International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(6): 2647-2650

Received: 07-09-2018
Accepted: 09-10-2018

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Effect of application of iron and zinc on nutrient availability and pearl millet yield in vertisols

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Abstract
The present investigation was carried out at farm of Bajra Research Scheme, College of Agriculture, Dhule during *kharif* 2016. The treatments comprised of foliar and soil application of iron and zinc sources of EDTA and sulphate form at two critical growth stages of pearl millet crop. The organic carbon content (8.31 g kg^{-1}), available N (171.44 kg ha^{-1}), P (23.47 kg ha^{-1}), K (495.32 kg ha^{-1}) and S (47.68 mg kg^{-1}) were observed highest with GRDF + soil application of 25 kg ha^{-1} $FeSO_4$ + 20 kg ha^{-1} $ZnSO_4$. Combined foliar application of 0.1% chelated Fe and Zn along with GRDF at tillering and panicle initiation stages also significantly improved the nutrient availability. However, the highest exchangeable Ca^{++} (27.27 me 100 g^{-1} soil) was noted in treatment consisting of GRDF + combined application of 25 kg ha^{-1} $FeSO_4$ + 20 kg ha^{-1} $ZnSO_4$. The maximum exchangeable Mg^{++} content (17.92 me 100 g^{-1} soil) was recorded under GRDF + foliar application of 0.2% chelated Fe at two crop growth stages. The availability of micronutrients (Fe, Mn, Zn and Cu) significantly increases with application of Fe and Zn as soil or foliar. The maximum available Fe (5.92 mg kg^{-1}) and Mn (9.34 mg kg^{-1}) was noticed under GRDF + soil application of 25 kg ha^{-1} $FeSO_4$, while, the maximum availability of Zn and Cu (0.62 and 1.10 mg kg^{-1}, respectively) was observed with GRDF + soil application of 20 kg ha^{-1} $ZnSO_4$. The increase in grain and stover yield under the treatments is of 17.33 and 25.61 per cent, respectively for T_7 and 12.88 and 18.20 per cent, respectively for T_4 over GRDF alone (T_2). Among the foliar application, GRDF + foliar application of 0.1% chelated Fe + 0.1% chelated Zn at two crop growth stages (T_8) produces the higher grain) and stover yield and it was increased by 10.00 and 17.44 per cent, respectively over GRDF alone.

Keywords: Soil and foliar application of Fe and Zn, macro and micro nutrients, pearl millet

Introduction

Pearl millet is an indispensable arid and semi-arid crop of India cultivated as dual purpose (food and feed) crop in over 8.3 m ha ranking 4th among total cereals (Yadav *et al*., 2011) [19]. Pearl millet is the richest source of nutrition, especially Fe, Ca and Zn among cereals and hence, can provide all the nutrients at the least cost compared to wheat and rice (Parthasarathy Rao *et al*., 2006) [14]. The first iron-rich pearl millet variety (ICTP-8203Fe) was commercialized in 2012 in Maharashtra, India. It also provides more zinc, high yielding, disease and drought tolerant. Results indicate that children could get their full daily iron needs from just 100 grams of this pearl millet flour. Children aged under two, who might eat less, would still benefit substantially from eating iron-rich pearl millet. More than 30,000 Indian farmers have purchased and planted this new variety marketed as *Dhanshakti* (meaning prosperity and strength). Scientists are now developing more iron-rich pearl millet varieties that will have even higher levels of iron to be released in India (v.s.vidushi@cgiar.org).

Foliar spraying is a new method for crop feeding in which micronutrients in the form of liquid are used into leaves (Nasiri *et al*., 2010) [9]. Foliar application of micronutrient is more beneficial than soil application. Since, application rates are lesser as compared to soil application, same quantity of nutrient application could be supplied easily and crop reacts to nutrient application immediately. Undoubtedly higher yield and quality especially oil will be obtained by micronutrient foliar spraying. Foliar spraying of micronutrient is very helpful when the roots cannot provide necessary nutrients. Moreover, soil pollution would be a major problem by soil application of micronutrients. As people are concerned about the environment and uptake of nutrients through plant leaves is better than soil application, foliar spraying was advised (Bozorgi *et al*., 2011) [1]. Crop roots are unable to absorb some important nutrients such as zinc, because of soil properties, such as high pH, lime or heavy texture, and in this situation, Foliar spraying could be more effective 6 to 20 times as compared to soil application. The role of micronutrients enables rapid change in physiology of plant within one season to achieve desirable results. Looking to widespread deficiency of Fe and Zn and its response to pearl millet crop in terms of foliar as well as soil application, the present field investigation will be undertaken to study the response of hybrid pearl millet to soil and foliar application of Fe and Zn on vertisol.

Material and Methods

The present investigation was carried out at farm of Bajra Research Scheme, College of Agriculture, Dhule during kharif 2016. The experiment was laid in Randomized Block Design with eight treatments each replicated thrice. GRDF was common to all treatments (60:30:25 NPK kg ha-1 + FYM @ 5t ha-1) except control. The treatment comprised T1: Control, T2: GRDF (60:30:25 NPK kg ha-1 + FYM @ 5t ha-1), T3: GRDF + Soil application of 25 kg ha-1 FeSO4, T4: GRDF +Soil application of 20 kg ha-1 ZnSO4, T5: GRDF + Foliar application of 0.2 % chelated Fe @ two stages, T6: GRDF + Foliar application of 0.2 % chelated Zn @ two stages,T7: GRDF+Soil application of 25 kg ha-1 FeSO4 + 20 kg ha-1 ZnSO4, andT8: GRDF + Foliar application of 0.1% chelated Fe + 0.1% chelated Zn @ two stages. The two critical growth stages are tillering and panicle initiation stages of pearl millet crop. The soil was deep black, vertisol having clayey in nature with pH-7.80, EC-0.149 dSm-1, organic carbon– 7.7 g kg-1, available N-156.45 kg ha-1, P2O5-19.15 kg ha-1, K2O-475.30 kg ha-1 and DTPA, Fe-4 mg ka-1, Zn-0.37 mg ka-1, Mn-6.30 mg ka-1, and Cu-0.97 mg ka-1, however, exchangeable Ca++ 23.90 me 100 g-1 soil and exchangeable Mg++ was 15.72 me 100 g-1 soil. The standard methods were adopted for estimation of soil properties viz., pH and EC by potentiometry and conductometry, respectively (Jackson 1973) [4], organic C by wet oxidation (Nelson and Sommer 1982), available N by alkaline permanganate (Subbiah and Asija 1956), available P by colorimetric NaHCO3 extraction (Watanabe et. al, 1965), available K by neutral normal ammonium acetate (Jackson1973) [4], echangeable Ca++ and Mg++ by versenate titration (Page 1982) [10, 11], avalable S by 0.15% CaCl2 extractable (Williams and Steinberg 1959) [18] and available Fe, Mn, Zn and Cu were estimated by atomic absorption spectrophotometer (Lindsay and Norvell 1978) [6].

Results and Discussion

Available nutrient status

Organic carbon content at harvest (Table 1) was ranged between 7.72 to 8.31 g kg-1. The highest content of 8.31 g kg-1 was noted with GRDF + soil application of 25 kg ha-1 FeSO4 + 20 kg ha-1 ZnSO4 (T7) followed by GRDF + soil application of 25 kg ha-1 FeSO4 (T3) and GRDF + soil application of 20 kg ha-1 ZnSO4 (T4) i.e. 8.25 and 8.21 g ha-1, respectively. Among the foliar application treatments, the higher organic carbon (8.17 g kg-1) was recorded in GRDF + foliar application of 0.1% chelated Fe + Zn at two crop stages. Individual foliar spray of 0.2% Fe and Zn along with GRDF also increased organic carbon over GRDF alone and control.

Significantly maximum N, P and K content in soil (171.44, 23.47 and 495.32 kg ha-1, respectively) were noticed in treatment receiving GRDF + soil application of 25 kg ha-1 FeSO4 and 20 kg ha-1 ZnSO4 (T7) which was followed by application of GRDF + soil application of 20 kg ha-1 ZnSO4 (T4). Among the foliar treatments, the higher available N, P and K contents (167.45, 22.10 and 490.43 kg ha-1, respectively) were recorded with GRDF + foliar application of 0.1% chelated Fe + 0.1% chelated Zn (T8) at tillering and panicle initiation stage and the magnitude of increase was 5.69, 9.57 and 2.07 per cent, respectively over GRDF alone (T2). The treatment T7 was at par with T4, T8 and T3. Similar results were found by Mahatma (2007) by equal application of RDF to all treatments in combination with sulphur, zinc and iron (soil) for cotton. Reddy *et al*. (2007) [14] observed that either soil application or seed treatment along with uniform dose of RDF to pigeon pea have shown significant change in soil P status. Durgude *et al*. (2014) [2] observed the similar effects with soil and foliar application of zinc and iron in maize.

The maximum exchangeable Ca++ (27.27 me 100 g-1 soil) was found in treatment T7 i.e. 25 kg ha-1 FeSO4 + 20 kg ha-1 ZnSO4 along with GRDF which was at par with all rest of the treatments except control. However, soil application of 20 kg ZnSO4 (T4) and 25 kg ha-1 (T3) along with GRDF increased exchangeable Ca++ in soil (26.93 and 26.03 me 100 g-1 soil, respectively). Chelated Fe and Zn (T8) along with GRDF (25.47, 24.93 and 24.70 me 100 g-1 soil, respectively). The maximum exchangeable Mg++ was found in treatment T5 i.e. GRDF + foliar application of 0.2% chelated Fe at two stages (17.92 me 100g-1 soil) and was at par with T6i.e.GRDF + foliar application of 0.2% chelated Zn at two stages (16.51 me 100 g-1 soil) and T8 (15.87 me 100g-1soil) which comprises foliar application of both Zn and Fe @ 0.1% along with GRDF. Soil application of Zn and Fe recorded less content of exchangeable Mg++ as compared to their foliar application. However, the higher content (14.82 me 100 g-1 soil) was noted with soil application of 25 kg ha-1 FeSO4 along with GRDF (T3) which was followed by soil application of 20 kg ha-1 ZnSO4 (T4) and combined soil application of Zn and Fe (T7) along with GRDF (14.42 and 14.05 me 100 g-1 soil, respectively). Similar results were found by Durgude *et al*. (2014) [2] with soil and foliar application of zinc and iron in cotton.

The data regarding to the available sulphur showed that the maximum available sulphur content was (47.68 mg kg-1) recorded in T7 followed by T4 GRDF + soil application of 20 kg ha-1 ZnSO4 (46.53 mg kg-1). Next to this, foliar application of both Fe and Zn @ 0.1% at two crop growth stages + GRDF (T8) noted the higher content of S (46.11 mg kg-1). Foliar application of Fe (T5) and Zn (T6) alone with GRDF also significantly increases the available S (44.92 and 45.45 mg kg-1, respectively) over control. Higher availability of sulphur may be due to the incorporation of organic sources which improved the availability of secondary and micronutrients in the soil. Similar beneficial effect of organic source on soil fertility was also noticed by Kanzariya *et al*. (2010).

The iron content in soil ranged between 3.90 to 5.92 mg kg-1 under different treatments. The GRDF + soil application of 25 kg ha-1 FeSO4 (T3) recorded the maximum iron content (5.92 mg kg-1) followed by GRDF + combined soil application of 25 kg ha-1 FeSO4 and 20 kg ZnSO4i.e. T7 (5.53 mg kg-1). These T3 and T7 increases Fe content by 46.69 and 34.22 per cent, respectively over GRDF alone (T2). Treatment (T3) receiving GRDF + soil application of 25 kg ha-1 FeSO4 recorded the highest Mn content (9.34 mg kg-1) which was followed by foliar application of 0.2% chelated Fe at tillering and panicle initiation stage along with GRDF (9.27 mg kg-1) and GRDF + soil application of 20 kg ha-1 ZnSO4 (9.02 mg kg-1). These treatments T3, T4 and T5 were found statistically at par. The Zn ranged in soil 0.32 to 0.62 mg kg-1 at harvest of pearl millet. Among the soil application of Fe and Zn treatments, the maximum zinc content (0.62 mg kg-1) was noted under GRDF + 20 kg ha-1 ZnSO4 (T4) followed by the treatment T7 i.e. GRDF + 25 kg ha-1 FeSO4 + 20 kg ha-1 ZnSO4 (0.60 mg kg-1) and both the treatments were found at par, while, increase in Zn content due to these treatments was 72.22 and 66.67 per cent, respectively over GRDF alone (T2). However, among foliar application treatments, GRDF + 0.2% spray of chelated Fe at two growth stages of crop (T5) recorded the higher Zn content of 0.42 mg kg-1 which was 16.67 per cent higher over GRDF alone. It is clearly evident that soil application of Fe and Zn showed higher content of copper when compared with their foliar treatment, although, all treatments were found at par. The highest copper content of 1.10 mg kg-1 was recorded in GRDF + soil application of 20 kg ha-1 ZnSO4 (T4) followed by the treatment T3 i.e. GRDF + soil application of 25 kg ha-1 FeSO4 (1.05 mg kg-1) and the magnitude of increase in Cu under these treatments were 27.91 and 22.09 per cent, respectively over GRDF over alone (T2). Combined soil application of Fe and Zn along with GRDF (T7) also recorded higher Cu content (0.93 mg kg-1). While, with foliar application, spraying of 0.2% chelated Zn at two crop growth stages + GRDF (T6) noted the higher Cu content (0.92 mg kg-1). Increase in availability of micronutrients due to foliar application in rice was previously observed by Radhika *et al*. (2013) [13]. While, soil application of Zn and Fe contributed in improvement of nutrient availability was noticed by Ghritlahare *et al*. (2015) [3].

Grain and stover yield

The results revealed that the grain and stover yields of pearl millet were significantly affected due to different iron and zinc treatments (Table 2) The significantly highest grain (42.71 q ha-1) and stover (77.73 q ha-1) yield of pearl millet was recorded in the treatment receiving GRDF + soil application of 25 kg ha-1 FeSO4 + 20 kg ha-1 ZnSO4 (T7) followed by GRDF + soil application of 20 kg ha-1 ZnSO4 (T4) i.e. 41.09 and 73.14 q ha-1, respectively. The increase in grain and stover yield under these treatments is of 17.33 and 25.61 per cent, respectively for T7 and 12.88 and 18.20 per cent, respectively for T4 over GRDF alone (T2). And T7 was at par with T4, T8 and T3 respectively. Increase in wheat yield due to foliar application of micronutrients was observed by Narimani *et al*. (2010) [8]. While, NPK along with Fe and Zn increased the cotton yield was reported by Sangh *et al*. (2012) [15]; and pearl millet yield was noted by Prasad *et al*. (2014) [12].

Table 1: Effects of different treatments of iron and zinc on soil fertility status

Treatments	Organic carbon ($g\ kg^{-1}$)	Available nutrients ($kg\ ha^{-1}$)			Ex. Ca^{++}	Ex. Mg^{++}	Available S ($mg\ kg^{-1}$)
		N	P	K	(me 100 g^{-1} soil)		
T_1: Control	7.72	145.50	15.35	465.13	23.23	13.17	40.54
T_2: GRDF (60:30:25 NPK kg ha^{-1} + FYM @ 5t ha^{-1})	7.74	158.44	20.17	480.47	25.10	13.87	44.55
T_3: GRDF + Soil application of 25 kg ha^{-1} $FeSO_4$	8.25	164.74	21.97	488.12	26.03	14.82	45.99
T_4: GRDF +Soil application of 20 kg ha^{-1} $ZnSO_4$	8.21	169.04	22.83	494.78	26.93	14.42	46.53
T_5: GRDF + Foliar application of 0.2 % chelated Fe @ two stages	7.86	159.74	20.63	483.92	24.93	17.92	44.92
T_6: GRDF + Foliar application of 0.2 % chelated Zn @ two stages	7.93	162.73	21.32	487.38	25.47	16.51	45.45
T_7: GRDF + Soil application of 25 kg ha^{-1} $FeSO_4$ + 20 kg $ha^{-1}$$ZnSO_4$	8.31	171.44	23.47	495.32	27.27	14.05	47.68
T_8: GRDF + Foliar application of 0.1% chelated Fe + 0.1 % chelated Zn @ two stages	8.17	167.45	22.10	490.43	24.70	15.87	46.11
S.E.±	0.270	4.325	1.257	5.844	0.828	1.016	1.367
C.D. @ 5%	0.577	13.088	3.803	17.686	2.505	3.076	4.138

Table 2: Soil available micro nutrients at harvest as influenced by iron and zinc application

Treatments	Available micronutrients ($mg\ kg^{-1}$)			
	Fe	Mn	Zn	Cu
T_1: Control	3.90	7.10	0.32	0.82
T_2: GRDF (60:30:25 NPK kg ha^{-1} + FYM @ 5t ha^{-1})	4.12	7.58	0.36	0.86
T_3: GRDF + Soil application of 25 kg ha^{-1} $FeSO_4$	5.92	9.34	0.38	1.05
T_4: GRDF +Soil application of 20 kg ha^{-1} $ZnSO_4$	4.42	9.02	0.62	1.10
T_5: GRDF + Foliar application of 0.2 % chelated Fe @ two stages	4.30	9.27	0.42	0.89
T_6: GRDF + Foliar application of 0.2 % chelated Zn @ two stages	4.23	8.54	0.34	0.92
T_7: GRDF + Soil application of 25 kg ha^{-1} $FeSO_4$ + 20 kg $ha^{-1}$$ZnSO_4$	5.53	7.90	0.60	0.93
T_8: GRDF + Foliar application of 0.1% chelated Fe + 0.1 % chelated Zn @ two stages	4.31	8.04	0.35	0.88
S.E.±	0.129	0.252	0.025	0.098
C.D. @ 5%	0.392	0.764	0.076	0.258

Table 3: Grain and stover yield of pearl millet as influenced by Fe and Zn application

Treatments	Yield ($q\ ha^{-1}$)	
	Grain Yield	Stover Yield
T_1: Control	26.84	44.88
T_2: GRDF (60:30:25 NPK kg ha^{-1} + FYM @ 5t ha^{-1})	36.40	61.88
T_3: GRDF + Soil application of 25 kg ha^{-1} $FeSO_4$	39.80	72.11
T_4: GRDF +Soil application of 20 kg ha^{-1} $ZnSO_4$	41.09	73.14
T_5: GRDF + Foliar application of 0.2 % chelated Fe @ two stages	37.04	62.96
T_6: GRDF + Foliar application of 0.2% chelated Zn @ two stages	37.60	64.29
T_7: GRDF + Soil application of 25 kg ha^{-1} $FeSO_4$ + 20 kg ha^{-1} $ZnSO_4$	42.71	77.73
T_8: GRDF + Foliar application of 0.1% chelated Fe +0.1 % chelated Zn @ two stages	40.04	72.67
S.E.±	1.46	2.34
C.D. @ 5%	4.42	7.07

Conclusion

Experimental findings indicate that soil application of 25 kg ha-1 FeSO4 + 20 kg ha-1 ZnSO4 along with GRDF significantly increases the soil organic carbon content, available N, P, K, S and micronutrients (Fe, Mn, Zn and Cu) and also positive effect on exchangeable ca++ mg++ and grain and stover yield. Application of 20 kg ha-1 ZnSO4+ GRDF found better for enhancing this nutrients status in soil as compared to 25 kg ha-1 FeSO4 + GRDF. It can be concluded that consumption of iron and zinc fertilizer considerably improved yield and yield components of pearl millet on vertisol.

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