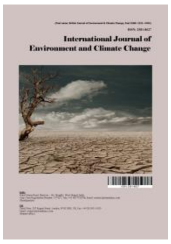

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Effect of Organic Manures and Zinc on Growth, Yield and Economics of Foxtail Millet (*Setaria italica* L.)

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The field experiment was conducted during *Kharif* season 2022-23 at Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology And Sciences, Prayagraj, Uttar Pradesh, India. The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 7.8), low in organic carbon (0.62%), available nitrogen (225 kg/ha), available phosphorus (38.2 kg/ha) and available potassium (240.7 kg/ha). The treatments consist of organic manures (FYM 10t/ha, Goat manure 1.6t/ha, Poultry manure 1.6t/ha) and foliar spray of zinc (0.2%, 0.4%, 0.6%) at 30, 45 Days after sowing. The experiment was layout in Randomized Block Design with nine treatments each replicated thrice. Significant and higher plant height (92.69 cm), maximum number of tillers/ hill (8.40), higher plant dry weight (15.93 g), higher panicle length (15.36 cm), number of grains/ panicle (1262.33), grain yield (2.76 t/ha), straw yield (4.65 t/ha), maximum gross return (INR 78300.00), net return (INR 52670.40) and B:C ratio (2.05) were recorded in treatment 9 with the application of Poultry Manure1.6t/ha along with 0.6% Zinc.

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Keywords: Foxtail millet; organic manures; zinc; growth; yield; economics.

1. INTRODUCTION

One of the world's oldest crops, foxtail millet is mostly grown in arid and semi-arid regions of Asia and Africa, as well as in some other economically developed nations where it is more frequently used for bird feed. It is a excellent source of protein, fibre, minerals, and phytochemical content. By adopting the right processing techniques, anti-nutrients in this millet, like phytic acid and tannin, can be decreased to negligible amounts. Millet is also said to have hypolipidemic, low-glycemic index, and antioxidant properties. Foxtail millet, like most millet varieties, is under-utilised as a food source. However, due to the fact that it can grow in challenging conditions and the fact that its cultivation does not require a lot of agricultural inputs, it is currently a topic of considerable study and research. It has the potential to increase dietary quality and food security. Worldwide production of millets is 89.17 mm.tons. from an area of 74.00 m.ha in 2020. In India area under the cultivation of small millets is 0.459 m.ha, production is 0.33 m.tons and its productivity is 809 kg/ha, Foxtail millet predominates all millets in terms of productivity, yielding about 2166 kg/ha" [1]. In terms of protein, fibre, minerals, and vitamins, foxtail millet has a superior nutritional profile compared to rice and wheat. It has good nutritive value as it is rich in proteins (12.3 g), carbohydrates (60.9 g), fat (4.3 g), crude fiber (8.0 g), calcium (3.1 g), vitamins and thiamin (50 mg) per100g. The grains are a good source of Beta-carotene, antioxidants, dietary fibre and minerals like Ca, Fe, Mg, Zn" [2].

In addition to being more expensive, inorganic fertilizers have a negative impact on human health, soil physicochemical properties and the environment also. Soil organic matter management and the balanced use of organic and inorganic fertilizers will be a major issue in designing sustainable agriculture systems. In the coming decades, preventing plant nutrient depletion besides maintaining soil health and improving crop quality and productivity are of major topics to be discussed and implemented. Integrated Nutrient Management (INM) improves soil health and nutrient availability to plants, which leads to improvement in plant growth and development which ultimately results in increased crop yield. The integration of chemical and organic sources, as well as their efficient management, have yielded promising results not only in sustaining productivity but also in preserving soil health [3].

"Zinc deficiency in plants causes, stunting (reduced height), interveinal chlorosis (yellowing of the leaves between the veins), bronzing of chlorotic leaves, small and abnormally shaped leaves and/or stunting and rosetting of leaves" [4]. "Zinc deficiency in the plant retards development and maturation of panicles of grain crops" [5].

To correct Zinc deficiency and prevent yield losses in crop plants, Zn is applied to deficient soil, typically in the form of $ZnSO_4$, at rates that range typically from 5 to 25 kg Zn/ha. The rates of soil Zn application vary depending on the crop species, soil characteristics and method of application; higher rates are associated with crops sensitive to Zn deficiency, alkaline or calcareous soil and broadcasting rather than banding. Development of Zn-rich cultivars or the use of Zn-fertilizers is significant practices to enrich the Zn-contents of grains" [6]. "Zinc plays an important role in photosynthesis, nitrogen metabolism and regulates auxin concentration in the plant" [7].

"Farmyard manure occupies a important position among organic manures. It seems to act directly on improving crop yield by acceleration of respiratory process or by cell permeability or by hormonal growth action. Under organic conditions, nutrients release and crop demand synchrony is very much required; hence, a thorough understanding of nutrients release pattern of organic sources is most important to avoid nutrients stress in plants. Thus, the development and implementation of efficient nutrient management system is most important for successful organic production and to improve the product quantity and quality, besides improving soil health. Farmyard manure plays a major role in improving fertility, physical-chemical properties and biological activity of the soil" [8].

"Goat manure application to soil decreases the sorption of Phosphorus [9] and could thus improves the P availability to plants". "However, as reported for other organic materials [10,11], it is likely that the application of goat manure to soil could also improve the availability of P through enhanced biological cycling of soil and fertilizer P. Establishing the mechanisms whereby goat manure improves the biological cycling of P may help us to increase the availability of added P in P-fixing soils and thereby enhances yield".

"Poultry manure was reported to contain more plants nutrients compared to all other organic manures. Nitrogen (N) is one of the most important plant nutrients as it has a strong impact on cereal crop yield. Poultry manure is a excellent source of nutrients. Singh et al. [12] reported that a judicious use of organic and inorganic combination of fertilizers will maintain long-term soil fertility and sustained higher levels of productivity". "Poultry manure had the greatest content of organic C, N, P, K, Ca and lowest C:N ratio" reported by [13]. "Poultry manure have been found to be richer in nitrogen than other livestock wastes". It reduces the loss of nitrogen due to its nature of slow-release pattern.

"Zinc concentration is sufficient in many agricultural areas, but available Zn concentration for plant absorption is deficient because of different soil and climatic conditions. Zinc was one of the first micronutrients, essential for plant growth. Zinc also plays a role in nucleic acid and protein synthesis and helps in the utilization of phosphorus and nitrogen, as well as in seed formation. Zinc is an important element for terrestrial life since it is required as either a structural component or reaction site in numerous proteins" [14].

2. MATERIALS AND METHODS

The experiment was conducted during *Kharif* season 2022-23 at Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology And Sciences, Prayagraj (U.P,). The soil of the experimental field constituting a part of central Gangetic alluvium is neutral and deep. Pre-sowing soil samples were taken from a depth of 15 cm with the help of an auger. The composite samples were used for the chemical and mechanical analysis. The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 7.8), low in organic carbon (0.62%), available nitrogen (225 kg/ha), available phosphorus (38.2 kg/ha) and available potassium (240.7 kg/ha). The treatments consist of organic manures *viz,* FYM 10t/ha, Goat manure 1.6t/ha, Poultry manure 1.6t/ha and foliar spray of zinc *viz,*0.2%, 0.4%, 0.6% at 30, 45 Days after sowing. The experiment was layout in Randomized Block Design with nine treatments each replicated thrice. The treatment combinations are

T1- FYM 10t/ha + 0.2% Zinc,
T2- FYM 10t/ha + 0.4% Zinc,
T3- FYM 10t/ha + 0.6% Zinc,
T4- Goat Manure 1.6t/ha + 0.2% Zinc,
T5- Goat Manure 1.6t/ha + 0.4% Zinc,
T6- Goat Manure 1.6t/ha + 0.6% Zinc,
T7- Poultry Manure 1.6t/ha + 0.2% Zinc,
T8- Poultry Manure 1.6t/ha + 0.4% Zinc,
T9- Poultry Manure 1.6t/ha + 0.6% Zinc.

The data recorded on different aspects of crop viz., growth parameters, yield attributes and yield were subjected to statistical analysis by variance method Gomez and Gomez, [15].

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

3.1.1 Plant height (cm)

At 80 DAS, [Table 1] higher plant height 92.69 cm was recorded significantly with treatment 9 (Poultry Manure 1.6t/ha + 0.6% Zinc). However, treatment 8 (Poultry Manure 1.6t/ha + 0.4% Zinc) was found to be statistically at par with treatment 9. Significantly and higher plant height was recorded with the application of Poultry manure (1.6t/ha), could be due to application of poultry manure is an important supplier of nitrogen which may have increased cell number and elongation, increased leaf area and resulted in increasing plant height. Similar results are in support with Ledhan et al. [16] in finger millet. Further with the application of Zinc 0.6%, increased plant height might be due increased availability and absorption of zinc, improving the cell division and cell elongation. Similar results are in support with Shalini et al. [17] in wheat.

3.1.2 Number of tillers/hill

At 80 DAS, [Table 1] maximum number of tillers/ hill (8.40), was recorded higher in treatment 9 (Poultry Manure 1.6t/ha + 0.6% Zinc), However, treatment 8 (Poultry Manure 1.6t/ha + 0.4% Zinc) was found to be statistically at par with treatment 9. Significantly and higher number of tillers/ hill was recorded with the application of Poultry manure (1.6t/ha) might be due to the higher content of macro and micro nutrients in poultry manure, improving the nutrient uptake by plants resulting in increased number of tillers/hill. similar results are in support with Ashokh et al. [18] in finger millet. Further with the application of Zinc 0.6%, increased number of tillers/hill might be due to the influence of zinc on nutrient metabolism, biological activity and growth parameters resulting in improved activity of enzymes producing higher number of tillers/hill. Similar results are in support with Sompalli et al. [19] in finger millet.

3.1.3 Dry weight (g)

At 80 DAS, [Table 1] significantly higher plant dry weight (15.93 g) was recorded in treatment 9 (Poultry Manure 1.6t/ha + 0.6% Zinc). However, treatment 8 (Poultry Manure 1.6t/ha + 0.4% Zinc) was found to be statistically at par with treatment 9. Significant and higher plant dry weight was recorded with the application of Poultry manure (1.6t/ha), this might be due to the growth of new tissues and development of new shoots that have ultimately increased the dry mater accumulation. Similar results are in agreement with Amarghade and Singh, [20] in pearl millet. Further with the application of Zinc 0.6%, increased dry weight might be due to the involvement of zinc in auxin metabolism which results in improvement in overall biomass. Similar findings were obtained by Wilson and Debbarma, [21].

3.2 Yield Attributes and Yield

3.2.1 Panicle length (cm)

At Harvest, [Table 2] significantly higher panicle length (15.33 cm) was recorded in treatment 9 (Poultry Manure 1.6t/ha + 0.6% Zinc). However, treatment 8 (Poultry Manure 1.6t/ha + 0.4% Zinc) was found to be statistically at par with treatment 9. Significant and higher panicle length was recorded with the application of Poultry manure (1.6t/ha), this could be due to the release of essential nutrients by the poultry manure resulting in increase of nutrient availability to the plants, resulted in more nutrient uptake and its subsequent translocation to the developing spike. Similar findings was reported by Wilson and Debbarma, [21].

3.2.2 Number of grains/panicle

At Harvest, [Table 2] significantly higher number of grains/ panicle (1262.33) was recorded in treatment 9 (Poultry Manure 1.6t/ha + 0.6% Zinc). However, treatment 8 (Poultry Manure 1.6t/ha + 0.4% Zinc) is statistically at par with treatment 9. Significant and higher grains/ panicle was recorded with the application of Poultry manure (1.6t/ha), this could be due to the residual effect of organic manure which have favorably affected the balance of macro and micronutrients which increased assimilates for producing more grains/ spike. Similar findings was reported by Wilson and Debbarma, [21]. Further, higher number of grains/ splike was with application of Zinc 0.6%, might be due to the Zinc is crucial role in a myriad of physiological and metabolic processes such as the synthesis of tryptophane and used to produce growth harmones (auxins) such as IAA. Similar findings was reported by Vangala et al. [22] in pearl millet.

3.2.3 Grain yield (t/ha)

At harvest, [Table 2] significantly higher grain yield (2.76 t/ha) was obtained in treatment 9 (Poultry Manure 1.6t/ha + 0.6% Zinc). However, both treatment 7 (Poultry Manure 1.6t/ha + 0.2% Zinc) and treatment 8 (Poultry Manure 1.6t/ha + 0.4% Zinc) were found to be statistically at par with treatment 9. Significant and higher grain yield was recorded with the application of poultry manure (1.6t/ha), this might be due to release of macro and micro nutrients during the course of microbial decomposition, where the presence of organic matter also serves as a source of energy for soil microflora, resulting in the transformation of other nutrients held in soil or applied in other ways into a form that is easily utilised by growing plants. Similar findings were reported by Sompalli et al. [19] in finger millet. Further, the application of Zinc 0.6%, increased grain yield might be due to improved photosynthesis efficiency, increased nutrient availability due to increased organic matter decomposition rate, or improved individual plant performance. Similar findings were reported by Gudela and Debbarma, [14] in wheat.

3.2.4 Straw yield (t/ha)

At harvest, [Table 2] significantly higher straw yield (4.65 t/ha) was recorded in treatment 9 (Poultry Manure 1.6t/ha + 0.6% Zinc). However, both treatment 7 (Poultry Manure 1.6t/ha + 0.2% Zinc) and treatment 8 (Poultry Manure 1.6t/ha + 0.4% Zinc) were found statistically at par with treatment 9. Significant and higher straw yield was recorded with the application of Poultry manure (1.6t/ha), may be poultry manure produces more humic acid which form water soluble chelated phosphorus which helped in easy release of phosphorus to the crop which resulted in increased straw yield. Similar findings were reported by Ledhan et al. [16] in finger millet. Further, higher straw yield was with the application of Zinc 0.6%, which may have helped in many physiological process of plant such as chlorophyll formation, stomatal regulation, starch utilization and biomass accumulation enhanced straw yield. Similar findings were reported by Sompalli et al. [19] in finger millet.

Table 1. Effect of organic manures and zinc on growth attributes of foxtail millet (*Setaria italica*)

S. No.	Treatment combination	Plant height (cm)	Tillers/hill	Dry weight (g)
1.	FYM10t/ha+0.2% Zinc	85.08	6.73	12.34
2.	FYM10t/ha+0.4% Zinc	85.96	6.87	12.98
3.	FYM10t/ha+0.6% Zinc	87.30	6.93	13.35
4.	GoatManure1.6t/ha+0.2%Zinc	88.19	7.00	13.40
5.	GoatManure1.6t/ha+0.4%Zinc	89.83	7.73	13.89
6.	GoatManure1.6t/ha+0.6%Zinc	90.93	7.93	14.20
7.	PoultryManure1.6t/ha+0.2%Zinc	91.48	7.93	14.50
8.	PoultryManure1.6t/ha+0.4%Zinc	91.71	8.33	15.28
9.	PoultryManure1.6t/ha+0.6%Zinc	92.69	8.40	15.93
	F-test	S	S	S
	SEm(±)	0.34	0.07	0.25
	CD (p = 0.05)	1.02	0.21	0.73

Table 2. Effect of organic manures and zinc on yield attributes and yield of foxtail millets (*Setaria italica*)

S. No.	Treatment combination	Panicle length (cm)	Grains/ panicle	Grain yield (t/ha)	Straw yield (t/ha)
1.	FYM10t/ha+0.2% Zinc	13.48	1103.00	2.36	4.54
2.	FYM10t/ha+0.4% Zinc	13.53	1113.27	2.40	4.56
3.	FYM10t/ha+0.6% Zinc	13.73	1130.73	2.43	4.57
4.	GoatManure1.6t/ha+0.2%Zinc	13.91	1147.90	2.47	4.57
5.	GoatManure1.6t/ha+0.4%Zinc	14.30	1176.47	2.51	4.58
6.	GoatManure1.6t/ha+0.6%Zinc	14.57	1198.60	2.58	4.59
7.	PoultryManure1.6t/ha+0.2%Zinc	14.77	1214.80	2.61	4.62
8.	PoultryManure1.6t/ha+0.4%Zinc	15.10	1237.83	2.66	4.63
9.	PoultryManure1.6t/ha+0.6%Zinc	15.36	1262.33	2.76	4.65
	F-test	S	S	S	S
	SEm(±)	0.09	8.56	0.11	0.09
	CD (p = 0.05)	0.28	25.43	0.31	0.26

Table 3. Effect of organic manures and zinc on economics of foxtail millet (*Setaria italica*)

S. No.	Treatment combination	Cost of cultivation (INR/ha)	Gross return (INR/ha)	Net returns (INR/ha)	B C ratio (B:C)
1.	FYM10t/ha+0.2% Zinc	26310.00	68080.00	41770.00	1.58
2.	FYM10t/ha+0.4% Zinc	26470.00	69120.00	42650.00	1.61
3.	FYM10t/ha+0.6% Zinc	26630.00	69890.00	43260.00	1.62
4.	GoatManure1.6t/ha+0.2%Zinc	24510.00	70890.00	46380.00	1.89
5.	GoatManure1.6t/ha+0.4%Zinc	24670.00	71910.00	47240.00	1.91
6.	GoatManure1.6t/ha+0.6%Zinc	24830.00	73680.00	48850.00	1.96
7.	PoultryManure1.6t/ha+0.2%Zinc	25310.00	74490.00	49180.00	1.94
8.	PoultryManure1.6t/ha+0.4%Zinc	25470.00	75760.00	50290.00	1.97
9.	PoultryManure1.6t/ha+0.6%Zinc	25630.00	78300.00	52670.00	2.05

**Data was not subjected to statistical analysis*

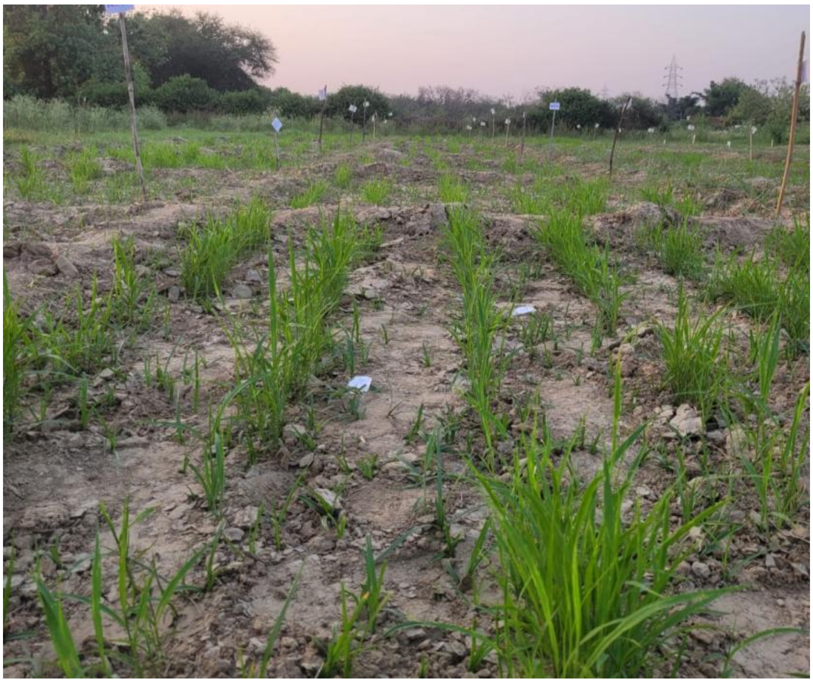

Fig. 1. Experimental field at 20 DAS

Fig. 2. Experimental field at 40 DAS

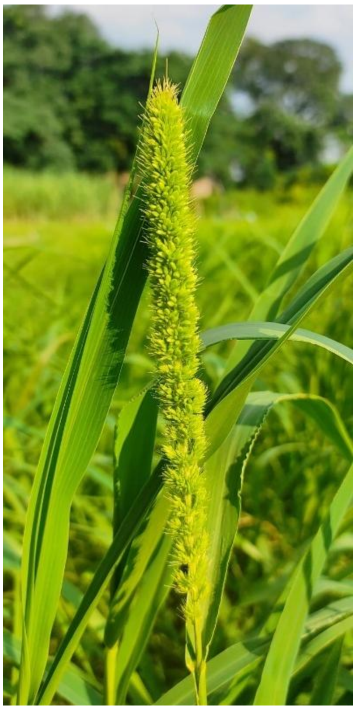

Fig. 3. Grain filling stage

Fig. 4. Panicle at harvest stage

3.3 Economics

Maximum gross returns (78300.00 INR/ha), net returns (52670.00 INR/ha) and B: C ratio (2.05) [Table 3] was found in treatment 9 (Poultry Manure 1.6t/ha + 0.6% Zinc). Higher net returns, gross returns and benefit cost ratio was obtained with the application of Zinc (0.6%) it may have enhanced the growth and development of the crop, made the crop more vigorous, improved the grain filling and thus, increased the yield as well as maintained the economics by increasing the net return and B:C ratio to the maximum. These results are in conformity with those observed by Shalini et al. [17] in wheat.

4. CONCLUSION

Based on above findings, it is concluded that with the application of Poultry Manure 1.6 t/ha along with 0.6% zinc has performed better in growth, yield attributes and yield in foxtail millet resulting in higher yield and B:C ratio.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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