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Influence of foliar application of iron on pearl millet growth, yield and economics under dryland condition

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Abstract
The present investigation was conducted at Regional Agricultural Research Station, Vijayapur during *kharif* 2015, 2016 and 2017 in medium black soil. The experiment was designed in a split plot design comprising three pearl millet hybrids as main plots (GHB-558, 86 M 88 and Kaveri super boss) and four levels of $FeSO_4$ foliar application (control, 0.25%, 0.50%, 0.75% of Fe) in sub plots. Kaveri super boss has recorded higher seed weight per plant (27.28 g), test weight (12.74 g), grain (2335 kg ha^{-1}), dry fodder (4109 kg ha^{-1}) yield and was on par with 86 M 88. Foliar application of $FeSO_4$ at 0.75% has reported significantly higher grain (2268 kg ha^{-1}) and dry fodder yield compared to control. Interaction of Kaveri super boss with 0.75% $FeSO_4$ foliar application reported highest grain yield (2491 kg ha^{-1}), net returns (Rs. 19,169) and B:C ratio (2.45) and was on par with 86 M 88 + 0.75% $FeSO_4$ foliar application.

Keywords: pearl millet, foliar application, iron sulphate, yield, economics

Introduction

Pearl millet [*Pennisetum glaucum* (L.)] is an important cereal crop of arid and semi-arid regions of India. It is popularly known as Bajra and being drought tolerant generally grown as rainfed crop on marginal lands under low input management conditions. Pearl millet grains are not only nutritionally comparable but are also superior to major cereals with respect to protein, energy, vitamins and minerals. Besides they are rich source of dietary fibre, phytochemicals, micronutrients, nutraceuticals and hence, now a days they are rightly termed as “nutricereal”. It occupies an area of 6.93 million ha with an average production of 8.61 million tones and productivity of 1243 kg ha^{-1} during 2018-19 (Anon., 2020) [2]. The major pearl millet growing states are Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana which account for more than 90% of pearl millet acreage in the country. The main causes of low productivity are prevailing abiotic stresses like drought, poor soil fertility, high soil pH and high temperature. These factors limit the uptake of applied nutrients by roots and also do not able to turn over the nutrients commensurate with crop nutritional requirement at different growth stages.

Iron (Fe) is an essential micronutrient for plants and for humans, and it is a constituent of a number of important macromolecules, including those involved in respiration, photosynthesis, chlorophyll synthesis, nitrogen fixation and metabolism (Kim and Rees, 1992) [7]. Plants obtain Fe from the soil, where Fe exists in either the ferrous (Fe^{2+}) or ferric (Fe^{3+}) ionic state. Although Fe is the fourth most abundant element in the earth’s crust, it is poorly bioavailable in soil because it binds rapidly to soil particles and forms insoluble complexes under aerobic conditions at a neutral or alkaline pH (Gomez-Galera *et al.*, 2010) [6].

Agronomic biofortification is defined as the process of increasing the concentrations of essential elements in the edible portions of staple food plants through soil application, foliar application, by adding the elements to irrigation water (fertilization) or genetic improvement. This strategy was developed as a food based method to address widespread deficiencies in Fe and Zn that remain prevalent to the greatest extent in low income countries (Sadeghzadeh and Rengel, 2013 [15]; Mao *et al.*, 2014 [10]).

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) [12]. 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. Foliar fertilizer sprays have proved to be a sustainable, effective and low cost strategy to improve Fe and Zn levels in edible portions of staple food crops (Ling *et al.*, 2013) [9]. Foliar spraying of micronutrient is very helpful when the roots cannot provide necessary nutrients (Babaeian *et al.*, 2011) [3]. Moreover, soil pollution would be a major problem by soil application of micronutrients. Narimani *et al.* (2010) [11] reported that microelements foliar applications improve the effectiveness of macronutrients. Therefore, the aim of the experiment was to assess the effect of ferrous sulfate applications on Fe biofortification also to study its impacts on the yield and economics of pearl millet.

Materials and Methods

The field experiment was conducted during *kharif* 2015, 2016 and 2017 for three years at Regional Agricultural Research Station, Vijayapur situated in the Northern Dry Zone (Zone-3) of Agro-climatic region-II of Karnataka. The field is located at 16^0 49’ N latitude and 75^0 43’ E longitude and 593 m above mean sea level with annual rainfall ranging from 550 to 680 mm. Soil of the experimental plot was clay loam in texture, alkaline in reaction (pH 8.1) with low organic carbon (0.61%). The available soil N, P and K were 184.00, 18.2 and 390.0 kg ha^{-1}, respectively (Table 1). The experiment was laid out in Split plot design with three main and four sub plot treatments replicated thrice. Each plot was 4 m in length and 3.6 m in width. There were twelve treatment combinations comprising three pearl millet hybrids i.e. M1: GHB-558, M2: 86 M 88, M3: Kaveri super boss and four levels of foliar application S1: control (No spray), S2: 0.25% of $FeSO_4$, S3: 0.50% of $FeSO_4$, S4: 0.75% of $FeSO_4$. Iron sulphate was applied at 25 to 30 days after sowing (DAS). Urea and diammonium phosphate (DAP) were used as source of nitrogen and phosphorus. Fertilizers were applied based on the state recommendation i.e. 50:25:0 kg NPK ha^{-1} and 2.5 t ha^{-1} of farm yard manure. After land preparation farm yard manure was applied and fertilizers were applied at the time of sowing. The seed rate used was 4 kg ha^{-1} with plant geometry at 45 x 15 cm in each experimental plot. Sowing was done plot wise, 45 cm marker was used for rows marking and seeds were placed manually by keeping the plant to plant spacing at 15 cm.

Table 1: Initial properties of the soil samples of experimental field

Soil Properties	Texture	pH	OM	Ca	Mg	N	P	K	S	Fe	Zn	Cu
			(g kg^{-1})	meq 100g-1		(kg ha^{-1})				(mg g^{-1})		
Result	Medium black soil	8.1	0.61	5.8	0.7	184	18.2	390	22.7	10.9	0.89	0.43
Critical level	-	Alkaline	0.5	2.0	0.5	-	10	120	10	4.0	0.6	0.2

Five plants from each plot were sampled randomly for collection of different plant characters and yield attributes. Data on growth parameters like plant height (cm), total and effective number of tillers $plant^{-1}$, earhead length (cm), earhead girth (cm) and on yield contributing characters such as seed weight $plant^{-1}$, 1000 grain weight, grain and dry fodder yield (kg ha^{-1}) were recorded. For seed weight per plant the earheads of sampled plants were threshed separately and grain weight recorded. The net plot and gross plots were harvested one by one, taking care that there will not be mixture. 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. Experimental data recorded was statistically analyzed with the help of statistical package MSTAT-C.

Weather data during the crop growth period average for last ten years (2008 to 2017) is presented in Fig 1. The average rainfall of growing period i.e. from July to October was 421 mm (average of 10 years, 2008 to 2017) and the rainfall received during growing period (July to October) was 428.9, 363.1, 572.1 mm in the year 2015, 2016 and 2017, respectively. The rainfall received during July, August and first week of September is useful for the crop growth. The mean weekly minimum and maximum temperature during the crop season fluctuated from 19.9 to 30.8 °C with average relative humidity from 36.3 to 86.9%. One or two irrigations with sprinkler were applied during the dry spells at early stage of crop establishment.

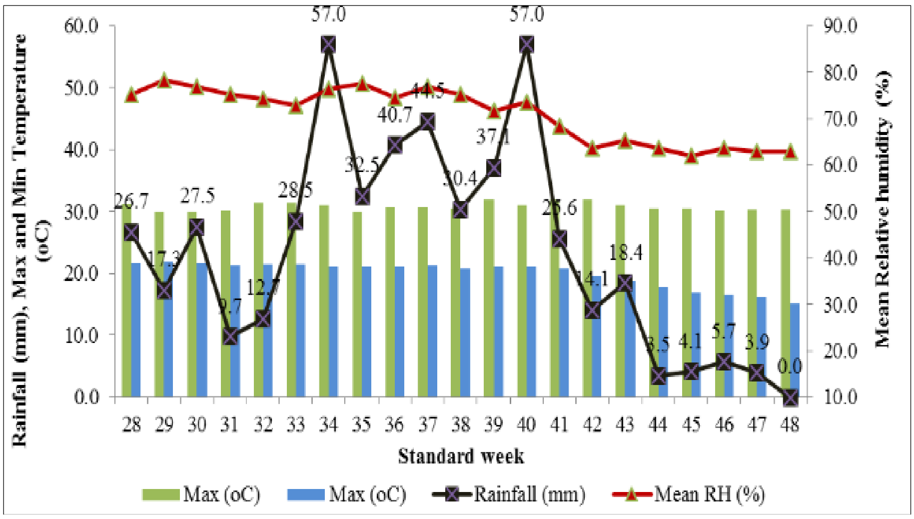

Fig 1: Rainfall, maximum and minimum temperature, mean relative humidity during the crop growth period (average of ten years 2008-2017)

Results and Discussion

Growth parameters

Among the main plot treatments, pearl millet hybrid Kaveri super boss has recorded statistically higher plant height, ear head length and ear head girth (173.8, 23.57 and 3.02 cm, respectively) than GHB 558 and it was on par with 86 M 88 (157.3, 22.77 and 3.00 cm, respectively) and 86 M 88 was superior in number of effective tillers per plant (3.01) (Table 2). Foliar application of 0.75% and 0.50% $FeSO_4$ at 25-30 DAS have recorded statistically higher plant height, no of effective tillers per plant, ear head length and girth compared to control and 0.25% foliar application of $FeSO_4$ and were on par with each other. Among the interaction, combination of pearl millet hybrid Kaveri super boss with 0.75% $FeSO_4$ spray has recorded higher plant height, ear lead length and girth (175.0, 24.0 and 3.10 cm, respectively). In Vijayapur, the crop will experience moisture stress condition during vegetative growth stage due to lesser rainfall. Foliar application of $FeSO_4$ increased the foliar nutrition and resistance to moisture stress condition, increased photosynthetic capacity and hence recorded higher growth. Similar results were reported by Cakmak *et al.* (2010) [4] under micronutrients deficiency conditions, antioxidant enzyme activities decrease and thus increases the sensitivity of plants to environmental stresses. Akbari *et al. (*2013) [1] reported that iron and zinc element in stress condition have an enhancing role on osmotic adjustment process (due to the increase of soluble carbohydrates). Under drought stress conditions the role of these elements can be seen as a contributor to osmotic regulation that with intervention in the synthesis of osmotic compounds for compatibility with stress and maintain turgor pressure performed their roles.

Yield attributes and yield

Kaveri super boss has recorded statistically higher seed weight per plant (27.28 g), test weight (12.74 g), grain (2335 kg ha^{-1}) and dry fodder (4109 kg ha^{-1}) yield, it was on par with 86 M 88 (27.08 g, 12.02 g, 2235 and 3461 kg ha^{-1}, respectively). GHB 558 was poor in grain and dry fodder yield compared to these hybrids (1699 and 2558 kg ha^{-1}, respectively) (Table 3). The higher grain yield of pearl millet seemed to be the cumulative effect of yield attribute which was booted by balanced nutrients supply. Likewise, fodder yield was also increased significantly due to significant response of plant growth *viz*., plant height and number of tillers per plant. The findings are supported by those of Kumar *et al*., 2009 [8] and Patil *et al*., 2014 [14].

Foliar application of $FeSO_4$ at 0.75 (2268 and 3503 kg ha^{-1}) and 0.50% (2120 and 3480 kg ha^{-1}) has resulted in higher grain and dry fodder yield, respectively. Plot without any foliar application has recorded lesser grain and fodder yield (1890 and 3111 kg ha^{-1}, respectively). Treatment combination of Kaveri super boss with 0.75% $FeSO_4$ foliar application was superior in grain yield (2491 kg ha^{-1}) and was on par with hybrid 86 M 88 with 0.75% $FeSO_4$ foliar application (2489 kg ha^{-1}). Foliar nutrition with micronutrient Fe enhances the early vigour and thus helps in better growth by increasing the uptake of other nutrients, increased the photosynthesis rate, physiological and metabolic processes of the plant followed by increased translocation toward yield contributing characters. The experimental results reported by Odeley and Animashaun (2007) [13] showed that foliar application of micronutrients increased the soybean yield, quality, resistance to pests and diseases and drought stress. Fulpagare *et al.* in 2018 [5] concluded that consumption of iron and zinc fertilizer considerably improved yield and yield components of pearl millet on vertisol.

Economics

Pearl millet hybrid Kaveri super boss (Rs.30,355 ha^{-1}, 17,274 ha^{-1} and 2.32, respectively) and 86 M 88 (Rs. 29,052 ha^{-1}, 15,670 ha^{-1} and 2.17, respectively) have recorded higher gross returns, net returns and B:C ratio compared to GHB 558 (Rs. 22,090 ha^{-1}, 9,909 ha^{-1} and 1.81, respectively). Foliar allocation of $FeSO_4$ at 0.75 and 0.50% has recorded higher gross returns, net returns and B:C ratio compared to control and 0.25% foliar application of $FeSO_4$ (Table 4). Interaction effect of hybrid Kaveri supper boss with foliar allocation of $FeSO_4$ at 0.75 % has recorded highest gross (Rs. 32,381 ha^{-1}), net returns (Rs. 19,169 ha^{-1}) and B:C ratio (2.45) compared to other treatments. Higher yield recorded in this interaction combination has resulted in higher gross returns and B:C ration. The treatment comprising of pearl millet hybrid GHB 558 with no foliar application with $FeSO_4$ has recorded lowest gross returns (Rs. 20,723 ha^{-1}), net returns (Rs. 8,673 ha^{-1}) and B:C ratio (1.72).

Conclusion

The present investigation showed that, application of 0.75% $FeSO_4$ as foliar spray at 25-30 days after sowing in pearl millet under dryland condition is useful in achieving higher grain yield, dry fodder yield, net retunes and B:C ration. Foliar application as being a low cost technology it gives higher returns to the cultivator. Hence, foliar feeding can be accepted an effective way to compensate soil deficiency and inability of soil to transfer nutrients to the plants to maintain high productivity of dryland crops.

Table 2: Plant height, total and effective no of tillers $plant^{-1}$, ear head length and girth as influenced by the genotypes and levels of $FeSO_4$ application (Pooled mean of 3 years)

Treatment details	Plant height (cm)	Total number of tillers $plant^{-1}$	No of effective tillers $plant^{-1}$	Ear head length (cm)	Ear head girth (cm)
Main plot treatments (M)					
M_1: GHB-558	126.9	4.41	2.91	19.20	2.79
M_2: 86 M 88	157.3	4.47	3.01	22.77	3.00
M_3: Kaveri super boss	173.8	4.27	2.83	23.57	3.02
S.Em ±	2.40	0.06	0.06	0.32	0.03
C.D.(0.05)	9.44	0.24	0.23	1.24	0.11
Sub plot treatments (S)					
S_1: Control	150.6	4.21	2.66	21.39	2.88
S_2: 0.25% at tillering/jointing stage	152.2	4.47	2.93	21.62	2.92
S_3: 0.50% at tillering/jointing stage	154.5	4.42	3.09	22.17	2.97
S_4: 0.75% at tillering/jointing stage	153.3	4.41	2.99	22.22	2.97
S.Em ±	2.75	0.07	0.07	0.29	0.03

C.D.(0.05)	8.16	0.22	0.20	0.87	0.10
Interaction (M X S)					
M_1S_1	125.0	4.24	2.62	18.97	2.75
M_1S_2	125.3	4.56	2.96	18.99	2.78
M_1S_3	129.9	4.36	3.07	19.30	2.81
M_1S_4	127.2	4.49	3.00	19.54	2.80
M_2S_1	154.2	4.29	2.76	21.82	2.94
M_2S_2	159.0	4.62	3.02	22.88	3.02
M_2S_3	158.2	4.62	3.27	23.27	3.05
M_2S_4	157.6	4.33	2.98	23.12	3.00
M_3S_1	172.5	4.11	2.60	23.39	2.94
M_3S_2	172.3	4.24	2.80	22.98	2.97
M_3S_3	175.4	4.29	2.93	23.92	3.06
M_3S_4	175.0	4.42	3.00	24.00	3.10
S.Em ±	4.76	0.13	0.11	0.51	0.06
C.D.(0.05)	14.14	0.38	0.34	1.50	0.17

Table 3: Effect of the different genotypes and levels of $FeSO_4$ application on seed weight per plant, test weight, grain and dry fodder yield (Pooled mean of 3 years)

Treatment details	Seed weight plant^{-1} (g)	Test weight (g)	Grain yield (kg ha^{-1})	Dry fodder yield (kg ha^{-1})
Main plot treatments (M)				
M_1: GHB-558	19.75	10.85	1699	2558
M_2: 86 M 88	27.08	12.02	2235	3461
M_3: Kaveri super boss	27.28	12.74	2335	4109
S.Em ±	0.43	0.29	35.90	56.61
C.D.(0.05)	1.70	0.91	140.97	222.26
Sub plot treatments (S)				
S_1: Control	23.17	11.18	1890	3111
S_2: 0.25% at tillering/jointing stage	23.95	11.41	2081	3410
S_3: 0.50% at tillering/jointing stage	25.54	12.37	2120	3480
S_4: 0.75% at tillering/jointing stage	26.15	12.52	2268	3503
S.Em ±	0.57	0.31	49.40	73.39
C.D.(0.05)	1.72	0.94	146.77	218.05
Interaction (M X S)				
M_1S_1	18.39	10.28	1594	2280
M_1S_2	19.27	10.67	1744	2703
M_1S_3	20.29	11.13	1635	2616
M_1S_4	21.05	11.32	1824	2634
M_2S_1	25.52	11.07	1994	3229
M_2S_2	26.31	11.25	2169	3490
M_2S_3	28.02	12.76	2288	3509
M_2S_4	28.48	13.01	2489	3616
M_3S_1	25.61	12.18	2083	3823
M_3S_2	26.28	12.32	2328	4038
M_3S_3	28.30	13.21	2438	4315
M_3S_4	28.91	13.24	2491	4258
S.Em ±	0.66	0.34	45.56	67.11
C.D.(0.05)	1.95	1.09	134.22	197.67

Table 4: Effect of different genotypes and levels of $FeSO_4$ application on economics of pearl millet (Pooled mean of 3 years)

Treatment details	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
Main plot treatments (M)				
M_1: GHB-558	12,181	22,090	9,909	1.81
M_2: 86 M 88	13,381	29,052	15,670	2.17
M_3: Kaveri super boss	13,081	30,355	17,274	2.32
S.Em ±	-	361.4	361.4	0.04
C.D.(0.05)	-	1101.6	1101.6	0.15
Sub plot treatments (S)				
S_1: Control	12,750	24,574	11,824	1.92
S_2: 0.25% at tillering/jointing stage	12,838	27,047	14,209	2.10
S_3: 0.50% at tillering/jointing stage	12,925	27,561	14,636	2.12
S_4: 0.75% at tillering/jointing stage	13,013	29,480	16,467	2.26
S.Em ±	-	442.3	442.3	0.05
C.D.(0.05)	-	1398.0	1398.0	0.15
Interaction (M X S)				
M_1S_1	12,050	20,723	8,673	1.72
M_1S_2	12,138	22,675	10,537	1.87
M_1S_3	12,225	21,255	9,030	1.74

M_1S_4	12,313	23,708	11,395	1.93
M_2S_1	13,250	25,920	12,670	1.96
M_2S_2	13,338	28,198	14,860	2.11
M_2S_3	13,425	29,739	16,314	2.22
M_2S_4	13,513	32,351	18,838	2.39
M_3S_1	12,950	27,080	14,130	2.09
M_3S_2	13,038	30,270	17,232	2.32
M_3S_3	13,125	31,690	18,565	2.41
M_3S_4	13,213	32,381	19,169	2.45
S.Em ±	-	412.3	412.3	0.09
C.D.(0.05)	-	1314.8	1314.8	0.26

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