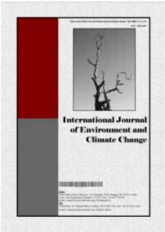

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Impact of Foliar Application of Zinc and Biofertilizers on Growth of Sorghum (*Sorghum bicolor* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The field experiment took place in the Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj, during the *Kharif* season of 2021. (UP), India. The objective of the experiment is to lessen the use of chemical fertilizers by using techniques of integrated nutrient management efficiently without compromising the nutrient availability to the crop, which ultimately reduces the effect of chemicals used in the agroecosystem. The experiment was set up in a Randomized Block Design with ten treatments, including control, replicated thrice using various biofertilizers. *viz*., *Azospirillum* species 25 gram/kilogram seeds, Phosphate solubilizing bacteria 25 g/kg seeds and combination of *Azospirillum* sp. 25 g/kg seeds + PSB 25 g/kg seeds and foliar application of 0.5% zinc at 30, 50 and 30 + 50 days after sowing per hectare. The research revealed that foliar application of zinc 0.5% at 50 DAS along with seed inoculation by *Azospirillum* sp. 25 g/kg Seeds + PSB 25 g/kg seeds significantly increased the growth parameters of Sorghum *viz*., plant height (163.31centimeter), dry matter accumulation (92.71 g), No. of Leaves (12.87), absolute growth rate (1.33 g/plant/day), crop growth rate (44.31 g/m^2/day) and leaf area (414.67 cm^2).

Keywords: Sorghum; biofertilizers; zinc; Azospirillum sp.; phosphate solubilizing bacteria; growth.

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1. INTRODUCTION

Sorghum is one of the most significant crops produced in India, and it is used daily by the majority of Indians. It ranks fifth in cereal production after wheat, corn, rice, and barley. It is also important in the industrial sector since it is used in malting, the production of high fructose syrup, bread, many value-added products, and animal feed [1,2]. Sorghum is a millet with many health benefits and it is recommended for diabetic patients. Sorghum is also a drought-tolerant crop; it can easily grow in areas with a dry climate and less rainfall. Minimum 350-400 mm of rainfall is good for cultivation; it can tolerate both droughts and water logging conditions. Sorghum can be grown on a wide range of soil, but sandy loam soil is considered best for its cultivation. Sorghum can be grown on a wide range of soil, but sandy loam soil is considered best for its cultivation [3-5]. Sorghum is a good source of vitamins and minerals and provides great protein content and makes up for a large portion of your dietary fiber intake [6,7,8]. For every 100 grams of sorghum cereal, you get about 3.5 grams of fat, out of which only 0.6 grams are saturated fat. The 100 g grain content includes 10.4 g proteins, 1.9 g fats, 72.6 g carbohydrates, 1.6 g crude fiber and 25 g calcium. Sorghum has a high content of vitamins and fibre-rich sources. Sorghum is known to be rich in phenolic compounds, many of which act as antioxidants, which help in the reduction of the tumor.

The sorghum productivity has been low due to the growing of this crop on small and marginal lands and the continuous use of harmful fertilizers [9,10]. Micronutrient deficiency in the soil, especially zinc, is the most common problem in the soil due to which there is severe yield loss and nutritional quality get affected. Integrated nutrient management is being implemented on many crops; because of that, biofertilizers have increased in all types of crops [11-15]. Especially using biofertilizers in cereal crops has been proven beneficial for fixing nitrogen. For successful cultivation, nutrient management is important and the quantity and quality of crops can be affected by biofertilizers [16]. In agriculture, the nitrogen-fixing bacteria, especially *Azotobacter* and *Azospirillum*, increase the yield in cereals and exert many positive effects on the crop when various biotic and abiotic factors influence crop growth and yield [17]. Biofertilizers are applied to either soil, plant surface or seed to increase the host plant's supply or availability of primary growth nutrients [18].

There are several approaches adopted to eliminate micronutrient malnutrition. The biofortification of zinc is a good and cost-effective measure to increase Zn concentration (agronomic biofortification) in cereal grain to address Zn malnutrition [19]. Application of nitrogen fertilizer positively affects Zinc concentrations in wheat grain and reported that change in mineral status of soil would affect the nutrient concentration of plant [20]. Nitrogen fertilization and zinc increase the yield and enhance zinc content in grain pearl millet [21]. Proper moisture management with zinc fortification has potential to improve productivity, solve zinc malnutrition problem, maintain soil health and economic sustainability [22]. The use of biofertilizers and foliar application of zinc combined can result in the good growth of the sorghum crop. Biofortification of zinc strategy appears to be essential in keeping a sufficient amount of available zinc in plants to maintain adequate zinc transport to grain during the reproductive and other growth stages [23-25].

2. MATERIALS AND METHODS

The experiment was conducted in the Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj, during the *Kharif* season of 2021. (U.P), India. Which is situated at 25^{o} 39' 42" north latitude, 81^{o} 67' 56" east longitude, and 98 meters above sea level. The soil in the experimental plot was sandy loam in texture, pH 7.7, low in organic carbon (0.57 percent), available N (230 kg/ha), available P (32.10 kg/ha), and available K (346.00 kg/ha). The crop was planted on July 19, 2021, with the NTJ-5 variety. The experiment used a randomized block design with three replications and ten treatments. *viz*., T1: Control - 80:40:40 kg NPK/ha (Farmer's Practice), T2: *Azospirillum* sp. 25 g/kg seeds + 0.5% zinc foliar spray 30 DAS, T3: *Azospirillum* sp. 25 g/kg seeds + 0.5 % zinc foliar spray 50 DAS, T4: *Azospirillum* sp. 25 g/kg seeds + 0.5 % zinc foliar spray 30 + 50 DAS, T5: PSB 25 g/kg seeds + 0.5% zinc foliar spray 30 DAS, T6: PSB 25 g/kg seeds + 0.5 % zinc foliar spray 50 DAS, T7: PSB 25 g/kg seeds + 0.5 % zinc foliar spray 30 + 50 DAS, T8: *Azospirillum* sp. + PSB: 25+25 g/kg seeds + 0.5% zinc foliar spray 30 DAS, T9: *Azospirillum* sp. + PSB: 25+25 g/kg seeds + 0.5% zinc foliar spray 50 DAS. T10: *Azospirillum* sp. + PSB: 25+25 g/kg seeds + 0.5% zinc foliar spray 30 + 50 DAS. All nutrients were applied as urea, single super phosphate (SSP), and muriate of potash through the soil (MOP). A full dose of P and K were applied basal for each plot, and half of the nitrogen (as urea) was applied. The remaining half of the nitrogen should be top-dressed 30-35 days following sowing. The growth parameters of the randomly selected five tagged plants in each treatment were measured at intervals of 20,40,60,80 DAS and harvest stage.

3. RESULTS AND DISCUSSION

3.1. The Impact of Foliar Application of Zinc and Biofertilizers and on Growth Parameters

Impact of foliar application of zinc and biofertilizers on growth parameters of sorghum are in Table 7.

3.1.1 Plant height

The findings showed that the treatment with dual inoculation of *Azospirillum* sp. and PSB and the foliar application of 0.5% zinc at 50 DAS/ha recorded maximum plant height (163.31 cm). Similar findings were reported by Rafi and Charyulu et al. [6] and Priyanka et al. [10,26].

3.1.2 Number of leaves per plant

The results revealed that the maximum number of leaves per plant (12.87) was recorded with dual inoculation of *Azospirillum* sp. and PSB along with the foliar application of 0.5% zinc at 50 DAS/ha over the other treatment combinations. Similar findings were reported by Ali Soleymani et al., [27] and Anil Kumar et al., [28,29,30].

3.1.3 Dry matter accumulation

Azospirillum sp. and PSB along with the foliar application of 0.5% zinc at 50 DAS/ha, which was higher over the treatments. It is due to the better availability of nitrogen and phosphorus and biofertilizers action that leads to overall better development of the crop. The combined biofertilizer and foliar application of zinc just before the flowering stage at 50 DAS helped in good foliage and good panicle development in the crop, which improved the growth parameters due to increased dry matter production, which in turn contributed to improved yield attributes. Similar findings were reported by Rafi and Charyulu et al. [6,31,32].

3.1.4 Absolute growth rate

At 80-100 DAS, results revealed that a significantly highest absolute growth rate (1.33 g/plant/day) was observed with dual inoculation of *Azospirillum* sp. and PSB along with the foliar application of 0.5% zinc at 50 DAS/ha, which was superior over the treatments.

3.1.5 Crop growth rate

At 80-100 DAS, the significantly highest crop growth rate (44.31 g/m^2/day) has been recorded with dual inoculation by *Azospirillum* sp. and phosphate solubilizing bacteria (PSB) along with the foliar application of zinc at 50 DAS over control [33].

3.1.6 Leaf area

At 80 DAS, the significantly highest leaf area (414.67 cm^2) has been recorded with dual inoculation by *Azospirillum* sp. and phosphate solubilizing bacteria (PSB) along with the foliar application of zinc at 50 DAS.

Table 1. ANOVA of Plant height (cm) at 80 DAS

Source	D.F.	SS	MSS	Cal. F	TAB F(5%)	TAB F(1%)
Treatment	**9**	830.953	92.328	5.625	S	S
Replication	**2**	27.755	13.877	0.845		
Error	**18**	295.405	16.411			
TOTAL	**29**	1154.115				

Table 2. ANOVA of Number of leaves in 80 DAS

Source	D.F.	SS	MSS	Cal. F	TAB F(5%)	TAB F(1%)
Treatment	**9**	7.558	0.839	2.487	S	NS
Replication	**2**	0.296	0.148	0.438		
Error	**18**	6.077	0.337			
TOTAL	**29**	13.932				

Table 3. ANOVA of Dry matter accumulation (g) at 80 DAS

Source	D.F.	SS	MSS	Cal. F	TAB F(5%)	TAB F(1%)
Treatment	**9**	578.42	64.27	30.89	S	S
Replication	**2**	4.18	2.09	1.00		
Error	**18**	37.45	2.08			
TOTAL	**29**	620.04				

Table 4. ANOVA of Absolute growth rate at (g/g/day) 80-100 DAS

Source	D.F.	SS	MSS	Cal. F	TAB F(5%)	TAB F(1%)
Treatment	9	0.52	0.06	5.87	S	S
Replication	2	0.00	0.00	0.08		
Error	18	0.18	0.01			
TOTAL	29	0.70				

Table 5. ANOVA of Crop growth rate (g/m^2/day) at 80-100 DAS

Source	D.F.	SS	MSS	Cal. F	TAB F(5%)	TAB F(1%)
Treatment	9	577.26	64.14	5.87	S	S
Replication	2	1.81	0.90	0.08	NS	NS
Error	18	196.70	10.93			
TOTAL	29	775.76				

Table 6. ANOVA of Leaf area (cm^2) at 80 DAS

Source	D.F.	SS	MSS	Cal. F	TAB F(5%)	TAB F(1%)
Treatment	**9**	24967.77	2774.20	433.16	S	S
Replication	**2**	39.98	19.99	3.12		
Error	**18**	115.28	6.40			
TOTAL	**29**	25123.03				

Table 7. Impact of biofertilizers and foliar application of zinc on growth parameters of sorghum

	Growth parameters (80DAS)					
Treatment Combinations	**Plant height (cm)**	**No. of leaves per plant**	**Dry matter accumulation (g)**	**Absolute growth rate (g/plant/day) 80-100 DAS**	**Crop growth rate ($g/m^2/day$) 80-100 DAS**	**Leaf area (cm^2)**
1. Control 80:40:40 kg NPK/ha (Farmer's Practice)	143.98	11.53	75.71	1.12	37.32	312.90
2. *Azospirillum* sp. 25 gm/kg seeds + 0.5% zinc foliar spray 30 DAS	153.75	11.67	81.66	1.15	38.32	343.03
3. *Azospirillum* sp. 25 gm/kg seeds + 0.5 % zinc foliar spray 50 DAS	153.90	12.47	83.30	1.19	39.57	337.50
4. *Azospirillum* sp. 25 gm/kg seeds + 0.5 % zinc foliar spray 30 + 50 DAS	157.07	12.67	85.54	1.25	41.74	383.00
5. PSB 25 gm/kg seeds + 0.5% zinc foliar spray 30 DAS	158.95	11.73	86.03	0.99	32.99	374.90
6. PSB 25 gm/kg seeds + 0.5 % zinc foliar spray 50 DAS	161.30	11.93	85.03	1.15	38.29	362.57
7. PSB 25 gm/kg seeds + 0.5 % zinc foliar spray 30 + 50 DAS	161.67	11.60	90.32	1.02	33.83	396.53
8. *Azospirillum* sp. + PSB 25+25g/kg seeds + 0.5% zinc foliar spray 30 DAS	155.91	11.53	86.19	0.86	28.81	386.13
9. *Azospirillum* sp. + PSB 25+25g/kg seeds + 0.5% zinc foliar spray 50 DAS	163.31	12.87	92.71	1.33	44.31	414.67
10. *Azospirillum* sp. + PSB 25+25g/kg seeds + 0.5% zinc foliar spray 30 + 50 DAS	154.73	12.60	86.69	1.00	33.35	378.07
test	S	S	S	S	S	S
SEd (±)	3.31	0.41	1.18	0.08	2.70	2.07
Sem (±)	2.34	0.34	0.83	0.06	0.91	1.46
CD (P=0.05)	6.95	1.00	2.47	0.17	5.67	4.34

4. CONCLUSION

The findings of the field experiment suggest that sorghum should be sown with dual inoculation of *Azospirillum* sp. and PSB along with the foliar application of 0.5% zinc at 50 DAS/ha as it has resulted in higher growth and development of sorghum crop.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Bhoya M, Chaudhary PP, Raval CH and Bhatt PK. Effect of nitrogen and zinc on growth and yield of fodder sorghum (*Sorghum bicolor* L.) varieties. International Journal of agricultural Science. 2014;10(1): 294-297.
2. Ghodpage RM, Balpande SS, Babhulkar VP and Sarika Pangade. Effect of phosphorous and zinc fertilization on nutrient content in root, yield and nutritional quality. Journal soils and crops. 2008; 18(2):458-461.
3. Jakhar SR, Singh M, Balai CM. Effect of farm yard manure, phosphorus and zinc levels on growth, yield, quality and economics of pearlmillet (*Pennisetum glaucum*). Indian Journal of Agricultural Sciences. 2006;76(1):58-61.
4. Jan M, Anwar-ul-haq, M, Tanveer-ul-haq, Ali S, Wariach EA. Evaluation of soil and foliar applied zinc sources on rice (*oryza sativa*) genotypes in saline environments. International Journal of Agriculture and Biology. 2016;18(3):643-648.
5. Jat MK, Purohit HS, Bahadur Singh, Garhwal RS, Mukesh Choudhary. Effect of integrated nutrient management on yield and nutrient uptake in sorghum (*Sorghum bicolor*). Indian Journal of Agronomy. 2013; 58(4):543-547.
6. Rafi MMD, Varalakshmi, Charyulu PBBN. Influence of *Azospirillum* and PSB inoculation on growth and yield of Foxtail Millet. Journal Microbiology and Biotechnology Research. 2012;2(4):558-565.
7. Rana DS, Bhagat Singh, Gupta K, Dhaka AK, Satyawan Arya. Response of Fodder Sorghum to Zinc and Iron. Forage Research. 2013;39(1):45-47.
8. Shanka MA, Thimmegowda MN, Bhavitha NC. Integrated nutrient management for enhancing the productivity of finger millet under dry land condition. Mysore Journal of Agricultural Science. 2015;49(3):502-509.
9. Kalibhavi CM, Patil RH and Kachapur MD. Studies on integrated nutrient management in rabi sorghum. Journal of Maharashtra Agricultural Universities. 2003;28:104-105.
10. Kaushik MK, Priyanka Pareek, Singh P, Sumeriya HK. Effect of iron and zinc on yield and quality of sorghum fodder. Forage Research. 2010;36:181-184.
11. Kotangale Vandana S, Bharambe PR, Katore, Ravankar HN. Influence of organic and inorganic fertilizers on fertility status of soil under sorghum-wheat cropping sequence in vertisol. Journal of Soils and Crops. 2009;19(2):347-350.
12. Krishna S, Bhushan. Effect of different closes of zinc and its methods of application on yield and chemical composition of wheat. Agriculture Science Digest. 2004;24(2):124-126.
13. Kubsad VS. Agronomic fortification of iron and zinc with organics in post-rainy season sorghum (*Sorghum bicolor*) Indian Journal of Agronomy. 2019;64 (4):501-505.
14. Kumar R, Kumar D, Singh RM, Kumar P and Khippal A. Effect of phosphorus and zinc nutrition on growth and yield of fodder cowpea. Legume Research. 2016;39(2): 262-267.
15. Manish Kushwaha, Magan Singh, Rakesh Kumar, Nitin Tyagi, Pooja Gupta Soni, Sunita Choudhary, Govind Makarana. Yield and quality of multicut fodder sorghum as affected by nutrient levels and biofertilizer application. Indian Journal of animal nutrition. 2018;35(1):82-89.
16. Kachroo D and Razdan R Growth, nutrient uptake and yield of wheat (*Triticum aestivum*) as influenced by biofertilizers and nitrogen. Indian Journal of Agronomy. 2006;51:37-39.
17. Saleem M, Zamir MSI, Haq I, Irshad MZ, Khan MK, Asim M. et al. Yield and quality of forage oat (*Avena sativa* L.) cultivars as affected by seed inoculation with nitrogenous strains. American Journal of Plant Sciences. 2015;6(3):251-3,259.
18. Yadav PC, Sadhu AC and Swarnkar PK. Yield and quality of multi-cut forage sorghum (*Sorghum sudanense*) as influenced by integrated nutrient management. Indian Journal of Agronomy 2007;52:330-334.

19. Singh MK, Prasad SK Agronomic aspects of zinc biofortification in rice (*Oryza sativa* L.). Proceedings of the National Academy of Sciences India Section B: Biological Science. 2014;84(3):613-623.
20. Germ M, Pongrac P, Regvar M, Vogel-Mikuš K, Stibilj V, Jaćimović R, Kreft I Impact of double Zn and Se biofortification of wheat plants on the element concentrations in the grain. Plant, Soil and Environment. 2003;59(7):316- 321.
21. Prasad SK, Singh MK, Singh R. Effect of Nitrogen and Zinc fertilizer on pearl millet under agri-horti system of eastern Uttar Pradesh. The Bioscan. 2014;9(1):163-166.
22. Choudhary GL, Rana KS, Bana RS, Prajapat K. Soil microbial properties, growth and productivity of pearl millet (*Pennisetum glaucum* L.) as influenced by moisture management and zinc fortification under rainfed conditions. Journal of Microbiology Research. 2014;8(36):3314-3323.
23. Mishra Thakur NS, Singh P, Kubsad VS, Kalpana R, Alse UN, Nemade SM. Tillage and integrated nutrient management in rainy season grain sorghum (*Sorghum bicolor*). Indian Journal of Agronomy. 2014; 59:619-623.
24. Mitesh Bhoya, Chaudhari PP, Raval CH, Bhatt PK. Effect of nitrogen and zinc on yield and quality of fodder sorghum varieties. Forage Research. 2013;39(1):24-26.
25. Mohan S, Dar EA, Singh M. Fodder quality of teosinte fodder as influenced by nitrogen, phosphorus and zinc application. International Journal of Pure and Applied Bioscience. 2017;5(3):596-604.
26. Harpreet Kaur oberoi, Gulab Pondove and Anupreet Kaur. Effect of pre-sowing seed inoculation with liquid biofertilizers on fodder yield and quality of sorghum (*Sorghum bicolor*). Indian Journal of Agronomy. 2020;65(1):100-106.
27. Ali Soleymani, Mohamad Hesam Shahrajabian. The effects of Fe, Mn and Zn foliar application on yield, ash and protein percentage of forage sorghum in climatic condition. International Journal of Biology. 2012;4(3):92-96.
28. Anil Kumar S, Chidanandappa HM, Vijay Sankar Babu M. Effect of different sources of zinc on growth, yield and uptake of nutrients by maize crop (*Zea mays* L.). Mysore Journal Agriculture Science. 2010;44(1):92-99.
29. Aref F. Effect of different zinc and boron application methods on leaf nitrogen, phosphorus and potassium concentrations in maize grown on zinc and boron deficient calcareous soils. Journal of Soil and Nature. 2012;6(1):1-10.
30. Chaudhary PP, Patel KH, Italia AP, Garaniy NH, Patel DD. Effect of sulphur and zinc with organics on yield and quality of fodder sorghum under south Gujarat condition. Journal of Pharmacognocy and Phytochemistry. 2018;7(5):1711-1714.
31. Chalwade PB, Bakan RG, Kulkarni VK, Khandare RN. Effect of organic manures and inorganic fertilizers on grain and stover yield of kharif sorghum. Annals of Plant Physiology. 2005;19(2):181-183.
32. Nataraja TH, Halepyati AS, Pujari BT, Desai BK. Grain yield, dry matter production and its partitioning in wheat as influenced by interactive effects of iron, zinc and phosphorus levels. Karnataka Journal Agriculture Science. 2005;18(4): 1071-1074.
33. Sutaria GS, Ramdevputra MV, Akbari K N. Effects of Potassium and Zinc Nutrition on Yield and Quality of Forage Sorghum. Indian Journal Agriculture Research. 2013; 47(6):540-544.

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