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Effect of bio-NP consortium, Fe and Zn on growth and yield of pearl millet (*Pennisetum glaucum* L.) in loamy sand

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Abstract
Field experiments were conducted during *kharif* 2019 and 2020 at Agronomy Instructional Farm, C. P. College of Agriculture, S. D. Agricultural University, Sardarkrushinagar, Gujarat to assess the "Effect of bio-NP consortium, Fe and Zn on growth and yield of pearl millet (*Pennisetum glaucum* L.) in loamy sand" under North Gujarat conditions. Experimental soil was normal in pH and EC, low in organic carbon, available nitrogen, DTPA extractable Fe and Zn; medium in available phosphorus and potassium. Eight treatment combinations comprising of two levels of fertilizer viz., 100% RDF and 75% RDF with seed treatment of bio-NP consortium; two levels of iron @ 3 kg ha^{-1} and 6 kg ha^{-1}; and two levels of zinc @ 2 kg ha^{-1} and 4 kg ha^{-1} were laid out under randomized block design with factorial concept with three replications. The growth, yield attributes and yield (grain and straw) of pearl millet were non-significantly influenced due to application of 100% RDF and 75% RDF with seed treatment of bio-NP consortium. Soil application of Fe @ 6 kg ha^{-1} and Zn @ 4 kg ha^{-1} gave significantly higher growth, yield attributes, yield (grain and straw). Higher net returns and benefit: cost ratio from pearl millet crop were obtained with combined application of 100% RDF or 75% RDF with seed treatment of bio-NP consortium and Fe @ 6 kg ha^{-1} along with Zn @ 4 kg ha^{-1}.

Keywords: Bio-NP consortium, Fe and Zn, growth and yield, pearl millet, *Pennisetum glaucum* L.

Introduction
Pearl millet (*Pennisetum glaucum* L.) is major coarse grain crop among the grains and considered to be a poor man's food. It belongs to the gramineae family and widely grown in Africa and Asia since pre-historic times. Geographically, pearl millet is an important cereal crop of India, Pakistan, China and southeastern Asian countries. Pearl millet is one of the important millet crops which flourish well even under the adverse weather condition and considered as the most drought-tolerant crop among cereals and millets. Pearl millet is adopted in stresses intensive conditions, yet it is highly versatile, input responsive and high-quality cereal with great potential to become a valuable component of a non-traditional season like summer under irrigated and high input management conditions. The nutritive value of the pearl millet crop is fairly high as it contains protein (11.6%), fat (5%), carbohydrates (67%) and minerals (2.7%). It is also rich in Vitamin A, B and imparts substantial energy (360 calories 100 g^{-1}) for the baby (Malik, 2015) [10]. India ranks first both in areas and production of pearl millet, it is cultivated over an area of 7.11 million hectares with a production of 8.66 million tonnes and the productivity is 1219 kg ha^{-1} (Anon., 2020) [2]. In Gujarat, pearl millet occupies an area of 0.39 million hectares and production of 0.89 million tonnes with the productivity of 2280 kg ha^{-1} (Anon., 2020) [2]. Summer cultivation of pearl millet in the irrigated areas of North Gujarat has got importance because of the assurance of higher crop yield.

The microbes are potential alternatives that could cater to plant zinc and iron requirements by solubilizing the complex zinc in soil. Biological nitrogen fixation plays an important and positive role in the maintenance of nitrogen in the soil. This has the additional advantage of protecting the environment in a long run. If biofertilizer applies to any crop it improves the availability of plant nutrients, create resistance to root diseases, and may reduce the 25% of nitrogen requirement to the plants (Kannaiyan, 2002) [7]. Integrated use of biofertilizers and inorganic sources of nutrients increase the crop yield as well as the soil properties (Syed *et al*., 2001) [16].

In addition to the high demand of macronutrients, micronutrients are also required in relatively very small quantities for adequate plant growth and production of plant. Micronutrient deficiency may cause great disturbance in physiological and metabolic processes of plant. As nearly half of the Indian soils and 24 percent soils of Gujarat are Zn deficient and 58 percent of soils of North Gujarat were found deficient to medium in available Zn status (Anon., 2018) [1].

Iron plays an important role in plant growth. Fe is present in high quantities in soils but it is availability to plants is usually low. The application of Fe fertilizer for crop production also reduces malnourishment in humans and animals. Therefore, approaches need to be developed to increase Fe uptake by roots, transfer to edible plant portions and absorption by humans from plant food sources. Zinc deficiency in agricultural soils is affecting both the yield and quality of the crop. Severe Zn deficiency in the soil may cause yield losses up to 30 percent in cereals. Zinc is an essential plant nutrient for plant growth and development. Zinc is one of the essential micronutrients, plays a significant role in various enzymatic and physiological activities of the plant system. Crops utilize very low amounts of Zn fertilizer but very high doses of Zn fertilizer are often applied to correct Zn deficiencies in crops due to a high fixation of applied Zn in the soil. Fertilizer Zn use efficiency is hardly 1 to 5 percent.

Material and Methods

Field experiments were conducted for two years during the *kharif* 2019 and 2020 at Agronomy Instructional Farm, C. P. College of Agriculture, S. D. Agricultural University, Sardarkrushinagar, Gujarat to assess the "Effect of bio-NP consortium, Fe and Zn on growth and yield of pearl millet (*Pennisetum glaucum* L.) in loamy sand" under North Gujarat conditions. Experimental soil was normal in pH and EC, low in organic carbon, available nitrogen and DTPA extractable Fe and Zn; medium in available phosphorus and potassium. Eight treatment combinations comprising of two levels of fertilizer viz., 100% RDF and 75% RDF with seed treatment of bio-NP consortium; two levels of iron @ 3 kg ha^{-1} and 6 kg ha^{-1}; and two levels of zinc @ 2 kg ha^{-1} and 4 kg ha^{-1} were laid out under randomized block design with factorial concept with three replications. The phosphorus was applied as diammonium phosphate, whereas source of N applied as a of urea. Whereas zinc and iron were applied in the form of zinc sulphate (21% Zn) and iron sulphate (19% Fe). Biometric observations were recorded from five randomly selected plants tagged in each net plot. The statistical analysis of the data generated during the investigation was carried out through software on a computer following the procedure described by Cochran and Cox (1967) [4]. The weather conditions were observed more or less normal and favourable for the satisfactory growth and development of the pearl millet crop during the *kharif* seasons of 2019 and 2020.

Result and Discussion

Effect of bio-NP consortium

Application of 100% RDF and 75% RDF with seed treatment of bio-NP consortium were exhibit non-significant influence on plant population, plant height, earhead length, effective tillers per meter row length, test weight, dry matter accumulation per plant, yield (grain and straw) and harvest index (Table 1, 2 and 3). Application of 100% RDF gave higher net realization and benefit-cost ratio (2.13) as compare to application of 75% RDF with seed treatment of bio-NP consortium (2.06). This indicted that the microbial consortium with 75% RDF could provide as much as plant nutrients to the crop to yielded non –significant impact on yield. Besides, the microbial consortium could also provide the congenial soil conditions for plant growth.

Effect of levels of iron

Different levels of iron had no significant effect on plant population per hectare at harvest and harvest index during 2019 and 2020 along in pooled analysis. Application of iron @ 6 kg ha^{-1} gave significantly higher plant height, earhead length, number of effective tillers per meter row length, test weight, dry matter accumulation per plant, grain and straw yield of pearl millet during 2019 and 2020 along with pooled analysis. The significant increase in straw yield due to application of iron could be due to more availability of iron to plant root system and better uptake could resulted in higher accumulation of photosynthates and better translocation of photosynthates from source to sink which ultimately increased productivity of plant. The beneficial effect of iron might also be due to the fact that the soil experimental plot was deficient in DTPA extractable iron and iron application could improve availability in soil which might have enhance the growth attributing characters such as plant height and finally contributed to higher straw yield. The similar line in research was done by Kadivala *et al*. (2018) [6], Meena *et al*. (2018) [11], Sharanappa *et al*. (2019) [14] and Kharadi *et al*. (2020) [8] in pearl millet. Application of iron @ 6 kg ha^{-1} gave higher net realization and benefit-cost ratio (2.18) as compare to application of iron @ 3 kg ha^{-1} (2.01).

Effect of levels of zinc

Zinc application under different levels had no-significant influence on plant population per hectare at harvest and harvest index during both the years and in pooled analysis. Application of zinc @ 4 kg ha^{-1}gave significantly higher plant height, earhead length, effective tillers per meter row length, test weight, dry matter accumulation per plant, grain and straw yield during both the years and in pooled analysis. The increased yield might be due to role of zinc in biosynthesis of IAA, initiation of primordia for reproductive parts and partitioning of photosynthates towards them, which might have been resulted in better flowering and fruiting, ultimately increased yield attributes of pearl millet which resulted in increased grain yield. Zinc plays important role in synthesis of various enzymes like carbonic anhydrase, glutamic acid dehydrogenase, lactic acid dehydrogenase and some peptidases. It is also considered as precursor for auxin synthesis involved in nitrogen metabolism and several oxidation-reduction reactions, stability of RNA and starch formation thus its adequate supply results higher straw production, ultimately increase growth and development of plants. The similar results also found by Singh *et al*. (2017) [15], Arshewar *et al*. (2018) [3], Sharanappa *et al*. (2019) [14] and Khardia *et al*. (2020) [9] in pearl millet. Application of zinc @ 4 kg ha^{-1} gave higher net realization and benefit-cost ratio (2.18) as compare to application of zinc @ 2 kg ha^{-1} (2.01).

Interaction effect

Higher dry matter accumulation per plant was recorded with the combined application of Fe @ 6 kg ha^{-1}+ 100% RDF, which was found at par with the 100% RDF + Fe @ 3 kg ha-

^{1}and 75% RDF with seed treatment of bio-NP + Fe @ 6 kg ha^{-1}. Significantly higher grain yield (3147 kg ha^{-1}) and straw yield (5726 kg ha^{-1}) were recorded in combined application of Fe @ 6 kg ha^{-1} + Zn @ 4 kg ha^{-1}, which was found at par with Fe @ 6 kg ha^{-1} + Zn @ 2 kg ha^{-1} and Fe @ 3 kg ha^{-1} with Zn @ 4 kg ha^{-1}during the year 2019. In the year 2020, highest grain yield (3569 kg ha^{-1}) (Table 4 and 5). and straw yield (6761 kg ha^{-1}) were obtained with the application of Fe @ 6 kg ha^{-1}+ Zn @ 4 kg ha^{-1} (Table 6 and 7). This might be due to the synergistic effect of combined application of zinc and iron in the soils which enhanced the better translocation of nutrients by developing more root growth, which ultimately lead to higher growth and yield attributing characters of pearl millet. The increase in the yield attributes could be due to sufficient supply of micronutrients (zinc and iron) to the crop along with the recommended dose nutrients. Zinc and iron play actively in the photosynthesis, assimilation and translocation of photosynthates from source (leaves) to sink which ultimately increase the straw yield of pearl millet, similar trend was noticed by Mehta *et al*. (2008) [12], Fulpagare *et al*. (2018) [5], Sharanappa *et al*. (2019) [14], Kharadi *et al*. (2020) [8] and Reddy *et al*. (2020) [13] in pearl millet.

Higher harvest index was recorded in treatment combination of 100% RDF + Fe @ 3 kg ha^{-1} which was found at par with 75% RDF with seed treatment of bio-NP + Fe @ 3 kg ha^{-1} during the year 2020 and in pooled analysis, while during the 2020 also found at par with 100% RDF + Fe @ 6 kg ha^{-1} and in pooled analysis it was also recorded at par with 75% RDF with seed treatment of bio-NP + Fe @ 6 kg ha^{-1} (Table 8 and 9). The increase in harvest index is the result of higher growth, yield attributes and yield of pearl millet by the balanced application of fertilizer. Data presented in Table 10, indicated that the highest BCR (2.27) was recorded in treatment combination of 75% RDF with seed treatment of bio-NP consortium + iron @ 6 kg ha-1 + zinc @ 2 kg ha^{-1}. While the highest net realization; and BCR value of 2.26 was found under the treatment combination of 100% RDF + iron @ 6 kg ha^{-1}+ zinc @ 2 kg ha^{-1}.

From two years experimentation, it is concluded that for securing higher yield of pearl millet, the crop should be fertilized with either 100% RDF (80:40:0; $N:P_2O_5:K_2O$ kg ha^{-1}) or 75% RDF along with seed treatment of bio-NP consortium and Fe @ 6 kg ha^{-1} along with Zn @ 4 kg ha^{-1}.

General view of field experiment

$B_1Fe_2Zn_2$: 100% RDF + Fe @ 6 kg ha^{-1} + Zn @ 4 kg ha^{-1}

$B_2Fe_2Zn_2$: 75% RDF with seed treatment of bio-NP + Fe @ 6 kg ha^{-1} + Zn @ 4 kg ha^{-1}

Table 1: Effect of bio-NP consortium, Fe and Zn on plant population, plant height and earhead length of pearl millet

Treatments			Plant population at harvest (hectare^{-1})			Plant height (cm)			Earhead length (cm)		
			2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Bio-NP consortium (B)											
B_1	:	100% RDF	203212	203465	203339	180.7	187.7	184.2	23.73	25.12	24.42
B_2	:	75% RDF + seed treatment of bio-NP consortium	201681	201786	201733	175.0	176.1	175.5	23.67	24.71	24.19
S.Em.±			7071	6618	4843	6.2	6.5	4.5	0.57	0.53	0.39
C.D. (P=0.05)			NS	NS	NS	NS	NS	NS	NS	NS	NS
Iron (Fe)											
Fe_1	:	Fe @ 3 kg ha^{-1}	201504	202038	201771	167.9	171.8	169.9	22.80	24.10	23.45
Fe_2	:	Fe @ 6 kg ha^{-1}	203389	203213	203301	187.8	192.0	189.9	24.60	25.73	25.16
S.Em.±			7071	6618	4843	6.2	6.5	4.5	0.57	0.53	0.39
C.D. (P=0.05)			NS	NS	NS	18.7	19.8	13.0	1.74	1.61	1.13
Zinc (Zn)											
Zn_1	:	Zn @ 2 kg ha^{-1}	201525	201917	201721	165.8	169.4	167.6	22.70	24.01	23.35
Zn_2	:	Zn @ 4 kg ha^{-1}	203369	203334	203352	189.9	194.4	192.1	24.70	25.82	25.26
S.Em.±			7071	6618	4843	6.2	6.5	4.5	0.57	0.53	0.39
C.D. (P=0.05)			NS	NS	NS	18.7	19.8	13.0	1.74	1.61	1.13
Interactions											
B × Fe			NS	NS	NS	NS	NS	NS	NS	NS	NS
B × Zn			NS	NS	NS	NS	NS	NS	NS	NS	NS
Fe × Zn			NS	NS	NS	NS	NS	NS	NS	NS	NS
B × Fe × Zn			NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V. %			12.1	11.3	11.7	12.0	12.4	12.2	8.4	7.4	7.9

Table 2: Effect of bio-NP consortium, Fe and Zn on number of effective tillers per meter row length, test weight and dry matter accumulation per plant of pearl millet

Treatments			Number of effective tillers per meter row length			Test weight (g)			Dry matter accumulation per plant (g)		
			2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Bio-NP consortium (B)											
B_1	:	100% RDF	20.3	20.6	20.5	12.96	13.04	13.00	31.4	31.6	31.5
B_2	:	75% RDF + seed treatment of bio-NP consortium	18.7	20.0	19.3	12.74	12.83	12.79	30.2	31.1	30.7
S.Em.±			0.7	0.6	0.4	0.16	0.14	0.11	0.7	0.8	0.5
C.D. (P=0.05)			NS	NS	NS	NS	NS	NS	NS	NS	NS
Iron (Fe)											
Fe_1	:	Fe @ 3 kg ha^{-1}	18.4	19.4	18.9	12.56	12.69	12.62	29.7	29.2	29.4
Fe_2	:	Fe @ 6 kg ha^{-1}	20.6	21.1	20.9	13.14	13.18	13.16	31.9	33.6	32.8
S.Em.±			0.7	0.6	0.4	0.16	0.14	0.11	0.7	0.8	0.5
C.D. (P=0.05)			2.0	1.7	1.2	0.48	0.43	0.31	2.1	2.3	1.5
Zinc (Zn)											
Zn_1	:	Zn @ 2 kg ha^{-1}	18.5	19.0	18.7	12.54	12.67	12.61	29.6	30.0	29.8
Zn_2	:	Zn @ 4 kg ha^{-1}	20.6	21.6	21.1	13.15	13.19	13.17	32.0	32.7	32.3
S.Em.±			0.7	0.6	0.4	0.16	0.14	0.11	0.7	0.8	0.5
C.D. (P=0.05)			2.0	1.7	1.2	0.48	0.43	0.31	2.1	2.3	1.5
Interactions											
B × Fe			NS	NS	NS	NS	NS	NS	NS	NS	2.1
B × Zn			NS	NS	NS	NS	NS	NS	NS	NS	NS
Fe × Zn			NS	NS	NS	NS	NS	NS	NS	NS	NS
B × Fe × Zn			NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V. %			11.6	9.6	10.6	4.3	3.8	4.0	7.9	8.5	8.2

Table 3: Effect of bio-NP consortium, Fe and Zn on grain yield, straw yield and harvest index of pearl millet

Treatments			Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})			Harvest index (%)		
			2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Bio-NP consortium (B)											
B_1	:	100% RDF	3087	3203	3145	5621	5927	5774	35.49	35.13	35.31
B_2	:	75% RDF + seed treatment of bio-NP consortium	2880	3043	2962	5234	5609	5421	35.50	35.19	35.35
S.Em.±			98	94	68	183	163	122	0.29	0.34	0.22
C.D. (P=0.05)			NS	NS	NS	NS	NS	NS	NS	NS	NS
Iron (Fe)											
Fe_1	:	Fe @ 3 kg ha^{-1}	2831	2972	2902	5147	5423	5285	35.51	35.41	35.46
Fe_2	:	Fe @ 6 kg ha^{-1}	3137	3273	3205	5708	6113	5911	35.48	34.91	35.20
S.Em.±			98	94	68	183	163	122	0.29	0.34	0.22
C.D. (P=0.05)			296	284	196	554	493	354	NS	NS	NS
Zinc (Zn)											
Zn_1	:	Zn @ 2 kg ha^{-1}	2825	2969	2897	5125	5368	5246	35.54	35.66	35.60
Zn_2	:	Zn @ 4 kg ha^{-1}	3143	3276	3210	5730	6169	5949	35.45	34.66	35.05
S.Em.±			98	94	68	183	163	122	0.29	0.34	0.22
C.D. (P=0.05)			296	284	196	554	493	354	NS	NS	NS
Interactions											
B × Fe			NS	NS	NS	NS	NS	NS	NS	1.46	0.91
B × Zn			NS	NS	NS	NS	NS	NS	NS	NS	NS
Fe × Zn			419	402	NS	784	698	NS	NS	NS	NS
B × Fe × Zn			NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V. %			11.3	10.4	10.9	11.7	9.8	10.7	2.8	3.4	3.1

Table 4: Interaction effect of Fe and Zn on grain yield (2019)

Levels of Zn			Levels of Fe	
			Fe_1: Fe @ 3 kg ha^{-1}	Fe_2: Fe @ 6 kg ha^{-1}
Zn_1	:	Zn @ 2 kg ha^{-1}	2523	3126
Zn_2	:	Zn @ 4 kg ha^{-1}	3139	3147
S.Em.±			138	
C.D. (P=0.05)			419	

Table 5: Interaction effect of Fe and Zn on grain yield (2020)

Levels of Zn			Levels of Fe	
			Fe_1: Fe @ 3 kg ha^{-1}	Fe_2: Fe @ 6 kg ha^{-1}
Zn_1	:	Zn @ 2 kg ha^{-1}	2962	2977
Zn_2	:	Zn @ 4 kg ha^{-1}	2983	3569
S.Em.±			133	
C.D. (P=0.05)			402	

Table 6: Interaction effect of Fe and Zn on straw yield (2019)

Levels of Zn			Levels of Fe	
			Fe_1: Fe @ 3 kg ha^{-1}	Fe_2: Fe @ 6 kg ha^{-1}
Zn_1	:	Zn @ 2 kg ha^{-1}	4561	5690
Zn_2	:	Zn @ 4 kg ha^{-1}	5734	5726
S.Em.±			258	
C.D. (P=0.05)			784	

Table 7: Interaction effect of Fe and Zn on straw yield (2020)

Levels of Zn			Levels of Fe	
			Fe_1: Fe @ 3 kg ha^{-1}	Fe_2: Fe @ 6 kg ha^{-1}
Zn_1	:	Zn @ 2 kg ha^{-1}	5269	5466
Zn_2	:	Zn @ 4 kg ha^{-1}	5577	6761
S.Em.±			230	
C.D. (P=0.05)			698	

Table 8: Interaction effect of bio-NP consortium and Fe on harvest index (%) (2020)

Levels of fertilizers			Levels of Fe	
			Fe_1: Fe @ 3 kg ha^{-1}	Fe_2: Fe @ 6 kg ha^{-1}
B_1	:	100% RDF	36.04	34.78
B_2	:	75% RDF + seed treatment of bio-NP consortium	35.29	34.53
S.Em.±			0.48	
C.D. (P=0.05)			1.46	

Table 9: Interaction effect of bio-NP consortium and Fe on harvest index (pooled)

Levels of fertilizers			Levels of Fe	
			Fe_1: Fe @ 3 kg ha^{-1}	Fe_2: Fe @ 6 kg ha^{-1}
B_1	:	100% RDF	35.78	34.84
B_2	:	75% RDF + seed treatment of bio-NP consortium	35.14	35.55
S.Em.±			0.32	

Table 10: Cost of cultivation, gross return, net return and benefit: cost ratio as affected by different treatment combinations

Treat. No.	Treatment combination	Yield (kg ha-^{1})		Cost of cultivation (₹ ha^{-1})	Gross Realization (₹ ha^{-1})	Net Realization (₹ ha^{-1})	BCR
		Seed	Stover				
T_1	$B_1Fe_1Zn_1$	2887	5169	23399	46424	23025	1.98
T_2	$B_1Fe_1Zn_2$	3225	5804	23941	51919	27978	2.17
T_3	$B_1Fe_2Zn_1$	3087	5677	23870	49942	26072	2.09
T_4	$B_1Fe_2Zn_2$	3382	6447	24411	55164	30753	2.26
T_5	$B_2Fe_1Zn_1$	2598	4661	22670	41797	19127	1.84
T_6	$B_2Fe_1Zn_2$	2897	5506	23211	47226	24015	2.03
T_7	$B_2Fe_2Zn_1$	3016	5478	23140	48662	25522	2.10
T_8	$B_2Fe_2Zn_2$	3335	6040	23682	53766	30085	2.27
(Grain ₹12.5 kg^{-1} and Straw ₹2.0 kg^{-1})							

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