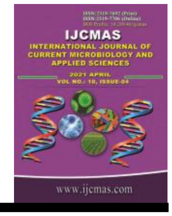
Int.J.Curr.Microbiol.App.Sci (2021) *10*(04): 307-315



International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 10 Number 04 (2021)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2021.1004.032

Response of Iron and Zinc on Yield, Quality and Soil Nutrient Dynamics of Pearl Millet on Vertisol

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A B S T R A C T

Keywords

Iron, zinc and pearl millet

Article Info

Accepted:
12 March 2021
Available Online:
10 April 2021

The field experiment was conducted to study the "Response of iron and zinc on yield, quality and soil nutrient dynamics of pearl millet on vertisol" was carried out at experimental farm, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Parbhani during *kharif* 2019. The field experiment was laid out in Randomized Block Design with three replications and eight treatment combinations. The treatments consist of absolute Control, RDF (60:30:30 N:P_2O_5:K_2O kg ha^{-1}), RDF + $FeSO_4$ 25 kg ha^{-1}, RDF + $ZnSO_4$ 25 kg ha^{-1}, RDF+ $FeSO_4$ 25 kg ha^{-1} + $ZnSO_4$ 25 Kg ha^{-1}, RDF+ foliar spray of $FeSO_4$ @ 0.5 % at 30 DAS & 45 DAS, RDF+ foliar spray of $ZnSO_4$ @ 0.5 % at 30 DAS and 45 DAS and RDF + foliar spray of $FeSO_4$ and $ZnSO_4$ @ 0.5 % at 30 DAS & 45 DAS. Significantly higher grain and stover yield was produced with RDF + soil application of 25 kg ha^{-1} $FeSO_4$ + 25 kg ha^{-1} $ZnSO_4$ and it was followed by the treatment RDF+ foliar spray of $ZnSO_4$ and $FeSO_4$ @ 0.5 % each at 30 & 45 DAS. The uptake of nutrient was significantly influenced by different soil and foliar application treatments of Fe and Zn. The maximum N, P and K uptake by pearl millet grain and stover was noticed in treatment consisting of RDF+ 25 kg ha^{-1} $FeSO_4$ + 25 kg ha^{-1} $ZnSO_4$ followed by the RDF+ foliar spray of $ZnSO_4$ and $FeSO_4$ @ 0.5 % each at 30 & 45 DAS. Similarly, significantly highest Fe and Zn uptake by grain and stover was observed with RDF+ 25 kg ha^{-1} $FeSO_4$ +25 kg ha^{-1} $ZnSO_4$. The soil application of Fe and Zn to pearl millet significantly contributed in improving soil fertility and there by crop yield. The organic carbon content was highest in treatment RDF + $FeSO_4$ 25 kg ha^{-1} + $ZnSO_4$ 25 kg ha^{-1}, available nitrogen was highest in treatment RDF + foliar spray of $ZnSO_4$ @ 0.5 % at 30 DAS & 45 DAS, available phosphorus was highest in treatment RDF + foliar spray of $FeSO_4$ @ 0.5 % at 30 DAS & 45 DAS, available potassium was highest in treatment RDF and sulphur was observed highest with RDF + 25 kg ha^{-1} $FeSO_4$ + 25 kg ha^{-1} $ZnSO_4$, Combined foliar application of RDF + 0.5 % chelated Fe and Zn at tillering and panicle initiation stages also significantly improved the nutrient availability. The maximum available Fe was noticed under RDF + 25 kg ha^{-1} $FeSO_4$ +25 kg ha^{-1} $ZnSO_4$ and the maximum availability of Zn was observed with RDF + 25 kg ha^{-1} $FeSO_4$ + 25 kg ha^{-1} $ZnSO_4$. Soil and foliar application of Fe and Zn along with RDF found beneficial in improving the soil nutrient status, nutrient uptake and there by pearl millet yield.

Introduction

Pearl millet (*Pennisetum glaucum*) is most commonly grown type millet. It is commonly known as bajara. It is being grown in Indian continent since prehistoric times. Pearl millet is well adapted to growing area characterized by drought, low productivity and high temperature. India is largest producer of pearl millet with an area of 6.93 million ha with production of 8.61 million tones with productivity of 1243 kg ha^{-1} during 2018 - 2019 (Anonymous, 2019).

In Maharashtra, this crop is grown on 7.01 lakh ha of land with 3.32 lakh tones of grain production having productivity of 412 kg ha^{-1} in 2018-2019. Iron and Zinc deficiency in Indian soils and response to their application to various crops have been reported by (Tiwari and Dwivedi, 1993). Nutrients play a vital role in biosynthesis of protein and amino acids. Use of manures and IPNS reduced the micronutrient fertilizer necessities of crops and enhances remaining effect. The problems of micronutrients after the green revolution are relatively different.

Continuous use of high analysis fertilizer under intensify crop and carelessness of organic manures manifested the amount of common micronutrients deficiencies of Fe and Zn in light texture soils of India (Singh, 2006). The function of micronutrients in various physical and biochemical processes in plant is well known, which enables quick change in physiology of plant within one season to realize popular results.

Looking to general deficiency of Iron and Zinc and its response to pearl millet crop in terms of foliar as well as soil application to this crop, the present field research was undertaken to study the response of hybrid pearl millet to soil and foliar application of Iron and Zinc on Vertisol.

Materials and Methods

A field experiment was conducted during *kharif* -2019 to study the response of iron and zinc on growth, yield and soil nutrient dynamics of pearl millet on vertisol at Research Farm of Soil Science and Agricultural Chemistry, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra (India). The experiment was laid out in randomized block design (RBD) with three replications and eight treatments. The treatment comprised of absolute control (T_1), RDF (60:30:30 $N:P_2O_5:K_2O$ kg ha^{-1}) (T_2), RDF + $FeSO_4$ 25 kg ha^{-1} (T_3), RDF + $ZnSO_4$ 25 kg ha^{-1} (T_4), RDF+ $FeSO_4$ 25 kg ha^{-1} + $ZnSO_4$ 25 Kg ha^{-1}(T_5), RDF+ foliar spray of $FeSO_4$ @ 0.5 % at 30 DAS & 45 DAS (T_6), RDF+ foliar spray of $ZnSO_4$ @ 0.5 % at 30 DAS and 45 DAS (T_7) and RDF + foliar spray of $FeSO_4$ and $ZnSO_4$ @ 0.5 % at 30 DAS & 45 DAS (T_8). The Pearl millet (Bajara) *Cv.* AHB1200 was taken as test crop. The chemical fertilizers were applied as per treatments. The plant observations were recorded during growth of the crop and at the time of harvest of the crop. The surface soil samples (0-15 cm) were collected initial and harvest of crops and analysed for chemical properties of soil by adopting standard procedures.

Results and Discussion

The data in respect of grain and stover yield of pearl millet as influenced by Fe and Zn application is presented in Table 1. There was significant increase in yield due to the different treatments. Highest grain yield (28.89 q ha^{-1}) and stover yield (61.31 q ha^{-1}) yield of pearl millet was recorded in the treatment receiving RDF + soil application of 25 kg ha^{-1} $FeSO_4$ + 25 kg ha^{-1} $ZnSO_4$ (T5) and it was followed by grain yield (27.48 q ha^{-1}) and stover yield (58.28 q ha^{-1}) RDF + foliar spray of ZnSO4 and FeSO4 @ 0.5 % each at

30 & 45 DAS (T8), respectively. Close examination of the results noticed that the treatment T5 was found statistically at par with treatments T8, T3 and T4. Increase in wheat yield due to foliar application of micronutrients was observed by Narimani *et al.,* (2010). While, NPK along with Fe and Zn increased the cotton yield was reported by Sangh *et al.*, (2012); and pearl millet yield was noted by Prasad *et al.,* (2014). This yield enhance in this study due to improvement in yield attributes because of balanced supply of nutrients.

The data on protein content in pearl millet grain are presented in table 1. The significantly highest protein content in grain (15.79 %) was observed in treatment T5 (RDF+25 kg ha^{-1} FeSO4 +25 kg ha^{-1} ZnSO4) which were at par with treatment T4 (14.72 %) (RDF +25 kg ha^{-1} ZnSO4) and with treatment T8 (14.09 %) (RDF+ foliar spray of ZnSO4 and FeSO4 @ 0.5% each at 30 & 45DAS). Palta *et al.,* (2005) reported that the seed protein content increased with nitrogen availability in chickpea. Similarly, Kinra *et al.,* (1967) also resulted that foliar versus soil application of nitrogen to pearl millet was not much difference in protein content and carbohydrates content.

The data regarding 1000 grain weight after harvesting of pearl millet is given in Table 1. The 1000 grain weight (g) of pearl millet was recorded at harvest. The results indicated the significant increase in grain weight due to the application of micronutrients as compared to RDF and control. The maximum grain weight (18.50 g) was recorded with RDF + soil application of 25 kg $FeSO_4$ + 25 kg $ZnSO_4$ treatment (T_5), followed by RDF + soil application of 25 kg $FeSO_4$ (T_3) having 17.62 g grain weight. The treatment (T_4) RDF + Soil application of $ZnSO_4$ also noticed increase in the grain weight (17.09 g). With foliar application, the treatment receiving RDF + foliar application of 0.5 % chelated Fe + 0.5 % chelated Zn @ two stages (T_8) recorded significantly higher grain weight of 16.59 g. The increase in grain weight was due to the application of RDF + soil application of 25 kg FeSO4+ 25 kg ZnSO4 which increased the uptake of nutrients by plants was previously noticed by Ravi and Channal (2010). Similar effect of soil application of Zn on growth and yield of maize was noticed by Asha *et al.,* (2012) and on pearl millet by Prasad *et al.,* (2014).

Total chlorophyll content of Pearl millet as influenced by application of iron and zinc are presented in table 1. The significantly highest total chlorophyll content (11.72 mg 100 g^{-1}) was observed in treatment RDF + soil application of 25 kg ha^{-1} $FeSO_4$ + 25 kg ha^{-1} $ZnSO_4$ (T_5) which was followed by total chlorophyll content (11.00 mg 100 g^{-1}) observed in treatment RDF + foliar spray of $FeSO_4$ and $ZnSO_4$ @ 0.5 % at 30 DAS & 45 DAS (T_8). The results are in conformity with (Kinra *et al.,* 1967).

Total data pertaining to total nutrient uptake by Pearl millet as influenced by application of iron and zinc are presented in table 2. The total nitrogen varied from 39.14 to 88.48 kg ha^{-1} with mean value 63.81 kg ha^{-1}. The significantly highest total nitrogen uptake (88.48 kg ha^{-1}) was recorded in the treatment with RDF + 25 kg ha^{-1} $FeSO_4$ + 25 kg ha^{-1} $ZnSO_4$ (T_5) found superior over rest of the treatments. Increase in uptake of nutrients by application of Zn and Fe to mustard crop previously reported by Kumar *et al.,* (2014) and in soybean crop by Goli *et al.*, (2015).

The total phosphorus uptake was varied from 13.43 to 43.34 kg ha^{-1} with mean value 28.38 kg ha^{-1}, respectively. The highest total phosphorus uptake (43.34 kg ha^{-1}) was found in the treatment RDF + 25 kg ha^{-1} FeSO4 + 25 kg ha^{-1} ZnSO4 (T5) and it was followed by the total phosphorus uptake (36.58 kg ha^{-1}) recorded in the RDF +25 kg ha^{-1} FeSO4 (T3). Increase in uptake of phosphorus uptake by application of Zn and Fe in soybean was also reported earlier by Goli *et al.*, (2015).

Among all the treatments treatment RDF + 25 kg ha^{-1} FeSO4 + 25 kg ha^{-1} ZnSO4 (T5) recorded significantly highest potassium uptake (213.65 kg ha^{-1}) and it was followed by the potassium uptake (197.31 kg ha^{-1}) recorded in the treatment RDF + foliar spray of ZnSO4 and FeSO4 @ 0.5 % each at 30 & 45 DAS (T8). The results were in conformity with Kumar *et al.*, (2014).

The significantly highest total sulphur uptake (7.00 kg ha^{-1}) was found in the treatment RDF + 25 kg ha^{-1} FeSO4 + 25 kg ha^{-1} ZnSO4 (T5) which was followed by the total sulphur uptake (5.96 kg ha^{-1}) recorded in RDF + foliar spray of ZnSO4 and FeSO4 @ 0.5 % each at 30 & 45 DAS (T8). The positive effect of S, Zn and Fe application on micronutrient uptake by safflower was noticed by Ravi and Channel (2010).

The data presented in Table 2 showed that the total uptake of micronutrients in pearl millet was influenced by different treatments of iron and zinc. The treatment RDF+ 25 kg ha^{-1} $FeSO_4$ + 25 kg ha^{-1} ZnSO4 (T_5) recorded the significantly highest iron uptake (785.65 g ha^{-1}) and it was followed by iron uptake (669.61 g ha^{-1}) recorded in the treatment RDF +25 kg ha^{-1} $FeSO_4$ (T_3). This trend may be due to the increase in growth and yield component which ultimately enhanced the nutrient uptake. Similar effect of increase in uptake was also pointed out by El-Fouly *et al.*, (2012).

The zinc uptake was significantly influenced by different fertilizer treatments. The highest zinc uptake (351.94 g ha^{-1}) was the treatment RDF+ 25 kg ha^{-1} FeSO4 +25 kg ha^{-1} ZnSO4 (T5) found superior over rest of the treatments. However, the lowest zinc uptake (161.44 g ha^{-1}) was observed in absolute control (T1). The uptake of zinc is more in treatment (T5) due to higher concentration of zinc in seed and stover and their yield is also higher in similar treatment. The results are in conformity with Ravi and Channel (2010).

The data pertaining to soil reaction and salt content is presented in table No 3. The pH and EC shows non-significant results and only small fluctuation seen due to the administration of treatments. The range of pH and EC was 8.03 to 7.78 and 0.40 to 0.31 dS m^{-1}, respectively. The average soil pH and electrical conductivity was 7.90 and 0.35 dS m^{-1}, respectively. There were no significant changes observed regarding soil pH and electrical conductivity at harvest stage.

The soil organic carbon content at harvest of pearl millet was ranged between 5.47 to 5.57 g kg^{-1}. The highest content of organic carbon (5.57 g kg^{-1}) was recorded with RDF + soil application of 25 kg ha^{-1} $FeSO_4$ + 25 kg ha^{-1} $ZnSO_4$ (T_5) and it was followed by RDF + soil application of 25 kg ha^{-1} $FeSO_4$ (T_3) i.e. 5.56 g kg^{-1}. Among the foliar application treatments, the higher organic carbon (5.55 g kg^{-1}) was recorded in RDF + foliar application of 0.5 % chelated Fe + 0.5 % chelated Zn at two crop stages (T_8). Individual foliar spray of 0.5 % Fe and Zn along with RDF also increased organic carbon over RDF alone and control. Similar results were found by Durgude *et al.*, (2014) with soil and foliar application of zinc and iron in cotton experiment.

The data regarding available nitrogen of pearl millet is given in Table 4. The available nitrogen content of pearl millet indicated the significant increase in available nitrogen content due to different treatments combination over control.

Table.1 Effect of different treatments of iron and zinc application on yield and quality of pearl millet

Tr. No.	Treatment	Yield (q ha^{-1})		1000 grain weight (g)	Protein content (%)	Total chlorophyll content (mg 100 g^{-1})
		Grain	Yield			
T_1	Absolute control	15.44	34.66	15.09	10.85	7.02
T_2	RDF (60:30:30 N:P_2O_5:K_2O kg ha^{-1}	25.18	54.55	15.85	12.96	8.34
T_3	RDF +25 kg ha^{-1} $FeSO_4$	26.78	57.57	17.62	13.39	10.46
T_4	RDF +25 kg ha^{-1} $ZnSO_4$	26.41	56.17	17.09	14.72	8.62
T_5	RDF+25 kg ha^{-1} $FeSO_4$ + 25 kg ha^{-1} $ZnSO_4$	28.89	61.31	18.50	15.89	11.72
T_6	RDF + foliar spray of $FeSO_4$ @ 0.5 % at 30 & 45 DAS	25.27	53.42	16.36	12.87	9.31
T_7	RDF + foliar spray of $ZnSO_4$ @ 0.5 % at 30 & 45 DAS	25.61	53.65	16.35	12.87	8.71
T_8	RDF+ foliar spray of $ZnSO_4$ and $FeSO_4$ @ 0.5 % each at 30 & 45 DAS	27.48	58.28	16.59	14.09	11.00
	Mean	**25.13**	**53.70**	**16.68**	**13.44**	**9.40**
	S.E. ±	1.05	2.19	0.38	0.73	0.57
	C.D. @ 5%	3.16	6.63	1.15	2.22	1.74

Table.2 Effect of different treatments of iron and zinc application on nutrient uptake in pearl millet

Tr. No.	Treatment	Nutrient uptake (kg ha^{-1})				Micronutrient uptake (g ha^{-1})	
		N	P	K	S	Fe	Zn
T_1	Absolute control	39.14	13.43	104.30	2.92	286.66	161.44
T_2	RDF (60:30:30 N:P_2O_5:K_2O kg ha^{-1}	67.40	30.93	173.72	4.47	566.33	289.66
T_3	RDF +25 kg ha^{-1} $FeSO_4$	76.65	36.58	186.74	5.84	669.61	309.49
T_4	RDF +25 kg ha^{-1} $ZnSO_4$	77.82	34.12	180.32	5.88	588.54	347.12
T_5	RDF+25 kg ha^{-1} $FeSO_4$ + 25 kg ha^{-1} $ZnSO_4$	88.48	43.34	213.65	7.00	785.65	443.85
T_6	RDF + foliar spray of $FeSO_4$ @ 0.5 % at 30 & 45 DAS	71.01	33.71	175.80	5.75	574.51	283.16
T_7	RDF + foliar spray of $ZnSO_4$ @ 0.5 % at 30 & 45 DAS	72.42	35.43	179.04	5.29	576.85	311.34
T_8	RDF+ foliar spray of $ZnSO_4$ and $FeSO_4$ @ 0.5 % each at 30 & 45 DAS	79.38	34.95	197.31	5.96	655.78	351.94
	Mean	**71.57**	**32.81**	**176.36**	**5.39**	**587.99**	**312.25**
	S.E. ±	2.92	1.44	7.74	0.35	23.2	16.78
	C.D. @ 5%	8.83	4.37	23.39	1.07	70.06	50.91

Table.3 Effect of different treatments of iron and zinc application on soil properties at harvest of pearl millet

Tr. No.	Treatment	pH (1:2.5)	EC (dS m^{-1})	OC (g kg^{-1})
T_1	Absolute control	7.85	0.31	5.47
T_2	RDF (60:30:30 $N:P_2O_5:K_2O$ kg ha^{-1}	8.01	0.34	5.53
T_3	RDF +25 kg ha^{-1} $FeSO_4$	7.78	0.40	5.55
T_4	RDF +25 kg ha^{-1} $ZnSO_4$	7.90	0.35	5.54
T_5	RDF+25 kg ha^{-1} $FeSO_4$ + 25 kg ha^{-1} $ZnSO_4$	7.91	0.32	5.57
T_6	RDF + foliar spray of $FeSO_4$ @ 0.5 % at 30 & 45 DAS	7.89	0.39	5.54
T_7	RDF + foliar spray of $ZnSO_4$ @ 0.5 % at 30 & 45 DAS	8.03	0.37	5.53
T_8	RDF+ foliar spray of $ZnSO_4$ and $FeSO_4$ @ 0.5 % each at 30 & 45 DAS	7.99	0.37	5.55
	Mean	**7.92**	**0.35**	**5.54**
	S.E. $\pm$	0.52	0.021	0.011
	C.D. @ 5%	NS	NS	0.034

Table.4 Effect of different treatments of iron and zinc application on soil properties at harvest of pearl millet

Tr. No.	Treatment	Available nutrients (kg ha^{-1})				DTPA Micronutrient (mg kg^{-1})	
		N	**P**	**K**	**S**	**Fe**	**Zn**
T_1	Absolute control	148.33	13.14	553.00	33.21	3.914	0.614
T_2	RDF (60:30:30 $N:P_2O_5:K_2O$ kg ha^{-1}	167.00	17.66	586.67	37.44	4.802	0.621
T_3	RDF +25 kg ha^{-1} $FeSO_4$	165.67	16.86	573.00	39.35	5.011	0.734
T_4	RDF +25 kg ha^{-1} $ZnSO_4$	170.67	17.18	583.67	41.26	4.791	0.872
T_5	RDF+25 kg ha^{-1} $FeSO_4$ + 25 kg ha^{-1} $ZnSO_4$	168.33	16.59	572.67	43.16	5.233	1.015
T_6	RDF + foliar spray of $FeSO_4$ @ 0.5 % at 30 & 45 DAS	170.33	17.86	584.67	38.19	4.761	0.637
T_7	RDF + foliar spray of $ZnSO_4$ @ 0.5 % at 30 & 45 DAS	173.33	17.39	583.33	38.47	4.772	0.697
T_8	RDF+ foliar spray of $ZnSO_4$ and $FeSO_4$ @ 0.5 % each at 30 & 45 DAS	168.67	16.82	568.33	36.23	4.781	0.647
	Mean	**166.54**	**16.69**	**575.67**	**38.41**	**4.758**	**0.730**
	S.E. $\pm$	4.48	0.57	5.96	1.69	0.14	0.039
	C.D. @ 5%	13.55	1.72	18	5.11	0.42	0.119

Maximum available nitrogen (173.33 kg ha^{-1}) at harvest of pearl millet was recorded in the treatment receiving RDF + foliar spray of ZnSO4 @ 0.5 % at 30 and 45 DAS (T_5) and it was followed by RDF + soil application of 25 kg ha^{-1} $ZnSO_4$ (T_4). The results are in conformity with Mahatma (2007).

The maximum available phosphorus content was at harvest of pearl millet was recorded with RDF + foliar spray of $FeSO_4$ @ 0.5 % at 30 & 45 DAS (T_6) followed by soil application of RDF (T_2) and RDF + foliar spray of $ZnSO_4$ @ 0.5 % at 30 & 45 DAS (T_7) i.e. 17.86, 17.66 and 17.39 kg ha^{-1}, respectively. Reddy *et al.*, (2007) 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.

The highest available potassium (586.67 kg ha^{-1}) was recorded in treatment receiving RDF (T_2) and it was followed by the available potassium (584.67 kg ha^{-1}) found in the treatment with application of RDF + foliar spray of $FeSO_4$ @ 0.5 % at 30 & 45 DAS (T_6). These results were close conformity with Mahatma (2007).

The data regarding available sulphur at harvest of pearl millet is given in Table 4.The treatment RDF + soil application of 25 kg ha^{-1} $FeSO_4$ + 25 kg ha^{-1} $ZnSO_4$ (T_5) recorded the maximum available sulfur content (43.16 mg kg^{-1}) followed by RDF + soil application of 25 kg ha^{-1} $ZnSO_4$ (41.26 mg kg^{-1}). These results matched with the finding of Kanzariya *et al.*, 2010.

The data pertaining to the DTPA extractable iron presented in table 4. The iron content in soil ranged between 39.14 to 5.233 mg kg^{-1} in different treatments. Although, it was bring the fact that soil application of Fe and Zn showed the higher values as compared to foliar application. The RDF + 25 kg ha^{-1} $FeSO_4$ + 25 kg ha^{-1} $ZnSO_4$ (T_5) recorded the maximum iron content (5.233 mg kg^{-1}) followed by RDF + 25 kg ha^{-1} $FeSO_4$ (T_3) (5.011 mg kg^{-1}). While, RDF + foliar spray of $ZnSO_4$ and $FeSO_4$ @ 0.5 each at 30 and 45 DAS (T_8) showed the higher Fe content (4.781 mg kg^{-1}) as compared to their individual spray while, the increase in Fe content in these treatments was 33.69 per cent over control. The findings are in conformity with Radhika *et al.*, (2013).

Among the soil application of Fe and Zn treatments, the maximum zinc content (1.015 mg kg^{-1}) while, the increase in Zn content due to these treatments was 65.30 percent was noted under RDF + 25 kg ha^{-1} $FeSO_4$ + 25 kg ha^{-1} $ZnSO_4$ (T_5) followed by the treatment T_4 i.e. RDF + 25 kg ha^{-1} $ZnSO_4$ (0.872 mg kg^{-1}) and both the treatments were found at par. However, among foliar application, RDF + foliar spray of $ZnSO_4$ @ 0.5 % at 30 & 45 DAS (T_7) recorded the higher Zn content of 0.697 mg kg^{-1}. Similar line of results was reported earlier by Ghritlahare *et al.*, (2015).

Soil and foliar application of Fe and Zn along with RDF found beneficial in improving the soil nutrient status, nutrient uptake and there by pearl millet yield.

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How to cite this article:

Waikar, S. L., S. M. Todmal and Shete, V. S. 2021. Response of Iron and Zinc on Yield, Quality and Soil Nutrient Dynamics of Pearl Millet on Vertisol. *Int.J.Curr.Microbiol.App.Sci.* 10(04): 307-315. doi: https://doi.org/10.20546/ijcmas.2021.1004.032