ppm. The same trend of significant increased of available Zn in soil at harvest was observed in respect of application of $ZnSO_4$ @ 20 kg ha^{-1} with cow dung slurry treatments of T_8 (0.84 ppm), T_7 (0.81 ppm) and alone T_4 (0.71 ppm) with GRDF. However, rests of the treatments were showed deficient in available Zn in soil as the critical limit of DTPA Zn is 0.6 ppm.

The pooled mean data of available Mn in soil showed significantly increased and sufficient in treatments of T_6 and T_8 (5.39 and 5.35 ppm respectively) as compared to rest of all the treatment under study. In respect of available Cu in soil, the results showed non significant (Table 4).

Total uptake of iron and zinc

The three years pooled mean data of total uptake of iron and zinc in grain and stover of sorghum are presented in table 5. The total uptake of Fe in grain and stover of sorghum significantly increased in treatment of T_8 (3347 g ha^{-1}) over all the treatments except treatment T_3, T_5, T_6, T_7 and T_{10} which were at par. The same trend of significant increased in total uptake of Zn in grain and stover also observed in treatment of T_8 (1320 g ha^{-1}) over all the treatments except treatment T_7 (1302 g ha^{-1}) which was at par.

The economics of *rabi* sorghum as influenced by application of zinc and iron to *rabi* sorghum are presented in table 6, which revealed that the highest monetary returns and net monetary returns were recorded in the treatment of T_8 and T_7 however, B:C ratio was recorded highest (2.74) in the treatment of T_7 (GRDF + $ZnSO_4$ @ 20 kg ha^{-1} with cow dung slurry (1:4 ratio @ 500 L ha^{-1} at 30 DAS) followed by treatment T_8 (2.73). Patel *et al.* (2016) in sorghum reported that soil application of 7.5 kg ha^{-1} $ZnSO_4$ + three foliar sprays of $ZnSO_4$ (0.5%) realized the higher net returns (32753 Rs. ha^{-1}) and BC ratio (4.86) compared to other treatments. Tamboli *et al.* (2013) in sorghum reported that the application of fertilizers as per soil test (75 kg N + 31 kg P_2O_5 ha^{-1}) + Zn @ 15 kg ha^{-1} to *rabi* sorghum was beneficial for achieving higher grain, stover yield of sorghum, net returns and B:C ratio and maintaining higher residual soil fertility.

Table 1: Pooled mean data of leaf area, chlorophyll content and yield of rabi sorghum

Tr. No.	Treatment	Leaf area (cm^2)	Chlorophyll Content (mg g^{-1})	Yield	
				Grain	Stover
T_1	Control (RDF)	292	2.17	30.43	87.23
T_2	GRDF (80:40:40 N:P_2O_5:K_2O kg ha^{-1} + FYM @ 5 t ha^{-1})	298	2.29	33.18	87.27
T_3	T_2 + Soil application of $FeSO_4$ @ 25 kg ha^{-1} at sowing	323	2.60	35.53	91.83
T_4	T_2 + Soil application of $ZnSO_4$ @ 20 kg ha^{-1} at sowing	318	2.41	38.68	91.27
T_5	T_2 + $FeSO_4$ @ 25 kg ha^{-1} + cow dung slurry (1:4) @ 500 Lha^{-1} through irrigation at 30 DAS	344	2.69	36.27	90.87
T_6	T_2 + $FeSO_4$ @ 25 kg ha^{-1} + cow dung slurry (1:4) @ 500 Lha^{-1} through irrigation at 30 and 45 DAS	349	2.66	36.22	93.87
T_7	T_2 + $ZnSO_4$ @ 20 kg ha^{-1} + cow dung slurry (1:4) @ 500 Lha^{-1} through irrigation at 30 DAS	354	2.76	41.30	99.90
T_8	T_2 + $ZnSO_4$ @ 20 kg ha^{-1} + cow dung slurry (1:4) @ 500 Lha^{-1} through irrigation at 30 and 45 DAS	372	3.18	41.95	104.35
T_9	T_2 + Foliar application of chelated Fe (0.1%) at two critical growth stages	313	2.48	34.51	86.80
T_{10}	T_2 + Foliar application of chelated Zn (0.1%) at two critical growth stages	314	2.48	35.94	89.37
T_{11}	Cow dung slurry alone (1:4) @ 500 Lha^{-1} at 30 DAS	284	2.12	26.63	74.00
T_{12}	Cow dung slurry alone (1:4) @ 500 Lha^{-1} at 45 DAS	287	2.06	25.79	71.43
	SE $\pm$	2.958	0.045	1.148	2.558
	CD at 5 %	8.731	0.132	3.39	7.55

Table 2: Pooled mean data of soil pH, EC, organic carbon and calcium carbonate status of soil at harvest

Tr. No.	Treatment	pH (1:2.5)	EC (dSm^{-1})	Org. C. (%)	$CaCO_3$ (%)
T_1	Control (RDF)	7.96	0.27	0.70	4.76
T_2	GRDF (80:40:40 N:P_2O_5:K_2O kg ha^{-1} + FYM @ 5 t ha^{-1})	7.92	0.28	0.80	4.55
T_3	T_2 + Soil application of $FeSO_4$ @ 25 kg ha^{-1} at sowing	7.89	0.30	0.75	4.54
T_4	T_2 + Soil application of $ZnSO_4$ @ 20 kg ha^{-1} at sowing	7.88	0.31	0.80	4.39
T_5	T_2 + $FeSO_4$ @ 25 kg ha^{-1} + cow dung slurry (1:4) @ 500 Lha^{-1} through irrigation at 30 DAS	7.82	0.33	0.84	4.12
T_6	T_2 + $FeSO_4$ @ 25 kg ha^{-1} + cow dung slurry (1:4) @ 500 Lha^{-1} through irrigation at 30 and 45 DAS	7.76	0.36	0.85	4.14
T_7	T_2 + $ZnSO_4$ @ 20 kg ha^{-1} + cow dung slurry (1:4) @ 500 Lha^{-1} through irrigation at 30 DAS	7.77	0.32	0.88	4.11
T_8	T_2 + $ZnSO_4$ @ 20 kg ha^{-1} + cow dung slurry (1:4) @ 500 Lha^{-1} through irrigation at 30 and 45 DAS	7.72	0.34	0.90	4.06
T_9	T_2 + Foliar application of chelated Fe (0.1%) at two critical growth stages	7.93	0.27	0.81	4.74
T_{10}	T_2 + Foliar application of chelated Zn (0.1%) at two critical growth stages	7.96	0.28	0.83	4.56
T_{11}	Cow dung slurry alone (1:4) @ 500 Lha^{-1} at 30 DAS	7.78	0.30	0.88	4.26
T_{12}	Cow dung slurry alone (1:4) @ 500 Lha^{-1} at 45 DAS	7.79	0.32	0.86	4.26
	Initial	7.69	0.28	0.74	4.87
	SE $\pm$	0.039	0.014	0.028	0.092
	CD at 5 %	0.115	0.042	0.082	0.271

Table 3: Pooled mean data of soil available N, P, K and NUE at harvest

Tr. No.	Treatment	Av. N (kg ha^{-1})	Av. P (kg ha^{-1})	Av. K (kg ha^{-1})	NUE (kg kg^{-1})
T_1	Control (RDF)	191	7.57	229	2.63
T_2	GRDF (80:40:40 N:P_2O_5:K_2O kg ha^{-1} + FYM @ 5 t ha^{-1})	207	10.47	257	4.36
T_3	T_2 + Soil application of $FeSO_4$ @ 25 kg ha^{-1} at sowing	201	11.63	254	5.83
T_4	T_2 + Soil application of $ZnSO_4$ @ 20 kg ha^{-1} at sowing	199	9.97	260	7.79
T_5	T_2 + $FeSO_4$ @ 25 kg ha^{-1} + cow dung slurry (1:4) @ 500 Lha^{-1} through irrigation at 30 DAS	202	14.08	258	6.28
T_6	T_2 + $FeSO_4$ @ 25 kg ha^{-1} + cow dung slurry (1:4) @ 500 Lha^{-1} through irrigation at 30 and 45 DAS	205	13.10	248	6.26
T_7	T_2 + $ZnSO_4$ @ 20 kg ha^{-1} + cow dung slurry (1:4) @ 500 Lha^{-1} through irrigation at 30 DAS	205	13.78	254	9.43
T_8	T_2 + $ZnSO_4$ @ 20 kg ha^{-1} + cow dung slurry (1:4) @ 500 Lha^{-1} through irrigation at 30 and 45 DAS	208	14.37	257	9.84
T_9	T_2 + Foliar application of chelated Fe (0.1%) at two critical growth stages	200	12.26	259	5.19
T_{10}	T_2 + Foliar application of chelated Zn (0.1%) at two critical growth stages	199	12.08	262	6.08
T_{11}	Cow dung slurry alone (1:4) @ 500 Lha^{-1} at 30 DAS	192	8.08	248	-
T_{12}	Cow dung slurry alone (1:4) @ 500 Lha^{-1} at 45 DAS	195	10.04	219	-
	Initial	198	6.18	274	-
	SE $\pm$	5.977	0.892	9.517	-
	CD at 5 %	N S	2.634	NS	-

Table 4: Pooled mean data of soil available micronutrient in soil at harvest

Tr. No.	Treatment	Fe (mg kg^{-1})	Zn (mg kg^{-1})	Mn (mg kg^{-1})	Cu (mg kg^{-1})
T_1	Control (RDF)	3.91	0.40	3.99	0.73
T_2	GRDF (80:40:40 $N:P_2O_5:K_2O$ kg ha^{-1} + FYM @ 5 t ha^{-1})	4.07	0.46	4.87	0.79
T_3	T_2 + Soil application of $FeSO_4$ @ 25 kg ha^{-1} at sowing	4.89	0.44	4.55	0.83
T_4	T_2 + Soil application of $ZnSO_4$ @ 20 kg ha^{-1} at sowing	3.86	0.71	4.85	0.86
T_5	T_2 + $FeSO_4$ @ 25 kg ha^{-1} + cow dung slurry (1:4) @ 500 Lha^{-1} through irrigation at 30 DAS	5.61	0.51	5.07	0.85
T_6	T_2 + $FeSO_4$ @ 25 kg ha^{-1} + cow dung slurry (1:4) @ 500 Lha^{-1} through irrigation at 30 and 45 DAS	5.33	0.50	5.39	0.84
T_7	T_2 + $ZnSO_4$ @ 20 kg ha^{-1} + cow dung slurry (1:4) @ 500 Lha^{-1} through irrigation at 30 DAS	4.09	0.81	4.77	0.76
T_8	T_2 + $ZnSO_4$ @ 20 kg ha^{-1} + cow dung slurry (1:4) @ 500 Lha^{-1} through irrigation at 30 and 45 DAS	4.24	0.84	5.35	0.78
T_9	T_2 + Foliar application of chelated Fe (0.1%) at two critical growth stages	4.09	0.45	4.14	0.83
T_{10}	T_2 + Foliar application of chelated Zn (0.1%) at two critical growth stages	4.12	0.43	4.73	0.82
T_{11}	Cow dung slurry alone (1:4) @ 500 Lha^{-1} at 30 DAS	3.73	0.44	4.83	0.87
T_{12}	Cow dung slurry alone (1:4) @ 500 Lha^{-1} at 45 DAS	4.01	0.45	4.94	0.87
	Initial	**3.87**	**0.51**	**4.66**	**0.97**
	SE ±	0.13	**0.020**	**0.132**	**0.035**
	CD at 5 %	0.39	**0.058**	**0.389**	**NS**

Table 5: Pooled mean data of total micronutrient uptake by *rabi* sorghum

Tr. No.	Treatment	Total micronutrient uptake (g ha^{-1})					
		Fe			Zn		
		Grain	Stover	Total	Grain	Stover	Total
T_1	Control (RDF)	885	1387	2272	173	732	905
T_2	GRDF (80:40:40 $N:P_2O_5:K_2O$ kg ha^{-1} + FYM @ 5 t ha^{-1})	933	1491	2424	192	741	933
T_3	T_2 + Soil application of $FeSO_4$ @ 25 kg ha^{-1} at sowing	1053	1839	2892	196	734	930
T_4	T_2 + Soil application of $ZnSO_4$ @ 20 kg ha^{-1} at sowing	1101	1581	2682	246	932	1178
T_5	T_2 + $FeSO_4$ @ 25 kg ha^{-1} + cow dung slurry (1:4) @ 500 Lha^{-1} through irrigation at 30 DAS	1072	1870	2942	207	806	1013
T_6	T_2 + $FeSO_4$ @ 25 kg ha^{-1} + cow dung slurry (1:4) @ 500 Lha^{-1} through irrigation at 30 and 45 DAS	1084	1963	3047	215	833	1048
T_7	T_2 + $ZnSO_4$ @ 20 kg ha^{-1} + cow dung slurry (1:4) @ 500 Lha^{-1} through irrigation at 30 DAS	1174	1921	3095	261	1041	1302
T_8	T_2 + $ZnSO_4$ @ 20 kg ha^{-1} + cow dung slurry (1:4) @ 500 Lha^{-1} through irrigation at 30 and 45 DAS	1199	2148	3347	275	1045	1320
T_9	T_2 + Foliar application of chelated Fe (0.1%) at two critical growth stages	1006	1820	2826	194	801	995
T_{10}	T_2 + Foliar application of chelated Zn (0.1%) at two critical growth stages	1015	1839	2854	222	827	1049
T_{11}	Cow dung slurry alone (1:4) @ 500 Lha^{-1} at 30 DAS	741	1040	1781	147	583	730
T_{12}	Cow dung slurry alone (1:4) @ 500 Lha^{-1} at 45 DAS	731	1002	1733	139	558	697
	SE ±	35.62	187.6	167.81	10.52	52.34	47.8
	CD at 5 %	105.16	553.9	495.34	31.06	154.4	141.1

Table 6: Economics of *rabi* sorghum as influence by zinc and iron application

Tr. No.	Treatment	Yield (q ha^{-1})		Cost of cultivation	Monetary returns	Net Monetary returns	B:C ratio
		Grain	Stover	Rs ha^{-1}			
T_1	Control (RDF)	30.43	87.23	30768	83580	52812	1.72
T_2	GRDF (80:40:40 $N:P_2O_5:K_2O$ kg ha^{-1} + FYM @ 5 t ha^{-1})	33.18	87.27	36768	87996	51228	1.39
T_3	T_2 + Soil application of $FeSO_4$ @ 25 kg ha^{-1} at sowing	35.53	91.83	37268	93580	56312	1.51
T_4	T_2 + Soil application of $ZnSO_4$ @ 20 kg ha^{-1} at sowing	38.68	91.27	37568	98396	60828	1.62
T_5	T_2 + $FeSO_4$ @ 25 kg ha^{-1} + cow dung slurry (1:4) @ 500 Lha^{-1} through irrigation at 30 DAS	36.27	90.87	38393	94380	55987	1.46
T_6	T_2 + $FeSO_4$ @ 25 kg ha^{-1} + cow dung slurry (1:4) @ 500 Lha^{-1} through irrigation at 30 and 45 DAS	36.22	93.87	39518	95500	55982	1.42
T_7	T_2 + $ZnSO_4$ @ 20 kg ha^{-1} + cow dung slurry (1:4) @ 500 Lha^{-1} through irrigation at 30 DAS	41.30	99.9	38693	106040	67347	1.74
T_8	T_2 + $ZnSO_4$ @ 20 kg ha^{-1} + cow dung slurry (1:4) @ 500 Lha^{-1} through irrigation at 30 and 45 DAS	41.95	104.35	39818	108860	69042	1.73
T_9	T_2 + Foliar application of chelated Fe (0.1%) at two critical growth stages	34.51	86.8	38518	89936	51418	1.33
T_{10}	T_2 + Foliar application of chelated Zn (0.1%) at two critical growth stages	35.94	89.37	38418	93252	54834	1.43
T_{11}	Cow dung slurry alone (1:4) @ 500 Lha^{-1} at 30 DAS	26.63	74	27919	72208	44289	1.59
T_{12}	Cow dung slurry alone (1:4) @ 500 Lha^{-1} at 45 DAS	25.79	71.43	27919	69836	41917	1.50

Note: Rs. 12.34/ kg N, Rs. 46.67/ kg P_2O_5, Rs. 28/kg K_2O, Rs. 1200/t FYM, Rs. 20/kg $FeSO_4$, Rs. 40/kg $ZnSO_4$, Rs. 1500/kg chelate Fe, Rs. 1300/kg chelate Zn, Grain Rs. 1600/q, stover Rs. 400/q, Rs. 500/q fresh cow dung

Conclusion

Thus, it is concluded that the application of $ZnSO_4$ @ 20 kg ha^{-1} incubated with cow dung slurry @ 500 L ha^{-1} at 30 and 45 DAS with the general recommended dose of nutrients (80:40:40 kg ha^{-1} $N:P_2O_5:K_2O$ + 5 t ha^{-1} FYM) found beneficial for increase in leaf area, chlorophyll content in leaves, uptake of total Fe, Zn, availability of Zn, Fe in soil, agronomic efficiency, grain and stover yield of *rabi* sorghum under Vertic Inceptisol. However, this treatment was at par with treatment of T_7 (GRDF + $ZnSO_4$ @ 20 kg ha^{-1} with cow dung slurry at 30 DAS) with the higher B:C ratio (2.74).

References

1. Adsul PB, Pawar A, Gaikwad G, Puri A, Shaikh MSS. Uptake of N, P, K and yield of *kharif* sorghum as influenced by soil and foliar application of micronutrients. Bio infolet. 2014; 11(2C):578-582.
2. Annonymous, 2014. www.Indiastat.com.

3. Dwivedi SK, Singh RS, Dwivedi KN. Effect of sulphur and zinc nutrition on yield and quality of maize in Typic Ustochrept soil of Kanpur. Journal of the Indian Society of Soil Science. 2002; 50(1):70-74.
4. Hossain MA, Jahiruddin M, Khatun F. Response of maize (*Zea mays* L) varieties to zinc fertilization. Bangladesh Journal of Agriculture Research. 2011; 36:437-47.
5. Kochar RK, Arora BR, Nayyar VK. Effect of sulpur and zinc application on maize crop. Journal of the Indian Society of Soil Science. 1990; 38(2):339-341.
6. Kumar A, Sen A, Dev CM. Effect of iron, zinc and manganese levels on yield and yield attributing characters of rice. Bioinfolet. 2013; 10(3B):924-929.
7. Kumssa DB, Joy EJM, Ander JEL, Watts MJ, Young SD, Walker S, *et al*. Dietary calcium and zinc deficiency risks are decreasing but remain prevalent. Sci. Rep. 2015; 5:10974.
8. Meena MC, Patel KP, Rathod DD. Effect of Zn and Fe enriched FYM on mustard yield and micronutrients availability in loamy sand soil of Anand. Journal of the Indian Society of Soil Science. 2006; 54:495-499.
9. Nalina MS. Role of zinc in drought tolerance in sorghum. M.Sc. (Agri) Thesis, University of Agricultural Sciences, Dharwad, Karnataka (India), 2013.
10. Panse VG, Sukhatme PV. Statistical methods for agricultural workers, ICAR., publication New Delhi, 1967; p.359.
11. Patel IN, Patel DG, Patel NH, Vyas GK, Singh NR. Study on the effects of foliar and soil application of micronutrients on yield of sorghum. Proc.4th Int. Agron. Congress, 22-26 November, 2016, New Dehli. 2016; 2:855-857.
12. Singh R, Sharma PR, Singh M, Sharma R, Laura RD. Phosphorus, sulphur and zinc interactions in barley (*Hordeum vulgare* L.) yield, phosphorus concentration and its uptake. Crop Res. Hissar. 1997; 13:571.