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Effect of iron and zinc on growth and yield of pearl millet [*Pennisetum glaucum* (L.)]

Subhrajit Maharana and Shikha Singh

Abstract
A field experiment was conducted during *Zaid* 2021 Crop Research Farm, Department of Agronomy, SHUATS, Allahabad, (U.P.). The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 6.7), low in organic carbon (0.35%), available N (230 kg ha^{-1}), medium available P (20 kg ha^{-1}) and available K (189 kg ha^{-1}). The treatment consisted of 0.5% foliar spray of $FeSO_4$ and $ZnSO_4$ at 35 and 55 days after sowing with soil application of $FeSO_4$ and $ZnSO_4$ @ 20 kg/ha and 25 kg/ha respectively. There were 10 treatments each replicated thrice. The experiment was laid out in Randomized Block Design. The result showed that growth parameters *viz.*, plant height (181.71 cm), dry weight (77.32 g), number of leaves/plant (18.13), Leaf area index (4.40), CGR (15.33 g m^{-2} day^{-1}) and RGR (0.0155 g/g/day) and yield attributes *viz.*, number of grains/head (1980.40), test weight (12.02 g), grain yield (3.22 t/ha), stover yield (6.58 t/ha) and harvest Index (32.83%) were recorded maximum in treatment T_7 (75% RDN + 25% nitrogen through vermi compost + 0.5% Foliar spray of $FeSO_4$ at 35 and 55 Days after sowing). These parameters were significantly influenced by application of foliar spray of $FeSO_4$ along with vermi compost. However, net return of ₹ 74,023.32 and B.C. ratio 2.25 was recorded higher with application of 75% RDN + 25% nitrogen through vermi compost + 0.5% Foliar spray of $FeSO_4$ at 35 and 55 Days after sowing.

Keywords: Iron, zinc, growth, pearl, millet, *Pennisetum glaucum* L.

Introduction

Pearl millet [*Pennisetum glaucum* (L.)] belongs to family Poaceae is an important crop of rainfed areas of Africa and India and serves as staple food for West Africa. It is the most widely cultivated millet crop, occupying a prominent position in global agriculture. India is the largest producer of Pearl millet in the world occupying about 9.4 million hectare area with annual production 10.1 million tones with average productivity of 1069 kg/ha. India is the largest producer of Pearl millet covering about 8.75 million ha of marginal and sub-marginal lands primarily in the states of Rajasthan, Gujarat, Haryana, Uttar Pradesh and Maharashtra and ranking third after rice and wheat in acreage. The highest productivity levels that is above 1200kg/ha were observed in Uttar Pradesh since 2010. Uttar Pradesh shares 15% of India's total pearl millet production. In addition to its grain Consumption as human feed, it is also used as green fodder in India. Pearl millet may be an alternative crop that exhibits great advantages in physiological characteristics when compared to other cereals as it is resistant to drought, low soil fertility, high salinity and high temperature tolerance (Singh *et al*., 2019) [19]. Because of its drought escaping mechanism pearl millet can grow in areas that have extended dry periods. The balanced fertilization has shown positive effects on various aspects of growth development and biological yield of the crop in comparison to nutrient use in single or in combination

Micronutrients are important for maintaining soil health and also increasing productivity of crops. These are needed in very small amounts. The soil must be supplied with micronutrients for desired growth and development of plants. Increased removal of micronutrients as a consequence of adoption of HYVs and intensive cropping together with shift towards high analysis NPK fertilizers has caused decline in the level of micronutrients in the soil to below normal at which productivity of crops cannot be sustained. Zn is essential for several enzyme systems that regulate various metabolic activities in plants. It is involved in auxin production which is growth regulating substances in plants. Zinc is also vital for the oxidation processes in plant cells and helps in the transformation of carbohydrates and regulates sugar in plants. It is important in the synthesis of tryptophan, a component of some proteins and a compound needed for the production of growth hormones like indole acetic acid.

Reduced growth hormone production in Zn-deficient plants causes the shortening of internodes and smaller than normal leaves.

Zinc deficiency is now recognized as one of the most widespread mineral deficiencies in global human nutrition. Zinc is required for the structural and functional integrity of protein biosynthesis and is a key defense factor in detoxification of highly toxic oxygen free radicals, concluded that foliar or combined soil and foliar application of zinc fertilizer under field conditions is highly effective and very practical way to maximize uptake and accumulation of zinc in whole grain.

Iron is an essential micronutrient for almost all living organisms because of it plays critical role in metabolic processes such as DNA synthesis, respiration, and photosynthesis. Further, many metabolic pathways are activated by iron, and it is a prosthetic group constituent of many enzymes. An imbalance between the solubility of iron in soil and the demand for iron by the plant are the primary causes of iron chlorosis. Although abundant in most well-aerated soils, the biological activity of iron is low because it primarily forms highly insoluble ferric compounds at neutral pH levels. Iron plays a significant role in various physiological and biochemical pathways in plants. It serves as a component of many vital enzymes such as cytochromes of the electron transport chain, and it is thus required for a wide range of biological functions. In plants, iron is involved in the synthesis of chlorophyll, and it is essential for the maintenance of chloroplast structure and function (Rout *et al.,* 2015) [16].

Vermicompost are good superlatives for organic farming, vermicompost has significantly higher K contents than the cow dung compost. vermicompost providing nutrient such as available N, soluble K, exchangeable Ca, Mg, P and micro elements such as Fe, Mo, Zn and Cu, which can easily taken up by plants. Adding of vermicompost to soil improves the chemical and biological properties, improve the soil structure, increasing the water holding capacity and porosity. vermicompost is a mixture of macro and micro plant nutrients. It also increase the microbial activity and when applied, the soil will be enriched with a variety of nutrients that will be available for the indigenous microflora. It also increase the availability of nitrogen and phosphorus and improve the microbial action in the soil. So, the role of earthworms in maintaining soil fertility is well known and recently, emphasis is laid on their use for breaking down and stabilizing the organic waste. In terms of intangible returns vermicompost not only supplies essential elements to plant but also improves physiochemical and biological properties of soil replacement of nitrogen fertilizer in the soil through application of vermicompost can caused reduction in the environmental pollution developed by washing nitrate from soil (Kumar *et al.,* 2014) [15]

Materials and Methods

A field experiment was conducted to study the effect of iron and zinc on growth and yield of Pearl millet [*Pennisetum glaucum* L.]" during *Zaid* season of 2021 at the Crop Research Farm, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj which is located at geographical coordinates 25° 24' 42" N latitude, 81° 50' 56" E longitude and 98 m altitude above the mean sea level. The experimental soil contained 0.51% medium organic carbon, low nitrogen (78.9 kg/ha), high in available phosphorus and potassium levels (32.88 kg/ha and. 385.10 kg/ha respectively) with pH 7.4. Treatments comprised of T_1 - 100% RDF + Soil application of $FeSO_4$ @ 20 Kg/ha, T_2 - 100% RDF + Soil application of $ZnSO_4$ @ 25 kg/ha, T_3 - 100% RDF + 0.5% Foliar spray of $FeSO_4$ at 35 and 55 Days after sowing, T_4 - 100% RDF + 0.5% Foliar spray of $ZnSO_4$ at 35 and 55 Days after sowing, T_5 - 75% RDN + 25% nitrogen through vermi compost + Soil application of $FeSO_4$ @ 20 Kg/ha, T_6 - 75% RDN + 25% nitrogen through vermi compost + Soil application of $ZnSO_4$ @ 25 Kg/ha, T_7 - 75% RDN + 25% nitrogen through vermi compost + 0.5% Foliar spray of $FeSO_4$ at 35 and 55 Days after sowing, T_8 - 75% RDN + 25% nitrogen through vermi compost + 0.5% Foliar spray of $ZnSO_4$ at 35 and 55 Days after sowing, T_9 - 100% RDF and T_{10} - 75% RDN + 25% nitrogen through vermi compost. The experiment was laid out in Randomized Block Design. The growth parameters *viz.,* plant height, number of leaves, dry weight (g/plant), leaf area index, crop growth rate (g/m^2/day) and relative growth rate (g/g/day) also yield parameters *viz.,* number of grains/head, test weight, grain yield (t/ha), stover yield (t/ha), harvest index (%) with standard process were recorded data and was statistically analyzed with, Analysis of Variance (ANOVA) as applicable to Randomized Block Design (Gomez and Gomez., 1984). The expenses incurred for all the cultivation operations from preparatory tillage to harvesting including the cost of inputs *viz.,* seeds, manures, fertilizers, irrigation, etc. applied to each treatment was calculated on the basis of prevailing local charges. The gross realization in terms of rupees per hectare was worked out taking into consideration the seed and stover yields from each treatment and local market prices. Net return of each treatment was calculated by deducting the total cost of cultivation from the gross returns. The benefit: cost ratio (B:C) was calculated by dividing net return with total cost of cultivation. Statistical analysis of the individual data of various characters studied in the experiment was carried out using standard statistical procedures as described by. Standard error of mean, critical difference (C.D.) at 5 percent level of probability and coefficient of variance were worked out for the interpretation of the results.

Result and Discussion

Growth attributes

Data pertaining to growth parameters were recorded and depicted in table 1. Significantly highest plant height (181.71 cm) was recorded at harvest with treatment T_7 (75% RDN + 25% nitrogen through vermi compost + 0.5% Foliar spray of $FeSO_4$ at 35 and 55 Days after sowing) whereas, T_8 75% RDN + 25% nitrogen through vermicompost + 0.5% Foliar spray of $ZnSO_4$ at 35 and 55 Days after sowing (180.81cm) were found to be statistically at par with highest. Significantly highest leaf area index (4.40) and dry weight (77.32 g) per plant were also observed with treatment T_7 which was closely followed by treatment T_8 i.e,
75% RDN + 25% nitrogen through vermicompost + 0.5% Foliar spray of $ZnSO_4$ at 35 and
55 Days after sowing. Maximum no. of leaves (17.53) was observed with application of T_7 that is 75% RDN + 25% nitrogen through vermicompost + 0.5% Foliar spray of $FeSO_4$ at 35 and 55 Days after sowing. Similarly maximum crop growth rate (15.33 g/m^2/day) was observed in T_7 which was significantly superior over rest of the treatments. Maximum relative growth rate (0.0173 g/g/day) was found in T_4 100%

RDF + 0.5% Foliar spray of $ZnSO_4$ at 35 and 55 Days after sowing which was significantly superior over rest of the treatment.

Increase in plant height, number of leaves and dry weight per plant might be due to combined application of Iron along with vermicompost because iron plays critical role in metabolic process such as DNA synthesis, respiration, photosynthesis and it also involves in synthesis of chlorophyll which is essential for maintenance of chloroplast structure and function, due to continuous supply of iron to plants which have direct role in photosynthesis (photosystem I and photosystem II) and translocation of photosynthates from source to sink. Iron also helps in the proliferation of roots and thereby increasing the uptake of the plants nutrients from the soil supplying in to the aerial parts of the plant and ultimately enhancing the vegetative growth of the plant Organic carbon content was influenced significantly by the application of vermicompost which is also responsible for increasing plant height. The study was in close conformity with Rao *et al*.2019 [17], Shrivastava *et al*.2018 [21].

Table 1: Effect of Iron and Zinc on growth attributes of Pearl millet.

At harvest							
Treatment	**Treatment combinations**	**Plant height (cm)**	**No. of leaves/plant**	**Leaf area index**	**Dry weight (g/plant)**	**CGR (g/m^2/day)**	**RGR (g/g/day)**
T_1	100% RDF + Soil application of $FeSO_4$ @ 20 Kg/ha	169.34	10.40	3.36	65.17	13.02	0.0157
T_2	100% RDF + Soil application of $ZnSO_4$ @ 25 kg/ha	170.33	13.40	3.27	64.66	13.28	0.0162
T_3	100% RDF + 0.5% Foliar spray of $FeSO_4$ at 35 and 55 Days after sowing	172.63	14.00	3.58	66.75	12.88	0.0150
T_4	100% RDF + 0.5% Foliar spray of $ZnSO_4$ at 35 and 55 Days after sowing	171.16	10.87	3.45	67.49	14.64	0.0173
T_5	75% RDN + 25% nitrogen through vermi compost + Soil application of $FeSO_4$ @ 20 Kg/ha	173.79	14.67	3.76	69.40	14.60	0.0166
T_6	75% RDN + 25% nitrogen through vermi compost + Soil application of $ZnSO_4$ @ 25 Kg/ha	172.77	14.07	3.62	70.78	14.75	0.0165
T_7	75% RDN + 25% nitrogen through vermi compost + 0.5% Foliar spray of $FeSO_4$ at 35 and 55 Days after sowing	181.71	17.53	4.40	77.32	15.33	0.0155
T_8	75% RDN + 25% nitrogen through vermi compost + 0.5% Foliar spray of $ZnSO_4$ at 35 and 55 Days after sowing	180.81	17.13	4.11	73.37	14.57	0.0156
T_9	100% RDF	168.75	10.13	3.11	64.95	13.43	0.0163
T_{10}	75% RDN + 25% nitrogen through vermi compost	169.99	13.80	3.15	65.68	13.32	0.0159
	S.Em+	0.32	1.93	0.02	0.26	0.21	0.0002
	CD (P=0.05)	0.94	5.73	0.05	0.76	0.62	0.0006

Yield contributing characters and yield

Data related to yield attributes was recorded at harvest and presented in Table 2. The significantly highest number of grains/head (1980.40) were observed with application of 75% RDN + 25% nitrogen through vermicompost + 0.5% Foliar spray of $FeSO_4$ at 35 and 55 Days after sowing with 25.98% higher than the control (100% RDF) and was significantly superior over rest of the treatments. Significantly highest number of heads/plant (4.33) were recorded in T_7 whereas, T_8 and T_6 were found to be statistically at par with T_7. Highest test weight (12.02 g) was recorded in application of 75% RDN + 25% nitrogen through vermicompost + 0.5% Foliar spray of $FeSO_4$ at 35 and 55 Days after sowing which was significantly superior over rest of the treatments. Significantly maximum grain yield (3.22 t/ha) was recorded in T_7. Similarly maximum stover yield (6.58 t/ha) was recorded in T_7 also which was significantly superior over rest of the treatment. Significantly higher harvest index percentage (32.83%) was recorded in T_7 where as application of 75% RDN + 25% nitrogen through vermi compost + 0.5% Foliar spray of $ZnSO_4$ at 35 and 55 Days after sowing (32.61%) was found to be statistically at par with highest.

This increase in yield might be due to effective utilization of applied nutrients. The positive and significant improvement in LAI and DMP noticed at different stages, increase in yield attributes and nutrient uptake due to foliar application of $FeSO_4$ would have resulted in enhanced grain and stover yield. Iron plays a major role in biosynthesis of IAA and especially due to its role in initiation of primordial reproductive part and portioning of photosynthetic towards them which promotes the yield. Similar result was also observed by Rao *et al.* 2019 [17]. Increase in yield and yield attributes in pearl millet was also due to iron role in starch formation and protein synthesis as well as maintenance and synthesis of chlorophyll in plants. The increased in the availability of iron to plant might have stimulated the metabolic and enzymatic activities thereby increasing the growth of the crop. Similar findings were also reported by Yadav *et al*., (2013) [23]. Iron provides potential for many of the enzymatic transformations. Several of these enzymes are involved in chlorophyll synthesis, grain formation and dry matter production, which ultimately lead to increase in yield characters such as number of effective tillers per plant. These findings are in confirmation to the earlier reported by Gupta *et al*., (2002) [8] and Abbas *et al*., (2009) [1]. Vermicompost plays an important role in improving yield, it increases microbial activity and when applied, the soil will be enriched with a variety of nutrients that will be available for the indigenous microflora. It also increase the availability of nitrogen and phosphorus and improve the microbial activity in the soil. So, the role of earthworms in maintaining soil fertility is well known and recently, emphasis is laid on their use for breaking down and stabilizing the organic waste (Divya *et al*. 2017) [5]

Table 2: Effect of Iron and Zinc on yield and yield attributes of Pearl millet.

Treatment	Treatment combinations	At harvest					
		No. of grains/head	No. of heads/plant	Test weight (g)	Grain yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
T_1	100% RDF + Soil application of $FeSO_4$ @ 20 Kg/ha	1565.87	2.67	10.58	2.40	5.72	29.57
T_2	100% RDF + Soil application of $ZnSO_4$ @ 25 kg/ha	1525.93	2.67	10.29	2.33	5.65	29.18
T_3	100% RDF + 0.5% Foliar spray of $FeSO_4$ at 35 and 55 Days after sowing	1638.13	2.67	10.83	2.83	6.19	31.39
T_4	100% RDF + 0.5% Foliar spray of $ZnSO_4$ at 35 and 55 Days after sowing	1632.47	3.00	10.64	2.76	6.09	31.21
T_5	75% RDN + 25% nitrogen through vermi compost + Soil application of $FeSO_4$ @ 20 Kg/ha	1739.47	3.33	11.20	2.24	5.60	28.58
T_6	75% RDN + 25% nitrogen through vermi compost + Soil application of $ZnSO_4$ @ 25 Kg/ha	1734.80	3.67	11.09	2.23	5.54	28.71
T_7	75% RDN + 25% nitrogen through vermi compost + 0.5% Foliar spray of $FeSO_4$ at 35 and 55 Days after sowing	1980.40	4.33	12.02	3.22	6.58	32.83
T_8	75% RDN + 25% nitrogen through vermi compost + 0.5% Foliar spray of $ZnSO_4$ at 35 and 55 Days after sowing	1881.67	4.00	11.81	3.12	6.45	32.61
T_9	100% RDF	1465.73	2.33	10.12	2.12	5.46	27.92
T_{10}	75% RDN + 25% nitrogen through vermi compost	1536.47	2.33	10.21	2.29	5.61	28.97
	S.Em+	3.00	0.33	0.07	0.03	0.02	0.30
	CD (P=0.05)	8.91	0.98	0.20	0.09	0.07	0.90

Table 3: Effect of iron and zinc on economics of Pearl millet

Treatment	Treatment combinations	Total cost of cultivation (₹/ ha)	Gross return (₹/ ha)	Net return (₹ / ha)	Benefit cost ratio
T_1	100% RDF + Soil application of $FeSO_4$ @ 20 Kg/ha	32146.68	82880	50733.32	1.57
T_2	100% RDF + Soil application of $ZnSO_4$ @ 25 kg/ha	32246.68	80850	48603.32	1.50
T_3	100% RDF + 0.5% Foliar spray of $FeSO_4$ at 35 and 55 Days after sowing	30796.68	95510	64713.32	2.10
T_4	100% RDF + 0.5% Foliar spray of $ZnSO_4$ at 35 and 55 Days after sowing	30786.68	93360	62573.32	2.03
T_5	75% RDN + 25% nitrogen through vermi compost + Soil application of $FeSO_4$ @ 20 Kg/ha	34146.68	78400	44253.32	1.29
T_6	75% RDN + 25% nitrogen through vermi compost + Soil application of $ZnSO_4$ @ 25 Kg/ha	34246.68	77910	43663.32	1.27
T_7	75% RDN + 25% nitrogen through vermi compost + 0.5% Foliar spray of $FeSO_4$ at 35 and 55 Days after sowing	32796.68	106820	74023.32	2.25
T_8	75% RDN + 25% nitrogen through vermi compost + 0.5% Foliar spray of $ZnSO_4$ at 35 and 55 Days after sowing	32786.68	103800	71013.32	2.16
T_9	100% RDF	30746.68	74840	44093.32	1.43
T_{10}	75% RDN + 25% nitrogen through vermi compost	32746.68	79690	46943.32	1.43

Economics
Highest gross return (106820 INR/ha), net return (74023.32 INR/ha) and benefit-Cost ratio (2.25) were obtained with the application of 75% RDN + 25% nitrogen through vermicompost + 0.5% Foliar spray of FeSO4 at 35 and 55 Days after sowing

Conclusion
On the basis of research result, it may be concluded that in Pearl millet crop the application of 75% RDN + 25% nitrogen through vermicompost + 0.5% Foliar spray of FeSO4 at 35 and 55 Days after sowing is the suitable combination for obtaining better growth attributes like plant height, no. of leaves/plant, leaf area index, dry weight, crop growth rate, relative growth rate and higher yield attributes of pearl millet like number of grains/head, no. of heads/plant, test weight (g), grain yield (t/ha), stover yield (t/ha), harvest index (%) and can be recommended to the farmers of Prayagraj region for sustaining productivity and profitability of Pearl millet.

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