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Effect of agronomic biofortification of pearl millet (*Pennisetum glaucum* L.) cultivars with iron on growth parameters and quality

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Abstract
The effect of different iron sources on pearl millet cultivars was studied in an experiment conducted at College of Agriculture, Rajendranagar. This study was carried out during *kharif*-2019 in sandy loam soil. It comprised of two cultivars of bajra as main plot treatments and five iron treatments as subplot treatments which were tested under Split plot design in three replications. Plant height, number of tillers per square metre, leaf area index and protein content were found to rise with PBH-1625 compared to HHB-67. Application of iron sources resulted in increased growth and protein content of pearl millet with T_3 ($FeSO_4$ fortified manure @ 500 kg ha^{-1}) treatment followed by T_5 (RDF+ Fe-EDTA spray @ 0.2% applied two times *i.e.* before and after flowering). Days to 50% flowering differed between the cultivars but influence of iron treatments was non-significant.

Keywords: pearl millet, cultivars, growth, protein, iron sources

Introduction
Pearl millet (*Pennisetum glaucum* L.) is an indispensable arid and semi arid crop of India, cultivated as dual purpose (food and feed) crop. Though it is not one of the world's most abundant or widely consumed grains, pearl millet does provide a major food, staple for millions of people in the western parts of India and in Africa. Bajra is a significant source of iron and zinc and has been shown to account for 19 – 63 % of the total iron and 16 - 56 % of total zinc intake from all food sources in pearl millet growing states of Maharashtra, Gujarat and Rajasthan in India (ICRISAT) [5]. It is also the cheapest source of these micronutrients as compared to other cereals and vegetables. Thus pearl millet bio fortification opens up the possibility of a cost-effective strategy to beat malnutrition in women and children while simultaneously providing smallholder farmers a climate-ready crop to face the vagaries of climate change.

According to WHO [15], anaemia affects nearly 1.62 billion people (24.8% of the population) globally. In India, 54% of women and 29% of men are anaemic (NFHS, 2016) [7]. Biofortification is a process of increasing the micronutrient content of staple crops through plant breeding, transgenic techniques or agronomic practices. This technology is essential to improve nutrition quality by agricultural based strategies for poor farmers who solely rely on this crop. As such biofortification is seen as an upcoming strategy for dealing with deficiencies of micronutrients in the developing world. According to the study, recently published in the Journal of Nutrition, bio fortified high-iron pearl millet can stem the deleterious effect of iron deficiency by significantly improving nutrition and cognitive performance (Samuel *et al*., 2018) [12].

Material and methods
The experiment was carried out in research farm of College of Agriculture, Rajendranagar during *kharif*- 2019. The soil of experimental plot was sandy loam in texture with slightly alkaline in nature, low in organic carbon, low in available nitrogen, medium in phosphorus and potassium and low in iron. The pearl millet cultivars were sown with 45 cm of row spacing. The experiment was designed with two cultivars as main plot treatment and five iron sources as subplot laid out in split plot design with three replications. The 60 kg N, 30 kg P_2O_5 and 20 kg K_2O per hectare was optimum dose for pearl millet. Half dose of the N was applied as basal and remaining quantity of nitrogen was top dressed at 30 DAS. The complete doses of P and K were applied at the time of sowing. As per treatment, control plot (T_1) was added with optimum fertilizer dose without any iron source, T_2 plot was applied with iron sulphate basally,

T_3 plot with iron sulphate fortified manure prepared by fortification of farm yard manure @ 500 kg ha^{-1} and iron sulphate @ 25 kg ha^{-1} by fermenting for 21 days, T_4 and T_5 plots with foliar application of iron (before and after flowering) as per treatments @ 0.5% iron sulphate and 0.2% Fe-EDTA respectively. Data on growth parameters and quality of pearl millet were statistically analyzed duly following the analysis of variance technique for split plot design as suggested by Panse and Sukhatme (1978) [10]. Statistical significance was tested with F test at 0.05 level of probability and where ever the F value was found significant, critical difference (CD) was worked out to test the significance.

Results and discussion

Growth parameters

Cultivar PBH-1625 registered highest record on growth parameters *viz*., plant height, number of tillers m^{-2} and LAI over HHB-67. Days to 50% flowering different between the cultivars. Interaction effect of cultivars and iron sources on growth parameters, days to 50% flowering of pearl millet was found to be non significant. (Table. 1)

The plant height recorded at harvest stage of crop was significantly higher in hybrid PBH-1625 over HHB-67. The plant height difference between the cultivars in this study may be attributed due to hybrid vigour of the cultivar. These results are in conformity with Srikanth *et al*., (2000) [14]. The higher plant height when treated with T_3 (iron fortified manure) might be due to the fact that FYM would provide micronutrients at optimum level for a longer time and release nutrients slowly in soil system from formed stable organometallic complexes such that they are available throughout the crop growth period. Similar results were observed by Bandiwaddar and Patil (2015) [1], Nikhil and Salakinkop (2018) [9], Malav *et al*. (2019) [6].

The maximum number of tillers of PBH-1625 at all growth stages might be due to its higher tillering ability compared to rest of other cultivars, which can also be attributed to the genetic makeup of the cultivars. The results were in conformity with research findings of Bramhaiah *et al*. (2018) [2], Divya and Vani, (2019) [4], Shekara *et al*. (2019) [13]. The higher number of tillers when treated with T_3 (iron fortified manure) might be due to the fact that FYM would provide micronutrients at optimum level for a longer time and release nutrients slowly in soil system from formed stable organometallic complexes such that they are available throughout the crop growth period. Similar results were observed by Nikhil and Salakinkop (2018) [9], Malav *et al*. (2019) [6].

Significantly higher LAI with PBH-1625 was due to the higher plant height, variation in genetic constitution of different cultivars in producing more number of leaves and total leaf area per plant. The results were in conformity with research findings of Divya and Vani, (2019) [4]. The higher LAI when treated with T_3 (iron fortified manure) might be due to the fact that FYM would provide micronutrients at optimum level for a longer time and release nutrients slowly in soil system from formed stable organometallic complexes such that they are available throughout the crop growth period which increases leaf primordia and thus leaf area is increased. Similar results were observed by Nikhil and Salakinkop (2018) [9].

Days to 50 % flowering were significantly differed with hybrids. Between the cultivars HHB-67 hybrid came to early flowering in 42.1 days followed by PBH-1625 hybrid (53.2). Iron sources did not show any significant difference among the treatments. Interaction effect of cultivars and iron sources were found to be non-significant. Considerable variation in days to 50 percent flowering observed among the cultivars was due to variation in the duration of cultivars. These results also substantiate the findings of Yadav *et al.* (2003) [16], Divya and Vani (2019) [4].

Quality parameters

Protein content in grain was significantly influenced by cultivars and iron sources. The significantly maximum protein content in grain (11.4%) was recorded with PBH-1625 followed by HHB-67 (10.6%). In relation to iron sources, significantly maximum protein content in grain (11.8%) was recorded with (T_3) iron fortified manure compared to T_5 (Fe-EDTA spray @ 0.2% foliar spray applied two times *i.e.* before and after flowering) with protein content of 11.2%. Interaction effect between cultivars and iron sources were found to be non- significant.

The difference in the protein percentage between the cultivars might be attributed to the better growth and development of the cultivars, especially PBH-1625 and also higher nitrogen content resulting in higher protein content. Differences in the genetic makeup between cultivars can also be one of the reasons. These results are in-line with the findings of Prakash *et al*. (2014) [11], Divya (2017) [3].

The difference in the protein percentage among the iron sources might be attributed to better availability of iron by forming organometallic complexes which releases nutrients slowly to the plants and inturn helped in higher nitrogen availability, chlorophyll formation and nitrogen assimilation by enrichment process resulting in higher protein content. These results are in-line with the findings of Malav *et al*. (2019) [6]. Iron plays significant role in chlorophyll content and nitrogen assimilation which resulted in higher protein content. Nesa *et al*. (2012) [8] reported similar findings with iron foliar spray.

Table 1: Growth parameters and protein content of bajra hybrids as influenced by iron sources at harvest

Treatment	Plant height (cm)	Number of tillers m^{-2}	Leaf area index	Days to 50% flowering	Protein content (%)
Hybrids (Main plot)					
V_1: PBH-1625	208.2	34.4	2.32	53.2	11.4
V_2: HHB-67	174.3	27.9	1.77	42.1	10.6
SEm±	3.2	0.4	0.04	0.2	0.1
CD (P=0.05)	21.1	2.8	0.28	1.1	0.7
Iron sources (Sub plot)					
T_1: Control (RDF)	181.3	24.2	1.92	48.5	10.5
T_2: RDF+ 50 kg ha^{-1} of $FeSO_4$ applied to soil as basal	186.6	27.2	1.98	48.0	10.6
T_3: RDF+ $FeSO_4$ fortified manure @ 500 kg ha^{-1} (1:20 ratio of iron sulphate and FYM)	205.5	38.3	2.26	47.5	11.8

T_4: RDF+ $FeSO_4$ Spray (0.5% foliar spray applied two times *i.e.* before and after flowering)	189.6	31.2	1.97	47.5	11.0
T_5: RDF+ Fe-EDTA spray (0.2% foliar spray applied two times *i.e.* before and after flowering)	193.1	34.8	2.09	46.8	11.2
SEm±	3.9	1.1	0.05	0.4	0.2
CD (P=0.05)	11.9	3.5	0.14	NS	0.5
Hybrids x Iron sources					
Sub at same main					
SEm±	7.2	1.0	0.09	0.4	0.3
CD (P=0.05)	NS	NS	NS	NS	NS
Main at same or different sub					
SEm±	5.9	1.5	0.07	0.5	0.3
CD (P=0.05)	NS	NS	NS	NS	NS

Conclusion

Growth parameters and protein content were significantly higher in hybrid PBH-1625 and in T_3 (iron fortified manure) treatment. Days to 50% flowering were minimum in cultivar HHB-67.

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