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Effects of micronutrient on yield and uptake by summer pearl millet (*Pennisetum glaucum* L.)

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Abstract
A field experiment was conducted on loamy sand soil having low Fe and Mn status at Main Forage Research Station, AAU, Anand, during summer season of the year 2017 for studying effects of multi-micronutrients mixture in improving production of summer pearl millet (*Pennisetum glaucum* L.) (GHB-558). The higher grain yield was obtained with the 1% foliar spray of multi-micronutrient mixture grade-III (for Fe deficiency) having concentration of Fe-6.0%, Mn-1.0%, Zn-4.0%, Cu-0.3% and B-0.5% at 15, 30 and 45 DAT (Days after Transplanting). While straw and total yield was higher under the soil application of micronutrients of 50 kg $FeSO_4.5H_2O$ ha^{-1} and 40 kg $MnSO_4.3H_2O$ ha^{-1} as per STV (Soil Test Value). Micronutrient supplementation through 1.0% foliar application of multi-micronutrient mixture and soil application through grade-V as well as Soil Test Value (STV) was also found beneficial in increasing micronutrients concentration in different plant parts and their uptake by summer pearl millet.

Keywords: Multi-micronutrient mixture, summer pearl millet, yield, content and uptake

Introduction
Continuous use of high analysis fertilizers under intensified cropping and neglect of organic manures manifested the occurrence of wide spread micronutrients deficiencies; especially of Zn and Fe in light textured soils of India after 1960. But, later multiple nutrient deficiencies were reported in crops for N, NP, NPFe, NPFeZn, NPFeZnK, NPZnKS, NPZnKSB and NPZnKSMnMo within a time frame of 1960 to 2005. Multinutrient deficiencies are emerging for Zn + Fe in swell- shrink soils, Zn + Mn or Zn + Fe + Mn in alluvial soils of Indo-Gangatic plains, Zn + Fe, Zn + B, Zn + Fe + B in highly calcareous soils of Bihar, Gujarat, Zn + B in acid leached Alfisols, red and Lateritic soils of India. Despite application of adequate quantity of NPK, the yield remains low due to hidden hunger of micronutrients like Fe, Cu, Mn and B (Patel and Singh, 2010) [15]. Zn and Fe deficiency is one of the most frequently encountered micronutrients deficiencies in pearl millet (*Pennisetum glaucum* L.). Reports in literature indicated that Zn and Fe deficiency causes 50% loss in yield of pearl millet. Widely prevalent Zn-Fe deficiency warrants the need for research on Zn and Fe especially on their usage individually and in mixtures as foliar/soil application. Hence, the present investigation was undertaken to study the effect of different multi-micronutrient mixture on the yield and uptake of micronutrients by pearl millet.

Materials and methods
A field experiment was conducted at Main forage Research Station, AAU, Anand during summer season of the year 2017 for studying effects of multi-micronutrients mixture in improving production of summer pearl millet (*Pennisetum glaucum* L.) (GHB-558). The treatment was comprised of T_1-control, foliar spray treatments: T_2-multi-micronutrient mixture grade-I (general), T_3-multi-micronutrient mixture grade-II (for Zn deficiency), T_4-multi-micronutrient mixture grade-III (for Fe deficiency), T_5-multi-micronutrient mixture grade-IV (for Zn & Fe deficiency) and soil application treatments: T_6-multi-micronutrient mixture grade-V and T_7-soil application of micronutrients as per soil test value (STV). The multi-micronutrient mixture grades having concentration shown in table 1 were prepared on the basis of average removal of micronutrients by different crops (grades I and IV) and other grades (II to IV) on the basis of wide spread occurrences of Zn or Fe or Zn and Fe deficiencies in soils of Gujarat. The multi-micronutrients mixture facilitate the application of the wide range of plant nutrients in the proportion and to suit the specific requirements of a crop in different stages of

growth, and are more relevant under site specific nutrient management practices. Therefore, there is a need to promote balanced fertilization for which use of appropriate multi-micronutrient mixture grades would play a big role to improve nutrients use efficiency and enhance crops productivity for food and nutritional security.

Table 1: Composition of different grades

S. No.	Grade	Content (%)				
		Fe	Mn	Zn	Cu	B
1.	LF Grade I (General)	2	0.5	4.0	0.3	0.5
2.	LF Grade II (For Zn deficiency)	2	0.5	8.0	0.5	0.5
3.	LF Grade III (For Fe deficiency)	6	1.0	4.0	0.3	0.5
4.	LF Grade IV (For Zn & Fe deficiency)	4	1.0	6.0	0.5	0.5
5.	LF Grade V (Soil application)	2	0.5	5.0	0.2	0.5

The rate of application of different grades for foliar spray was kept 1%. The foliar application was made during crop growth period with three sprays at 15, 30 and 45 DAT (Days after Transplanting) of the crop and the soil application of grade-V was 20 kg ha^{-1} as basal. The treatments were tested against the standard recommended application of micronutrients (50 kg $FeSO_4.5H_2O$ ha^{-1} and 40 kg $MnSO_4.3H_2O$ ha^{-1}) on soil test value *i.e.* STV basis and control as well.

The treatments were replicated four times in a randomized block design. The soil of the experimental field was *Typic Ustochrepts*, loamy sand in texture and had $pH_{1:2.5}$-7.96, $EC_{1:2.5}$-0.44 dS m^{-1}, organic carbon-3.65 g kg^{-1}, available N-188 kg ha^{-1}, available P_2O_5-80.70 kg ha^{-1}, available K_2O-301.6 kg ha^{-1}, available S-9.24 mg kg^{-1}, Fe-4.20 mg kg^{-1}, Mn-4.39 mg kg^{-1}, Zn-1.20 mg kg^{-1}, Cu-0.59 mg kg^{-1} and B-0.37 mg kg^{-1}. Before field preparation the pearl millet nursery was raised at Model laboratory, Micronutrient Research Project (ICAR) during February, 2017. The soil was collected from the experimental site and filled in micro plot and then pearl millet seed were broadcasted and nursery was prepared as per recommendation. After fertilization, pre-transplanting irrigation was given to the experimental plot. The uniform healthy seedlings of pearl millet cv. GHB–558 having an age of twenty days were uprooted after applying the irrigation to the nursery and one seedling per hill was transplanted at 45 cm x 10 cm spacing.

The field observation on grain and straw yield was recorded. The produce of each net plot was threshed separately, cleaned and the grain yield was recorded in kg per net plot and then converted into kg ha^{-1}. Straw yield was obtained by subtracting the grain yield of each net plot from their respective total dry matter (Above ground) yield and computed in terms of kg ha^{-1} and converted it on hectare basis. The grain and straw samples of pearl millet were collected after harvest of the crop for the chemical analysis of micronutrients *viz.*, Fe, Mn, Zn, Cu and B and for computing their uptake by multiplying grain and straw yield with their respective nutrient content. These samples were air dried and kept in oven at 70ºC to constant weight. The micronutrients content in grain and straw of pearl millet was determined by using atomic absorption spectrophotometer from di-acid (nitric and perchloric acid) digested (Lindsay and Norvell 1978) [11]. Boron content in grain and straw samples was analysed by dry ashing method (Page *et al*. 1982) [14]. The soil samples drawn from the experimental field at harvest were analysed for available micronutrients by extracting with 0.005 M DTPA (Lindsay and Norvell, 1978) [11]. Boron content in soil was determined by spectrophotometer using azomethine-H by hot water method (Datta *et al.* 2002) [6].

Results and Discussion

Yield

Foliar application of 1% multi-micronutrient mixture Grade-III (grade for Fe deficiency) at 15, 30 and 45 DAT recorded significantly higher grain yield of pearl millet (2291 kg ha^{-1}), wherein an overall increase of 299 kg ha^{-1} was observed over control (1992 kg ha^{-1}). It was remained at par with three foliar spray of 1% multi-micronutrient mixture Grade-II (grade for Zn deficiency) and Grade-IV (for Zn & Fe deficiency) and soil application of Grade-V (T_6) and Soil Test Value (STV) treatment. The increase in grain yield of pearl millet could be attributed to greater response of applied Grade-III (Fe deficiency) may be due to experimental soil was deficient in available Fe. The effect of Fe on grain yield can also be explained on the basis of relatively higher doses of Fe tended to produce more vegetative growth resulting from efficient utilization of nutrients, water, radiation and increased metabolic activities followed by increased translocation toward yield contributing characters, which might have led to significant increase in grain yield. Further, the addition of the micronutrients also helps in better utilization of the major nutrients to produce higher yield of crops. Earlier workers, Chandrakumar *et al.* (2004) [5], Singh and Ram (2005) [8] and Esfahani *et al*. (2014) [8] have also reported similar increase in yield of wheat and rice due to Fe and/or Zn application under different agro-climatic conditions. Patel and Singh (2010) [15] also found the beneficial effect of multi-micronutrients could be the balanced nutrition of the crops and thereby improved crop growth as well as yield.

The application of micronutrients of 50 kg $FeSO_4.5H_2O$ ha^{-1} and 40 kg $MnSO_4.3H_2O$ ha^{-1} as per STV (Soil Test Value) increased straw (4906 kg ha^{-1}) and total (7138 kg ha^{-1}) yield of pearl millet was significantly higher over control. The maximum increase of 702 kg ha^{-1} and 942 kg ha^{-1} was observed respectively, over control. However, in case of straw yield it was at par with T_3 (Grade-II), T_4 (Grade-III) and soil application (Grade-V), while total yield was at par with T_3 (Grade-II), T_4 (Grade-III), T_5 (Grade-IV) and T_6 (Grade-V) (Table 4). It's might be due to the favourable effect of applied Fe on these growth parameters may be ascribed to synergetic effect of Fe on most of the photosynthesis, physiological and metabolic processes of the plant followed by increased translocation toward yield contributing characters, which might have led to significant increase in straw yields of rice (Ali *et al*. 2014, Abid *et al.* 2002 and Keram *et al*. 2012) [2, 1, 9].

Since, site of experiment was categorized as low with regard to soil available Mn, its supplementation through soil application might have increase that Mn-containing enzymes *viz.* alcohol dehydrogenase, carbonic anhydrase, alkaline phosphatase, phospholipase, carboxypeptidase, and RNA polymerase which improve the photosynthetic activity and translocation. Good responses to Mn fertilization in terms of attaining high crop yield on Mn-deficient soils have been reported by (Nayyer *et. al.* 1985, Soni 1996, Sharma and Bapat 2000, Bansal and Khurana 2002, Varshney *et al.* 2008 and Dhaliwal *et al*. 2009) [3, 19, 9, 4, 20, 7].

Khan *et al*. (2008) [10] also reported improvements in wheat yield with soil application of Mn. They indicated that the apparent mechanism for improvements in wheat yield due to application of Mn might be due to the increase in leaf area index, providing an improved resource generating base for the crop i.e. an improved carbohydrate source. The consequence of this improved source is the improvement in overall biomass and consequently improvements in yield components of the crop.

Table 2: Effect of multi micronutrient mixture on yield (kg ha^{-1}) of pearl millet

Treatments	Grain	Straw	Total
T_1: Control	1992	4204	6196
T_2: Grade-I (FS)	2014	4345	6359
T_3: Grade-II (FS)	2214	4650	6863
T_4: Grade-III (FS)	2291	4654	6945
T_5: Grade-IV (FS)	2268	4615	6883
T_6: Grade-V (SA)	2260	4792	7052
T_7: STV	2232	4906	7138
SEm ±	63	140	141
CD at 5%	187	417	419
CV (%)	5.8	6.1	4.1

Micronutrients content

The foliar spray of 1% multi-micronutrient mixture application at 15, 30 and 45 DAT significantly improved micronutrients concentration in grain of pearl millet except Mn and B (Table 3). The Fe content of grain was significantly maximum under grade-III (for Fe deficiency) over control, however it was at par with T_3 (Grade-II) and T_5 (Grade-IV), while Zn content of grain was significantly maximum under grade-II (for Zn deficiency) over control, which was at par with T_5 (Grade-IV). In case of Cu, the content was significantly maximum under multi-micronutrient mixture grade-IV (for Zn and Fe deficiency) which was at par with T_3 and T_6. The improvement of grain Fe under grade-III, Zn content under grade-II and Cu content under grade-IV was to the tune of 16.9, 17.9 and 52.1 per cent, respectively over control.

The Fe, Mn and Zn content of straw was significantly altered due to application of micronutrient under different treatments (Table 3). The Fe content of straw was significantly maximum under grade-III (for Fe deficiency) over control which was at par with rest of treatments. The Zn content of pearl millet straw was significantly maximum under grade-IV (for Zn and Fe deficiency) over control, while Mn content in straw was significantly maximum under soil application of micronutrients of 50 kg $FeSO_4.5H_2O$ ha^{-1} and 40 kg $MnSO_4.3H_2O$ ha^{-1} as per STV over control, however it was at par with T_3 (Grade-II), T_5 (Grade-IV) and T_6 (Grade-V). The maximum improvement of straw Fe content under grade-III, Zn content under grade-IV and Mn content of straw under STV was to the tune of 13.1, 20.8 and 19.4 per cent, respectively over control. While, there were no significant effect of application of multi-micronutrient mixture by various methods on grain and straw B concentration of pearl millet.

The higher utilization of micronutrients by crops could be mainly attributed to enhancement in the content as well as improvement in biomass production. The foliar and/ or soil application of micronutrients through multi-micronutrient mixture accumulate higher concentration of micronutrients in soil so plant can be greater absorb and accumulate in different parts of crop. Mobilization of these nutrients from vegetative tissues into the straw and grain is a significant source of the same in edible parts; various mechanisms govern such mobilization during this complex physiological phenomenon (Nayyar 1985) [3] in rice. Similar observations on foliar supplementation of micronutrients to significantly enhanced their contents in onion (Attia 2001) [3].

Micronutrients uptake

The micronutrients uptake by different plant parts *viz.*, grain and straw as influenced by application of multi-micronutrient mixture was computed and mean data over presented in Table 4 to 8.

The Fe uptake was significantly affected by multi-micronutrient mixture application. The Fe uptake by pearl millet grain was significantly maximum under the application of 1% foliar spray of multi-micronutrient mixture grade-III (for Fe deficiency) over control, it was at par with T_3 (Grade-II), T_5 (Grade-IV), T_6 (Grade-V) and T_7 (STV), while in case of Fe uptake by straw, the maximum was under T_7 (STV). The total uptake of Fe by pearl millet was higher under T_4 (Grade-III), which was at par with T_3 (Grade-II), T_5 (Grade-IV), T_6 (Grade-V) and T_7 (STV). The maximum of Fe uptake by grain, straw and total was to the tune of 34, 26.5 and 26.9 per cent higher over control, respectively.

The Mn uptake by grain was did not found significant effect of application of multi-micronutrient, while in case of Mn uptake by straw and total Mn uptake was maximum under T_7 (STV) over control. The Mn uptake by straw maximum in T_7 which was at par with T_3 (Grade-II), T_5 (Grade-IV) and T_6 soil application (Grade-V), similarly total Mn uptake was at par with T_3 (Grade-II) and T_6 (Grade-V). The maximum of Mn uptake by straw and total uptake was to the tune of 39.4 and 34.8 per cent, respectively over control.

The foliar application of 1% multi-micronutrient mixture grade-IV (for Zn & Fe deficiency) resulted in significantly maximum Zn uptake by grain, straw and total uptake by pearl millet. In case of Zn uptake by grain it was at par with T_3 (Grade-II), T_4 (Grade-III), T_6 soil application (Grade-V), while in case of Zn uptake by straw and total uptake was at par with T_3 (Grade-II) and T_4 (Grade-III). The maximum of Zn uptake by grain, straw and total uptake was to the tune of 32.8, 32.9 and 32.8 per cent, respectively over control.

Table 3: Effect of multi micronutrient mixture on micronutrients content (mg kg^{-1}) in grain and straw of pearl millet

Treatments	Fe		Mn		Zn		Cu		B	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1: Control	41.25	93.00	21.88	38.50	24.38	17.28	5.25	5.00	2.57	5.86
T_2: Grade-I (FS)	42.75	100.31	21.88	42.25	26.00	15.86	6.88	5.75	2.55	5.90
T_3: Grade-II (FS)	45.75	102.94	22.50	44.50	28.75	20.21	7.36	5.00	2.71	5.69
T_4: Grade-III (FS)	48.25	105.19	22.00	41.75	26.25	19.61	7.00	4.75	2.70	6.29
T_5: Grade-IV (FS)	46.13	103.69	21.92	43.00	28.39	20.89	7.99	5.01	2.42	6.09
T_6: Grade-V (SA)	44.63	103.13	21.50	45.00	26.88	14.51	7.25	5.00	2.62	6.20
T_7: STV	44.25	100.69	23.13	46.00	23.25	13.73	6.88	4.75	2.49	5.68
SEm ±	1.36	2.18	0.80	1.36	0.97	0.73	0.30	0.30	0.19	0.32
CD at 5%	4.03	6.47	NS	4.03	2.89	2.15	0.89	NS	NS	NS
CV (%)	6.07	4.30	7.22	6.31	7.40	8.32	8.64	11.87	14.72	10.85

Table 4: Effect of multi micronutrient mixture on Fe uptake (g ha^{-1}) by grain and straw of pearl millet

Treatments	Grain	Straw	Total
T_1: Control	82.35	390.50	472.85
T_2: Grade-I (FS)	86.11	435.76	521.87
T_3: Grade-II (FS)	101.28	479.35	580.63
T_4: Grade-III (FS)	110.42	489.94	600.36
T_5: Grade-IV (FS)	104.81	478.39	583.21
T_6: Grade-V (SA)	100.95	493.85	594.80
T_7: STV	98.70	494.07	592.77
SEm ±	4.71	18.71	19.34
CD at 5%	14.00	55.60	57.47
CV (%)	9.64	8.03	6.86

Table 5: Effect of multi micronutrient mixture on Mn uptake (g ha^{-1}) by grain and straw of pearl millet

Treatments	Grain	Straw	Total
T_1: Control	43.62	161.81	205.42
T_2: Grade-I (FS)	44.04	183.37	227.40
T_3: Grade-II (FS)	49.89	206.54	256.42
T_4: Grade-III (FS)	50.28	194.99	245.28
T_5: Grade-IV (FS)	49.70	198.73	248.43
T_6: Grade-V (SA)	48.46	215.88	264.35
T_7: STV	51.48	225.57	277.04
SEm ±	1.93	9.32	9.41
CD at 5%	NS	27.70	27.97
CV (%)	7.99	9.41	7.64

Table 6: Effect of multi micronutrient mixture on Zn uptake (g ha^{-1}) by grain and straw of pearl millet

Treatments	Grain	Straw	Total
T_1: Control	48.47	72.66	121.13
T_2: Grade-I (FS)	52.36	69.00	121.36
T_3: Grade-II (FS)	63.61	94.41	158.02
T_4: Grade-III (FS)	59.89	91.65	151.54
T_5: Grade-IV (FS)	64.38	96.61	160.98
T_6: Grade-V (SA)	60.79	69.69	130.48
T_7: STV	51.98	67.33	119.31
SEm ±	2.31	5.52	6.39
CD at 5%	6.87	16.39	18.98
CV (%)	8.07	13.76	9.29

The Cu uptake by pearl millet grain was maximum under grade-IV over control, which was at par with T_3 (Grade-II) and T_4 (Grade-III), similarly total Cu uptake was maximum under T_5 (Grade-IV) which was at par with T_2 (Grade-I), T_3 (Grade-II), T_4 (Grade-III), T_6 (Grade-V) and T_7 (STV) over control. But in case of Cu uptake by pearl millet straw did not found significant effect of multi-micronutrient application over control and STV treatment. The effect of multi-micronutrient application did not found significant on B uptake by grain, straw and total uptake by pearl millet, over control.

The higher micronutrients uptake by grain and straw as well total uptake by pearl millet mainly attributed to supplementation of higher dose of micronutrients through foliar and/or soil application as the uptake was increased with successive increase in micronutrients fertilization. The balanced nutrition also enhanced the synergistic effect on uptake by plant nutrients (Nawaz *et al*. 2012 and Rana *et al*. 2005) [12, 16].

Table 7: Effect of multi micronutrient mixture on Cu uptake (g ha^{-1}) by grain and straw of pearl millet

Treatments	Grain	Straw	Total
T_1: Control	10.48	20.95	31.43
T_2: Grade-I (FS)	13.87	25.10	38.97
T_3: Grade-II (FS)	16.28	23.25	39.53
T_4: Grade-III (FS)	16.08	22.18	38.26
T_5: Grade-IV (FS)	18.12	23.16	41.29
T_6: Grade-V (SA)	16.32	23.88	40.20
T_7: STV	15.33	23.26	38.59
SEm ±	0.75	1.58	1.71
CD at 5%	2.24	NS	5.09
CV (%)	9.91	13.70	8.95

Table 8: Effect of multi micronutrient mixture on B uptake (g ha^{-1}) by grain and straw of pearl millet

Treatments	Grain	Straw	Total
T_1: Control	5.08	24.55	29.63
T_2: Grade-I (FS)	5.12	25.62	30.74
T_3: Grade-II (FS)	6.00	26.39	32.39
T_4: Grade-III (FS)	6.19	29.27	35.45
T_5: Grade-IV (FS)	5.47	28.25	33.72
T_6: Grade-V (SA)	5.90	29.66	35.56
T_7: STV	5.58	27.86	33.44
SEm ±	0.42	1.67	1.66
CD at 5%	NS	NS	NS
CV (%)	14.91	12.22	10.04

Conclusion

The study showed that from yield point of view, soil application as per Soil Test Value (STV) or application of multi-micronutrient mixture (except Grade-I) were found significantly superior over control. The application of micronutrients showed the favourable changes in accumulation of micronutrients and their uptake by pearl millet.

Thus, the finding of the present study suggested that agronomic approach for yield and micronutrients concentration enhancement could be better accomplished by its supplementation through soil (basal) or foliar application at 15, 30 and 45 DAT (Days after Transplanting) of summer pearl millet.

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