Original Research Article

Zinc nutrition for improving the growth and yield of barnyard millet (*Echinochola frumantacea* l.)

ABSTRACT

Aims: To evaluate the effect of various levels and methods of zinc fertilization in improving the growth and yield of barnyard millet at different growth stages.

Study design: Randomized Block Design (RBD) with three replications.

Place and Duration of Study: A field experiment was conducted in the farmer's field at Pasur village, Coimbatore district from January to April, 2022.

Methodology: A field experiment was conducted with barnyard millet (*Echinochloa frumentacea* L.) var. MDU 1 by using different levels of $ZnSO_4$ at 5, 10, 15, 20 and 25 kg ha^{-1} as basal soil application and foliar spraying of 0.25, 0.50 & 0.75% twice along with soil test based NPK as control in Randomized Block Design with three replications. The growth and yield parameters such as plant height, SPAD index, root length, lateral root length, root volume, no. of tillers, panicle length, panicle weight, 1000 grain weight, grain and straw yield were recorded as per standard protocols.

Results: Application of soil test based NPK + 20 kg $ZnSO_4$ ha^{-1} performed better in increasing the plant height (157.0 cm), SPAD index (46.3), root length (21.1 cm), lateral root length (16.3 cm), root volume (3.80 cc) and yield attributes like number of tillers (5.06), panicle length (17.6 cm), panicle weight (29.2 g) and 1000 seed weight (3.89g) of barnyard millet. Higher grain (2606 kg ha^{-1}) and straw yield (3411 kg ha^{-1}) was also registered with the addition of soil test based NPK+20 kg $ZnSO_4$ ha^{-1} which was 27.1% increase over NPK.

Conclusion: Basal soil application of soil test based NPK + 20 kg $ZnSO_4$ ha^{-1} was found optimal and economical for improving the growth and yield of barnyard millet variety MDU 1.

Keyword: Barnyard millet, Zinc sulphate, - growth and, yield.

1. INTRODUCTION

Barnyard millet is grown in tropical region of India, China, Japan, Central African Republic, Tanzania and Malawi and is the fourth most produced minor millet worldwide (Renganathan *et al*. 2020). Although barnyard millet is nutritionally superior to other cereals, its utilization is very much limited due to the presence of anti-nutrients like phytates, polyphenols and tannins which reduce the bioavailability of micronutrients particularly Zn & Fe by chelation (Chandel *et al.,* 2014, Renganathan *et al.,* 2018). Further, Zn content in barnyard millet is also comparatively lesser (1.5 to 7.5 mg 100 g^{-1}). Hence increasing the grain zinc content is essential to improve the dietary requirement and also to address the human malnutrition issues.

Despite being the nutritious millet next to cereals, barnyard millet contains high phytic acid and phenolic compounds that act as an anti-nutritional factor in grains and flour, which reduces the bioavailability of Zn in human digestive tract. Research indicates that, Zn deficiency in soils can reduce the crop yield by 40% without showing any Zn deficiency symptoms in many crops. Hence developing effective Zn nutritional strategies is essential for achieving higher yield with better grain quality. Generally foliar spraying or combined soil and foliar application of zinc fertilizer under field conditions are highly effective and practical way to maximize the uptake and accumulation of zinc in whole grain (Xia *et al*., 2020).

In India, Zn and Fe deficiencies are the most common in soils, especially in the soils under intensive cereal cropping systems. Generally, plants takes Zn in its divalent form and plays a fundamental role in basic biochemical processes such as enzyme catalysis or activation, protein synthesis, carbohydrate and auxin metabolism, chlorophyll production, pollen formation, cytochrome and nucleotide synthesis, maintenance of membrane integrity, and energy dissipation (Alloway, 2009; Nandal, and Solanki, 2021). Deficiency of Zn resulted in various abnormalities in plants development and became visible as deficiency symptoms such as reduction in flowering and fruit development, prolonged growth periods, delayed maturity, decreased yield and quality, sub-optimal nutrient-use efficiency, reduction in photosynthesis and nitrogen metabolism (Kathpalia and Bhatla, 2018, Rivera-Martin *et al*., 2020b, González-Caballo *et al*., 2022).

Foliar application of micronutrients (Fe, Zn & B) plays critical role in crop growth by its involvement in photosynthesis process, respiration, biochemical and physiological activities of the crops (Sai Divya *et al*., 2021). Renganathan *et al*. (2020) reported that, foliar application of micronutrients at critical stages of the crop effectively absorbed and translocated to the developing panicle thereby producing more number of productive tillers and better filling in barnyard millet. The highest dry weight, leaf area index and plant height was recorded by the foliar spraying of 0.5% $ZnSO_4$ which plays a vital role in cell division and growth of the plant (Reddy *et al.*, 2018). Appropriate concentrations of Zn as foliar spraying is generally in the range of 0.1 to 0.5% $ZnSO_4 \cdot 7H_2O$ (w/v), but excessive concentrations could also cause severe foliar damage and reduce the crop yield (Zhang *et al*., 2020). The grain Zn recovery through foliar spraying was higher (26.4%) besides increasing the grain yield (Shankar *et al*., 2017).

Soil application of Zn sources, had differential effect on the yield and quality of crop produces and maintaining sufficient Zn in the soil which is essential to achieve higher yield and profit. Soil Zn application also had positive effect on grain Zn concentration (Kaya *et al*., 2009) and plant Zn contents. Anandhan *et al.* (2021) reported that DTPA-Zn in the soil has been maintained adequately by the use of chelated zinc fertilizers which slowly releases zinc for the growth of millets and increased the zinc content and uptake by plants. Rai *et al*. (2016) reported a significant increase in the yield of millets due to zinc fertilization and increased the total dry matter production by its beneficial effect on physiological process, plant metabolism and plant growth (Shanmudasundaram *et al*., 2006). In this context, the study was proposed to know the effect of zinc fertilization practices on the growth and yield of barnyard millet MDU 1 and to optimize the rate and method of Zn application for higher yield and benefit.

2. MATERIALS AND METHODS

2.1 Experimental soil and location

Field experiment was carried out at Pasur village, Coimbatore (N 11º16113, E 077º06.475) to know the role of zinc in improving the growth and yield of barnyard millet variety MDU 1 on a mixed black calcareous soil belonging to Periyanayakenpalayam series. Genetically pure seeds of barnyard millet variety MDU1 was obtained from the Department of Plant Breeding and Genetics, AC&RI, Madurai and used for the experiment. The experimental soil was having low N, medium P and K with sufficient micronutrients except Zn which was deficient in the soil (Table 1).

2.2 Treatments details

The effect of zinc was explored through soil and foliar application for evaluating the impact on crop growth and productivity of barnyard millet (MDU1). The treatment structure comprised of: T_1-Absolute control, T_2- soil test based NPK, T_3- NPK + soil application of 5.0 kg $ZnSO_4$ ha^{-1}, T_4 - NPK + soil application of 10 kg $ZnSO_4$ ha^{-1},T_5 - NPK + soil application of 15 kg $ZnSO_4$ ha^{-1}, T_6 - NPK + soil application of 20 kg $ZnSO_4$ ha^{-1}, T_7- NPK + soil application of 25 kg $ZnSO_4$ ha^{-1}, T_8- NPK + foliar spraying of 0.25% $ZnSO_4$ twice ,T_9-NPK + foliar spraying of 0.50% $ZnSO_4$ twice, T_{10} - NPK + foliar spraying of 0.75% $ZnSO_4$ twice ha^{-1}. The experiment was conducted with three replications on a plot size of 3m x 5m in a randomized block design. Growth and yield attributes of the crop was observed at harvest to know the effect of various levels and mode of Zn application. The grain and straw yield of the crop was recorded upon maturity to optimize the rate and method of Zn application.

2.3 Fertilizer application

Soil test based NPK (22:33:30 kg ha^{-1}) was applied as nitrogen in two splits i.e., 50% each at sowing and the remaining 50% at 45 days after sowing by top dressing. Entire dose of phosphorus and potassium was applied basally. The Zn treatments as soil application were carried out on the day of sowing and the foliar spraying was done twice at vegetative and panicle initiation stages of the crop.

2.4 Observations

2.4.1 Growth and yield attributes

Plant height was measured from ground level to tip of the leaf at harvest stage and the mean height was expressed in cm. The root traits like root length (cm), lateral root length (cm) and root volume (cc) was also measured. The SPAD readings were recorded at harvest stage, as per the procedure, 3rd leaf from the top (fully expanded leaf) was collected and measured at a wavelength of 940 nm using the chlorophyll meter (SPAD 502, Minolta Camera Co. Ltd., Japan). Five readings were taken in each plant at 90 DAS and the mean was expressed as the SPAD index.

Root length was determined by measuring the length of root from the base of stem to the tip of lengthiest root and expressed in centimetre (cm). Lateral root length was determined by measuring the length of nodal root and expressed in centimetre (cm). The root volume was measured after washing the uprooted plants with running tap water to remove all the adhering soil particles and shade dried for 15 minutes. The roots were then immersed completely in a measuring cylinder which was filled with water. The water spilled out from the cylinder was collected and the volume was measured using a measuring cylinder and expressed as cubic centimetre (cc). One thousand seeds from each treatment were chosen at random and their weight was recorded using electronic balance as ISTA procedure. The average of 1000 seed weight was expressed in g. The number of tillers, panicle length (cm) and weight (g) was also measured at harvest stage.

2.4.2 Grain and straw yield: Seeds were obtained from each plot and weighed after drying and seed yield per plot area of each treatment was recorded and expressed as kilogram. The straw yield of the crop was also measured from each plot and expressed as kilogram per hectare.

2.5 Data analysis

The data obtained from different components were statistically analyzed to find out the significance of difference among the treatments. The analysis of variance (ANOVA) was carried out to test the effect of treatments on the growth and yield of barnyard millet. Mean comparison was performed using the least significant differences test (LSD) at P = 0.05 (Panse and Sukhatme , 1978).

3. RESULT AND DISCUSSION

3.1 Growth parameters

The growth attributes were significantly influenced by different levels and methods of Zn application and the data were presented in table 2. The maximum plant height was obtained by the soil application of $ZnSO_4$ as compared to foliar spraying and the mean plant height ranged from 96 to 157 cm. The highest plant height (157 cm) was registered with the application of soil test based NPK +20 kg $ZnSO_4$ ha^{-1} and the lowest plant height (96 cm) was recorded in absolute control. The plant height at harvest was significantly higher due to Zn treatments which might be due to its involvement in chlorophyll formation, cell elongation and division which led to increase in many metabolic activities resulting in higher growth and in agreement with findings of Choudhary *et al*. (2005) and .Dadhich and Gupta (2016). The SPAD index of the leaf was recorded higher in soil test based NPK + 20 kg $ZnSO_4$ ha^{-1} (46.3) followed by NPK + 25 kg

$ZnSO_4$ (40.3) and the lowest SPAD index was recorded in absolute control (29.9). Addition of zinc regulates various metabolic activities in plants and is essential for the formation of chlorophyll and plays an important role in nitrogen metabolism (Suruthi *et al.* 2019).

As compared to foliar spray, the growth of barnyard millet was highly improved by the soil application of zinc sulphate. The accessibility of micronutrients played a vital role in protein synthesis and enzyme activities of crops besides helped in effective utilization of applied NPK which might have led to improved growth attributes (Nciizah *et al*., 2020).

3.2 Root traits

The effect of $ZnSO_4$ on the root traits of barnyard millet was recorded and reported in table 2. The longest root length and lateral root length was recorded with the application of soil test based NPK + 20 kg $ZnSO_4$ ha^{-1} (21.1 cm and 16.3 cm) which was closely followed by the addition of NPK + 25 kg $ZnSO_4$ (18.0 cm and 14.4 cm) and the least being noted in absolute control (10.7 cm and 8.53 cm). Higher root volume was also recorded with the same treatment (3.80 cc) and the lowest root volume was observed in absolute control (1.92 cc). Among the foliar treatments, spraying of 0.75% $ZnSO_4$ registered higher root length, lateral root length and root volume of 15.7 cm, 12.9 cm and 2.83 cc, respectively which were comparable with the soil application of 5 kg $ZnSO_4$ ha^{-1}. This could be attributed to the significant influence of Zn on root growth and responsible for cell wall formation and stabilization. Further its application also increases endogenous hormones like auxins, gibberellins, and melatonin which benefit growth and development of the crop (Rai *et al*. 2016, Prakash and Chitdeshwari, 2021).

3.3 Yield attributes

Inclusion of zinc sulphate in the fertilizer schedule had significant influence on the yield attributes of barnyard millet also (Fig.1). The highest number of tillers (5.06) and panicle length (17.6 cm) was recorded in soil test based NPK + 20 kg $ZnSO_4$ which was closely followed by the soil application of NPK + 25 kg $ZnSO_4$. Soil application of $ZnSO_4$ significantly increased the number of productive tillers per meter (Khan *et al.*, 2008). The weight of panicle and 1000 grain weight was also observed higher with the application of soil test based NPK + 20 kg $ZnSO_4$ (29.2 and 3.89 g) followed by the application of soil test based NPK + 25 kg $ZnSO_4$ (27.6 and 3.74 g). Among the foliar treatments, spraying of 0.75% $ZnSO_4$ showed better yield attributes. The lowest number of tillers, panicle length, panicle weight and 1000 grain weight were observed in absolute control (2.11, 10.3 cm, 18.7 g and 2.49 g, respectively). Application of zinc was effectively absorbed by the plants thereby producing more number of productive tillers and translocated to the developing panicle which resulted in better filling of barnyard millet grains. Similar studies were reported by Rajesh and Paulpandi (2013) in redgram and Sujatha *et al.* (2017) in panivaragu.

3.4. Grain and straw yield

There were significant differences among the treatments with respect to grain and straw yield of barnyard millet (Table 3). Higher grain (2606 kg ha^{-1}) and straw yield (3411 kg ha^{-1}) were recorded with the application of soil test based NPK + 20 kg $ZnSO_4$ ha^{-1} followed by the application of soil test based NPK + 25 kg $ZnSO_4$ (2509 and 3220 kg ha^{-1}). With regards to foliar spraying, soil test based NPK + 0.75% $ZnSO_4$ resulted in higher grain yield of 2314 kg ha^{-1} and straw yield of 2925 kg ha^{-1}. Between the two method of Zn application, basal soil application of $ZnSO_4$ showed marked increase (27.1%) in grain yield than the foliar spraying (12.9%) as compared to soil test based NPK. The absolute control recorded lesser grain and straw yield of 1701 kg ha^{-1} and 2117 kg ha^{-1}, respectively. Sandhya Rani *et al.,* (2017) reported higher grain and straw yield of finger millet with the application of recommended NPK with $ZnSO_4$. Vijyakumar *et al.,* (2020) found that application of Zn along with N and P enhanced the grain yield, stover biomass and total biomass of finger millet as compared to the addition of N and P alone. Further, addition of Zn might have activated the molecular and physiological mechanisms necessary for the biosynthesis and accumulation of secondary metabolites and supported better photosynthetic efficiency, thus increased the grain yield and dry matter production (Elizabath *et al*., 2017, Prakash & Chitdeshwari, 2021).

4. CONCLUSION

Results showed better growth and yield response of barnyard millet to various levels and method of zinc sulphate application. Soil application of zinc sulphate provided better nutrient availability and improved the growth, yield and yield attributes of barnyard millet than foliar application. Basal soil application of 20 kg ha^{-1} $ZnSO_4$ along with soil test based NPK was found to be superior in improving the growth, yield attributes and yield of barnyard millet. Based on the experimental results, it can be concluded that, for obtaining higher growth, yield and yield attributes of barnyard millet, inclusion of 20 kg $ZnSO_4$ ha^{-1} along with soil test based NPK may be followed.

DISCLAIMER

The products used for this research are commonly and predominantly used products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

REFERENCES

1. Alloway, BJ. Soil factors associated with zinc deficiency in crops and humans." Environmental Geochemistry and Health, 2009, 31:537–48.
2. Anandhan J, Shamugasundaram R, Saravana Pandian P, Swaminathan C, Vanniarajan C, Govindaraj M. Influence of soil application of iron and zinc on their content, uptake and total dry matter yield of pearl millet cultivars. Phar. Innov. J. 2021; 10(4): 98-104.
3. Chandel BS, Singh S, Singh H, Singh V. Direct and Residual Effect of Nutrient Management in Wheat–Maize Cropping Sequence. J. Indian Soc. Soil Sci. 2014;62(2):126-130.
4. Choudhary BR, Keshwa GL, Parihar CM. Effect of thiourea and zinc on productivity of pearl millet. Ann. Agric. Res. 2003;26(3):424-427.
5. Elizabath, A, Vijay Bahadur, Pragathi Misra, Vipin Mashi Prasad, T Thomas. Effect of different concentrations of iron oxide and zinc oxide nanoparticles on growth and yield of carrot (Daucus carota L.). Journal of Pharmacognosy and Phytochemistry 2017, 6 (4): 1266-1269.
6. Gonzalez-Caballo, P, V Barron, J Torrent, MC Campillo, ARS Rodriguez. Wheat and Maize Grown on Two Contrasting Zinc-deficient Calcareous Soils Respond Differently to Soil and Foliar Application of Zinc. Journal of Soil Science and Plant Nutrition, 2022, 1-14.

7. Gupta N, Ram H, Kumar B. Mechanism of Zinc absorption in plants: uptake, transport, translocation and accumulation. Rev. Environ. Sci. Biotechnol. 2016;15(1):89-109.
8. Kaya, M, Kuçukyumuk Z, Erdal I. Effects of elemental sulfur and sulfur-containing waste on nutrient concentrations and growth of bean and corn plants grown on a calcareous soil. Afr. J. Biotechnol. 2009;8(18).
9. Kathpalia, R, SC Bhatla. Plant mineral nutrition." *Plant physiology, development and metabolism* , 2018, pp. 37-81, Springer, Singapore.
10. Khan MA, Fuller MP, Baloch FS. Effect of soil applied zinc sulphate on wheat (*Triticum aestivum* L.) grown on a calcareous soil in Pakistan. Cereal Res. Commun. 2008;36(4):571-582.
11. Nandal, V Solanki, M. Zn as a vital micronutrient in plants. Journal of Microbiology, Biotechnology & Food Sciences, 2021, 11(3).
12. Nciizah AD, Rapetsoa MC, Wakindiki II, Zerizghy MG. Micronutrient seed priming improves maize (Zea mays) early seedling growth in a micronutrient deficient soil. Heliyon. 2020;6(8):04766.
13. Panse VG, Sukhatame PU. 1967. Statistical Methods for Agricultural Workers. ICAR, New Delhi
14. Prakash Ranjan Behera, Chitdeshwari T. Response of Capsicum Hybrids to Zinc (Zn) Fertilization under Protected Cultivation. Current Journal of Applied Science and Technology, 2021; 40 (41): 1-10
15. Rai R, Agrawal M, Agrawal SB. Impact of heavy metals on physiological processes of plants: with special reference to photosynthetic system. In *Plant responses to xenobiotics*, Springer, Singapore.2019;127-140.
16. Rajesh N, Paulpandi VK. Review of foliar nutrition in Redgram enhancing the growth and yield characters. American International Journal of Research in Formal, Applied and Natural Sciences.2013;13(142):9-13.
17. Reddy, S. Effect of Biofortification of Zinc on Growth, Yield, Zinc Uptake and Economics of Pearl Millet. Chem Sci Rev Lett. 2021;10 (39):359-366

18. Renganathan VG, Vanniarajan C, Karthikeyan A, Ramalingam J. Barnyard millet for food and nutritional security: current status and future research direction. Front. Genet.2020; 11:500.
19. Renganathan VG, Vanniarajan C. Exploring the Barnyard Millet (*Echinochloa frumentacea* L) Segregating Population for Isolation of High Yielding, Iron and Zinc Content Genotype. Int.J. Curr. Microbiol. App. Sci. 2018;7(4):3611-3621.
20. Rivera-Martin, A, MR Broadley, MJ Poblaciones. Soil and foliar zinc application to biofortify broccoli (*Brassica oleracea* var. italica L.): effects on the zinc concentration and bioavailability. Plant, Soil and Environment, 2022, 66 (3):113-118.
21. Sai Divya B, Singh R, Khan W. Effect of foliar application of iron and zinc on yield and economics of finger millet (Eleusine coracana. L). Phar. Innov. 2021;10(4): 897-899.
22. Sandhya Rani Y, Triveni U, Patro TSSK, Anuradha N. Effect of nutrient management on yield and quality of finger millet (*Eleusine coracana* (L.) Gaertn). Int. J. Chem. Stud. 2107;5(6):1211-1216.
23. Shankar MA, Thimmegowda MN, Bhavitha NC, Manjunatha BN. Comparative efficiency of soil and foliar application of boron on growth and yield of finger millet (*Eleusine coracana* L.). Mysore J. Agric. Sci. 2017;51(2):430-435.
24. Shanmugasundaram R, Savithri P. Effect of levels and frequency of zinc sulphate application on its content and uptake by maize and sunflower in their sequential cropping system. Agric. Sci. Digest. 2006;26(1):31-34.
25. Sujatha K, Anand R, Ragupathi K, Ahamed AS. Effect of organic Foliar Nutrition on Growth and Yield Attributes of Kodo millet (*Paspalum scrobiculatum* L.). American Int. J Res. Formal App. Nat. Sci. 2017;16(1):23-27.
26. Suruthi, S, Sujatha, K and C. Menaka. Effect of Organic and inorganic foliar nutrition on growth and yield attributes of banyard millets (*Echinochloa frumentacea* L.) var. MDU.1. Int. J. Chem. Stud. 2019;7(3):851-853.
27. Vijayakumar M, Sivakumar R, Tamilselvan N. Effect of Zinc and Iron application on yield attributes, available nutrient status and nutrient uptake of Finger Millet under rainfed condition. Int.J. Curr. Microbiol. App. Sci. 2020;9(5):3237-3246.

28. Xia H, Wang L, Qiao Y, Kong W, Xue Y, Wang Z, Sizmur T. Elucidating the source–sink relationships of zinc biofortification in wheat grains: A review. Food Energy Secur. 2020;9(4):243.

29. Zhang W, Xue YF, Chen, X. P., Zhang, FS, Zou CQ. Zinc nutrition for high productivity and human health in intensive production of wheat. Adv. Agron.2020;163:179-217.

Table 1: Initial characteristics of the experimental soil

pH	EC ($dS\ m^{-1}$)	Organic carbon ($g\ kg^{-1}$)	Available nutrients ($kg\ ha^{-1}$)			DTPA Zn ($mg\ kg^{-1}$)
			Nitrogen	Phosphorus	Potassium	
8.10	0.33	5.50	267	7.43	236	0.66

Table 2. Effect of various levels and mode of $ZnSO_4$ application on the growth attributes and root traits of barnyard millet

Treatments (ha^{-1})	Growth attributes		Root traits		
	Plant height(cm)	SPAD	Root length (cm)	Lateral root length(cm)	Root volume (cc)
T_1 - Absolute control	96^{f}	29.9^{f}	10.7^{f}	8.53^{h}	1.92^{f}
T_2 - Soil test based NPK	106^{e}	34.4^{de}	13.5^{e}	9.90^{g}	2.43^{e}
T_3 - NPK + Soil application of 5.0 kg $ZnSO_4$	120^{cd}	35.2^{cd}	14.8^{cd}	11.8^{ef}	2.67^{cd}
T_4 - NPK + Soil application of 10.0 kg $ZnSO_4$	127^{c}	37.6^{bc}	15.7^{c}	12.6^{de}	2.83^{c}
T_5 - NPK + Soil application of 15.0 kg $ZnSO_4$	142^{b}	39.8^{b}	17.3^{b}	13.5^{bc}	3.11^{b}
T_6 - NPK + Soil application of 20.0 kg $ZnSO_4$	157^{a}	46.3^{a}	21.1^{a}	16.3^{a}	3.80^{a}
T_7 - NPK + Soil application of 25.0 kg $ZnSO_4$	150^{ab}	40.3^{b}	18.0^{b}	14.4^{b}	3.23^{b}
T_8 - NPK+ Foliar spraying of 0.25% $ZnSO_4$ twice	109^{e}	29.8^{f}	14.1^{de}	10.4^{fg}	2.53^{de}
T_9 -NPK+ Foliar spraying of 0.50% $ZnSO_4$ twice	114^{ed}	31.8^{ef}	15.1^{c}	12.3^{de}	2.72^{c}
T_{10} - NPK+ Foliar spraying of 0.75% $ZnSO_4$ twice	118^{d}	33.6^{de}	15.7^{c}	12.9^{cd}	2.83^{c}
SEd	4.19	1.32	0.44	0.44	0.07
CD (P=0.05)	8.81	2.78	0.92	0.93	0.16

Table 3. Effect of various levels and mode of $ZnSO_4$ application on grain and straw yield of barnyard millet

Treatments (ha^{-1})	Yield ($kg\ ha^{-1}$)	
	Grain	Straw
T_1 - Absolute control	1701^{g}	2117^{h}
T_2 - Soil test based NPK	2050^{f}	2464^{g}
T_3 - NPK + Soil application of 5.0 kg $ZnSO_4$	2167^{de}	2611^{f}
T_4 - NPK + Soil application of 10.0 kg $ZnSO_4$	2247^{cd}	2793^{e}
T_5 - NPK + Soil application of 15.0 kg $ZnSO_4$	2471^{b}	3110^{c}
T_6 - NPK + Soil application of 20.0 kg $ZnSO_4$	2606^{a}	3411^{a}
T_7 - NPK + Soil application of 25.0 kg $ZnSO_4$	2509^{ab}	3220^{b}
T_8 - NPK+ Foliar spraying of 0.25% $ZnSO_4$ twice	2090^{e}	2687^{f}
T_9 -NPK+ Foliar spraying of 0.50% $ZnSO_4$ twice	2192^{de}	2811^{e}
T_{10} - NPK+ Foliar spraying of 0.75% $ZnSO_4$ twice	2314^{c}	2925^{d}
SEd	54.8	48.9
CD (P=0.05)	115	102

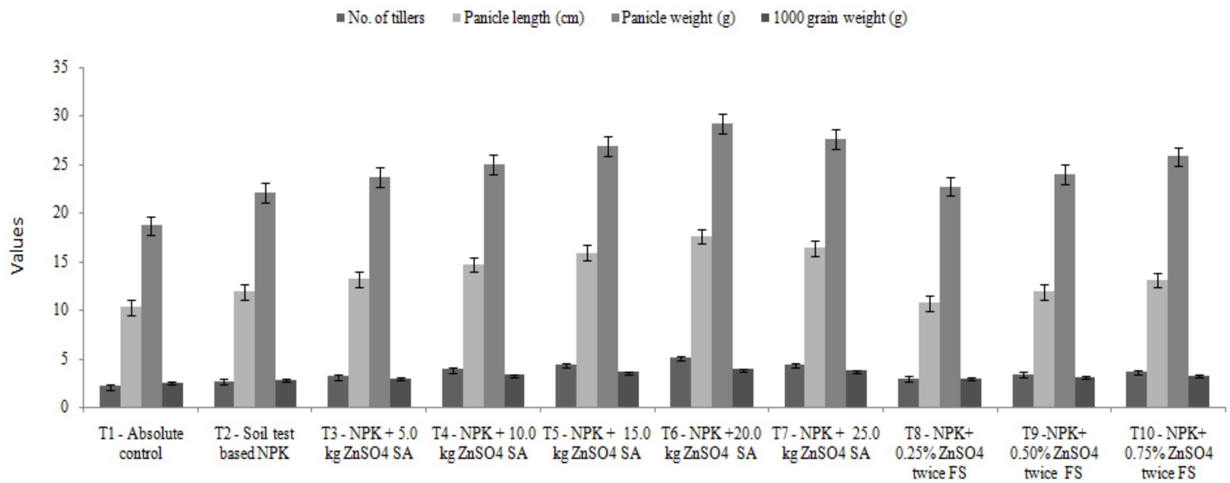

Figure 1. Effect of various levels and mode of $ZnSO_4$ application on the yield attributes of Barnyard millet