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Characterization of the Morpho-Physiology and Yield of Finger Millet (*Eleusine coracana* L. Gaertn) under the Influence of Lime, Compost, and Micronutrients

Gunturu Vaishnavi Srilekha, Rajendra Kumar Panda, Rabindra Kumar Nayak, Manoranjan Satapathy

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ABSTRACT

The objective of this study is to provide research attention on three primary components like lime, compost, and micronutrients on morpho-physiology and yield of finger millet as finger millet is usually cultivated on low fertility soils that are deficient in macro and micronutrients. The results of the field experiment conducted during *rabi* 2022–23 at Central Farm, Odisha University of Agriculture and Technology, Bhubaneswar, showed that the combined application of lime, FYM, boron, and zinc (T_{11}) had significant effect on higher plant height (48.4 cm), number of tillers (5.8), leaf area (23.1 cm^2) and improvement in yield characters such as the number of ear heads (4.8), fingers per ear head (6.2) and grains per ear head (115) than the other combination of treatments which also implied a positive coefficient with yield ($p<0.01$). Since applied fertility management with lime and organic fertilizer (FYM) alone never showed a significant difference in yield but the study confirms the importance of combined application of B and Zn in nutrient amendment for finger millet in problematic soil.

Keywords Finger millet, FYM, Lime, Boron, Zinc.

INTRODUCTION

Finger millet also known by the local names Mandua, Ragi, Kelvarugu, belongs to the family of Poaceae, is one of the important millet crops grown for grain and fodder purpose under varied agro-climatic conditions in India. Finger millet has C_4 photosynthesis system and able to grow in harsh environments as it is a short-day and often drought-tolerant plant. The crop requires low input and is ideal for dry land farming. It is cultivated in more than 25 countries, mainly in Africa and Asia. The major finger millet growing states in India are Karnataka, Uttarakhand, Tamil Nadu, Andhra Pradesh, Orissa, Jharkhand and Maharashtra. Finger millet contains about 65—75% carbohydrates, 8% protein, 15–20% dietary fiber and 2.5–3.5% minerals. Being the most nutrient-dense of all the leading cereals, finger millet was regarded as the ideal super cereal by the US National Academies (Kumar *et al.* 2016). The UN General Assembly has declared 2023 as the international year of Millets.

Gunturu Vaishnavi Srilekha[1]*, Rajendra Kumar Panda[2], Rabindra Kumar Nayak[3], Manoranjan Satapathy[4]

[1]Post-Graduate Research Scholar, [2]Assistant Professor,[3]Associate Professor, [4]Dean
[1, 2]Department of Plant Physiology, College of Agriculture, OUAT, Bhubaneswar, India

[3]Department of Soil Science and Agricultural Chemistry, College of Agriculture, OUAT, Bhubaneswar 751003, Odisha, India

[4]Dean, College of Agriculture, OUAT, Bhawanipatna, India

Email: vaishnavisrilekha1@gmail.com
*Corresponding author

In comparison to India's annual production of 1553.25 kg per hectare, Odisha has a cultivable area of 37 thousand hectares, producing 25 thousand million tonnes, and has a productivity of 690 kg per hectare (Vennila and Murthy 2021). The total production of finger millet has been declining over the years. This is attributed to their cultivation in marginal lands in rain-fed farming. The yield gap in Odisha is due to a range of poor soil status and management practices and socio-economic constraints that are yet to be well documented to guide future production. A wide range of studies indicate that higher rates of inorganic fertilizer application enhance finger millet production and output. Acid soils usually have problems like low nutrient status, nutrient imbalance, and multiple nutrient deficiencies (Ganeshamurthy *et al.* 2016). A vital microelement, zinc is involved in auxin synthesis, enzyme activation, pollen formation, carbohydrate metabolism, protein synthesis, gene expression. Boron is another important micro-element that also plays a major role in physiological processes like cell division, cell maturation, pod and seed formation, protein synthesis, and meristematic tissue development. It also promotes absorption of nitrogen from soil. However, information on application of lime, compost, B and Zn nutrition on finger millet is lacking. Therefore, in order to achieve higher yields considering the relatively marginal local growing factors, it is crucial to optimize nutrient management practices and other relevant aspects impacting finger millet production. So, this investigation was aimed to know effect of lime, compost and micronutrients on morpho-physiology and yield of finger millet.

MATERIALS AND METHODS

Under the AICRP on micronutrients, an experimental field trial was conducted during *rabi* 2022-23 at Central Farm, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India. The location is part of the East and South Eastern Coastal Plain Agro- Climatic Zone of Odisha and is located between 20°16' N latitude and 85°49' E longitude, with an elevation of 25.9 meters above mean sea level. The soil is sandy loam (pH- 4.7) with low available boron and zinc contents. The cultivar, Arjun, was line sown (line spacing: 30×30 cm) and laid out in 12 treatments (refer Table 1) considering 3 main plots like lime, FYM, lime+FYM with 4 sub-plots such as Zn, B, Zn+B, No B/Zn (Control) and was replicated three times in a split plot manner. Basal application of FYM (2.5 t/ha), boron (Borax-10 kg/ha), zinc ($ZnSO_4$-10 kg/ha) and lime (Dolomite-2.4 t/ha) was applied along with soil test dose (STD) of 62.5:50.0:31.5:: $N:P_2O_5:K_2O$ kg/ha. The weather conditions prevailed during the crop growth period was suitable that represent min/max temperature of 13.4°/35.5°C, RH-7 hr/14 hr ~ 93%/57%, BSH-6.7 hr, Wind velocity of 0.1–5 km/hr and 3.8 mm of evaporation. Morphological attributes like plant height, tiller number, leaf area and yield characters like number of ear heads per plant, number of fingers per ear head, finger length were taken in a regular intervals during the periods of growth and continues at harvest period. The data recorded were analyzed using Microsoft Office Excel 2019-unit operating system as per Gomez and Gomez (1984).

RESULTS AND DISCUSSION

The results recorded on morpho-physiological characterization of finger millet in Table 1 showed that maximum increase in plant height of 48.4 cm in T_{11} where combined application of Lime + farm yard manure + zinc + boron was used followed by T_{10} (Lime+FYM+Boron) (46.9 cm), T_9 (Lime+FYM+Zinc) (45.4 cm) with a percent increase of 26%, 22.1% and 18.2% over control respectively. The number of tillers increased to its maximum at 40 DAT and during the harvest. Tiller number was unchanged at 50 DAT. T_{11} exhibited the highest number of tillers (5.8). The plant height and tiller number were found significant to fertilizer and micronutrient but non-significant among their interaction. With a percentage increase of 62.7% over control, T_{11} had the largest leaf area (23.1 cm^2), which was highly correlated with yield (r=0.815**).

T_{11} has the highest reported LAI (2.9), followed by T_{10} (1.8) and T_9 (1.5). The total biomass per plot was calculated during harvest and the highest biomass was observed in T_{11} (32.6 kg $plot^{-1}$) followed by T_{10} (31.3 kg $plot^{-1}$) and T_9 (30.8 kg $plot^{-1}$). It was found significant to the application of micronutrients but was non-significant to fertiliser and among the inter-

Table 1. Impact of lime, compost, boron and zinc on morpho-physiological characters of finger millet.

Treatment	Plant height (cm)	Tiller number	LA (cm²)	LAI	Total biomass (kg/plot)
T_1: L+Zn	40.3	4.5	15.0	1.1	28.9
T_2: L+B	40.4	4.7	15.2	1.2	28.9
T_3: L+Zn+B	43.2	4.7	16.5	1.3	30.3
T_4: L	38.8	4.2	13.8	0.9	24.7
T_5: F+Zn	38.1	4.5	14.5	1.1	27.9
T_6: F+B	40.4	4.7	15.7	1.2	29.0
T_7: F+Zn+B	41.4	4.7	15.7	1.2	29.7
T_8: F	36.6	3.7	13.0	0.6	21.7
T_9: L+F+Zn	45.4	4.8	17.6	1.5	30.8
T_{10}: L+F+B	46.9	5.2	19.4	1.8	31.3
T_{11}: L+F+ Zn+B	48.4	5.8	23.1	2.9	32.6
T_{12}: L+F (control)	38.4	4.2	14.2	0.9	26.8
SEm±					
Fertilizer	0.611	0.121	0.609	0.106	0.696
Micronutrient	1.234	0.165	0.472	0.127	0.911
F within M	2.250	0.319	1.078	0.252	1.771
M within F	2.137	0.286	0.818	0.220	1.578
CD at 5%					
Fertilizer	2.397	0.477	2.389	0.417	NS
Micronutrient	3.665	0.491	1.402	0.377	2.707
F within M	NS	NS	3.640	0.805	NS
M within F	NS	NS	2.429	0.654	NS

action (refer Table 1). Zinc is crucial for the synthesis of IAA, and auxins promote cell division. Furthermore, the promotion of cell elongation and division by boron results in an increase in plant height. By increasing the availability of nitrogen, applying zinc and boron helps tiller nodes produce more cytokinin and promotes the more effective germination of the tiller primordium. Nitrogen and zinc interact synergistically, and boron facilitates nitrogen absorption, which promotes the development of tillers. In accordance with Kumar *et al.* (2017), applying zinc and boron increased plant height and the number of tillers. Since zinc and boron are involved in cell division, they contribute to the growth of leaves length and breadth, which increases the area of the leaf. FYM is critical for providing all the necessary nutrients, including micronutrients. Govinda *et al.* (2020) found that the combination of zinc, boron and FYM produced the highest LAI. Increased LAI results in higher CGR leading to more biomass production. These results were in concordance with those of Chowdary and Patra (2019) and Ashenafi *et al.* (2023). The highest number of ear heads (4.8) was seen at T_{11}, representing a 60% increase above control and a greater number of fingers were also observed in the same treatment (6.2). The ear head number and fingers per ear head were found significant to micronutrient and non-significant to fertilizer and among interaction.

A similar tendency was seen for test weight (r=0.926**) and a number of grains per finger (r=0.803**) in Table 2. Shankar *et al.* (2018) found similar outcomes, reporting that zinc and boron are required for the production of starch and seeds, respectively, which increase grain weight and number.

T_{11} and T_{10} both had identical finger lengths (4.6 cm), with a 27.8% increase above control (refer Ta-

Table 2. Correlation coefficient table showing relation of morpho-physiological attributes to yield. **signifies correlated at p value of 0.01 ($p<0.01$).

	Grain yield	Stover yield	Plant height	Tiller number	Leaf area	LAI	Ear heads/ plant	Fingers/ ear head	Finger length	Grains/finger
Stover yield	0.998**									
Plant height	0.859**	0.853**								
Tiller number	0.918**	0.910**	0.912**							
Leaf area	0.815**	0.809**	0.949**	0.954**						
LAI	0.793**	0.785**	0.897**	0.960**	0.985**					
Ear heads/ plant	0.919**	0.900**	0.877**	0.934**	0.849**	0.845**				
Fingers/ ear head	0.888**	0.883**	0.952**	0.958**	0.958**	0.933**	0.913**			
Finger length	0.880**	0.876**	0.960**	0.892**	0.907**	0.842**	0.867**	0.956**		
Grains/ finger	0.803**	0.799**	0.936**	0.930**	0.972**	0.940**	0.849**	0.968**	0.929**	
Test weight	0.926**	0.924**	0.894**	0.946**	0.886**	0.886**	0.924**	0.945**	0.869**	0.864**

Table 3. Impact of lime, compost, boron and zinc on yield and yield attributes of finger millet.

Treatment	Ear head/ plant	Fingers/ear head	Finger length	Grains/finger	Test weight (100 seeds)	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})
T_1 : L+Zn	3.8	4.3	3.7	97.0	0.308	30.81	49.37
T_2 : L+B	3.8	4.5	3.8	97.0	0.317	30.85	49.44
T_3 : L+Zn+B	4.2	5.0	4.2	102.7	0.328	32.37	50.74
T_4 : L	3.7	4.3	3.5	96.7	0.308	26.44	42.29
T_5 : F+Zn	3.7	4.3	3.6	98.0	0.306	29.78	47.72
T_6 : F+B	4.0	4.8	4.1	101.7	0.318	30.96	49.56
T_7 : F+Zn+B	4.0	5.0	4.1	102.0	0.319	31.70	50.75
T_8 : F	2.7	3.7	3.4	93.7	0.257	23.06	37.10
T_9 : L+F+Zn	4.2	5.2	4.4	103.0	0.340	32.91	49.50
T_{10} : L+F+B	4.3	5.5	4.6	111.0	0.343	33.33	50.38
T_{11} : L+F+Zn+B	4.8	6.2	4.6	115.3	0.369	34.94	52.37
T_{12} : L+F (control)	3.0	4.3	3.6	96.7	0.307	28.26	46.27
SEm±							
Fertilizer	0.146	0.201	0.108	1.591	0.011	0.592	0.967
Micronutrient	0.185	0.151	0.100	4.053	0.010	1.154	1.145
F within M	0.362	0.350	0.214	7.256	0.022	2.113	2.276
M within F	0.320	0.262	0.173	7.020	0.018	1.999	1.983
CD at 5%							
Fertilizer	NS	NS	0.424	6.244	NS	2.325	NS
Micronutrient	0.549	0.449	0.298	NS	0.031	3.429	3.401
F within M	NS	NS	NS	NS	NS	NS	NS
M within F	NS	NS	NS	NS	NS	NS	NS

ble 3). As stated by Wasaya *et al.* (2017), treatment of zinc and boron shows significant LAI, leading to greater crop growth rate. Grain yield and stover yield were observed highest in T_{11} (34.9 q ha^{-1}, 52.37q ha^{-1} respectively) with a percent increase of 23.7% and 20.4% over control.

The greater number of grains per ear head observed resulted in an increase in grain yield and the use of zinc and boron aids in the maximization of dry matter. Plants are able to absorb more water if NPK is blended into the soil as it contains phosphorus, which promotes transpiration and growth. The enhanced activity of these physiological mechanisms promotes the absorption of boron, regardless of lime declines boron mobility. The findings we obtained are consistent with the findings of Long and Peng (2023), who reported that the combined application of N and B fertilizers has been shown to significantly increase crop yields. According to Sharma *et al.* (2016), using lime together with 100% NPK increased garden pea yields above using NPK alone. The pH of the soil may have increased due to the use of lime in the lines, which may have decreased P and B fixation and increasing their availability in the acidic soil. The use of FYM may have improved the soil's biological, chemical, and physical properties. It may have also increased the amount of nutrients available, which improved growth due to improved physiological processes. The present results are consistent with the studies done by Shankar *et al.* (2016), Prashantha *et al*. (2019), and Kruthika *et al.* (2023). The increased yield parameter values might be explained by the possibility that the application of zinc and boron in combination than sole use improved photosynthesis and that photosynthates transitioned from source to sink.

CONCLUSION

The primary emphasis of our research was on enriching finger millet cultivation using lime, inorganic, organic, boron and zinc. The experiment's findings

demonstrated how crucial it is to amend soil that has been limed and employ micronutrients like B and Zn in combination for field crops rather than administering them solely. The best results were obtained when lime, FYM, zinc and boron were given in tandem. These nutrients were positively correlated to improved tiller number, plant height, leaf area and LAI. Yield potential have been enhanced due to increase in yield attributes like number of ear heads, fingers per ear head, grains per finger and test weight. This will lead to the need of N, P, K and micronutrients (B and Zn) use with lime on acid laterite soil. The application of soil test-based recommended NPK plus lime and FYM coupled with B and Zn has enhanced nutrient availability and stimulates growth, and may be advised as the best alternative for finger millet crop for yield enhancement out of all treatment management strategies.

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