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Effect of Zinc-enriched Bio-compost on Growth and Productivity of Transplanted Rice (*Oryza sativa* L.)

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ABSTRACT

The field experiments were conducted in two seasons during Navarai (*Rabi*, December, 2023–March, 2024) and Kuruvai (*Kharif*, June–October, 2024) at the Experimental Farm of Department of Agronomy, Annamalai University, Annamalai Nagar, Chidambaram, Tamil Nadu, India to assess the effectiveness of Zinc-Enriched Bio-compost in enhancing the growth, yield and economics of transplanted rice. The experiments were laid out in a randomized block design with eight treatments and three replications. In the present study, compost made from crop residues and cow dung (maize-stover+*Albizia saman* leaf litter+cowdung at 3:1:1 ratio) was enriched with $ZnSO_4$ (0.0, 1.0, 1.5, 2.0, 2.5 and 3.0% on w/w basis) along with bio-fertilizers (*Azospirillum*, *Pseudomonas*, *Phosphobacteria* and ZSB each at 0.2%) were used. The application of zinc enriched bio-compost significantly affected the plant growth parameters, physiological attributes and yield parameters. This also led to higher grain and straw yield as well as better economic returns compared to the control. From the study, it was observed that the best combination of zinc enriched bio-compost for optimum growth, yield and economic performance of transplanted rice was 0.5 t ha^{-1} of crop residue compost enriched with 2.0% $ZnSO_4$ (10 kg (0.5 t $ha^{-1})^{-1}$ of bio-compost) along with biofertilizers. The study concluded that zinc-enriched bio-compost application could be recommended as a sustainable and economically viable strategy for improving the growth, productivity and profitability of transplanted rice.

KEYWORDS: Bio-compost, crop residue, zinc enrichment, zinc solubilizing bacteria

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Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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1. INTRODUCTION

India plays a significant role in global agriculture with nearly 55% of its population depending on agriculture for their livelihood. As an agriculturally driven nation, it supports a vast agro-based industry. With its second largest agro-based economy and year round crop production it also generates a bulk amount of agricultural waste, including crop residues (Bhuvaneshwari et al., 2019). The highest potential of bio waste resources are available from the gramineae crop residues such as rice, wheat, sorghum, maize, sugarcane, etc. Every year in India Gramineae crop residues contribute about 2/3rd of total 683 mt of residue produced (Jain et al., 2018; Datta et al., 2020). In Tamil Nadu 190 lakh t of crop residues are available for use. These residues will contribute about 1.0, 0.5 and 2.0 lakh t of nitrogen, phosphorus and potassium, respectively. Composting crop residues is an effective strategy which diminishes soil nutrients loss from burning (Sharma and Singh, 2023). The meaning of composting is transforming degradable organic wastes into products which can be used safely and beneficially as biofertilizers and soil amendments (Yu et al., 2019). Composts can improve soil structure, organic matter, moisture and augment the soil biological activity (Saikia et al., 2019; Immanuel et al., 2021). The rice straw, wheat stubbles and maize stover tend to have a high C:N ratio and complex lingo-cellulosic structures which lead to slow decomposition and temporary nutrient immobilization when directly applied to the soil. These characteristics make them less suitable for immediate use as manure in their raw form. Therefore, composting is recommended as a pre-treatment step to convert these residues into a more stable and nutrient-available form before soil application. These composts can be also enriched with essential micronutrients and beneficial microbes which augment the productivity of the crops. On the other hand, Zinc deficiency is a widespread issue in agricultural soils globally, primarily due to the limited availability of zinc, as most of it is locked within structural minerals or bound to soil components (Ali et al., 2022). This deficiency had affected the millions of hectares of agricultural land and contributed to zinc malnutrition, impacting nearly one-third of the world's population (Montalvo et al., 2016). Enhancing the zinc content of food crops through agronomic practices has emerged as a cost-effective and sustainable solution to address zinc malnutrition. In India, zinc is considered as the fourth important yield limiting nutrient after N, P and K. It plays a significant role in many cellular functions such as metabolic processes, physiological processes and enzymes activation (Yang et al., 2020; Alsafran et al., 2022). It performs a vigorous part in important physiological processes like photosynthesis, cell wall development, gene regulation and stress tolerance (Merinero et al., 2022). Achieving zinc biofortification requires improving the availability of zinc in soil and its uptake by plants (Zeb et al., 2018). A major challenge in increasing zinc uptake in the phosphorus rich soil is that it can interfere with zinc availability due to antagonistic P–Zn interactions particularly in those soils that are very low in plant available Zn (Nadeem et al., 2024). Excessive phosphorus availability in the soils further declines zinc micronutrient content and thereby increasing the requirement for additional zinc fertilizer application (Imran et al., 2015). The present study was conducted to assess the effectiveness of compost made from crop residues enriched with zinc sulphate ($ZnSO_4$) and biofertilizers in enhancing the growth, yield and economics of transplanted rice.

2. MATERIALS AND METHODS

2.1. Experimental site and treatment details

The field experiments were conducted in two seasons during Navarai (*Rabi*, Dec–March, 2023–24) and Kuruvai (*Kharif*, June–Oct 2024) at the Experimental Farm of Department of Agronomy, Annamalai University, Annamalainagar (11°38'N latitude and 79°72'E longitude) located at an altitude of ±5.79 m above the mean sea level (MSL) which falls under the Cauvery Delta Region of Tamil Nadu. The weather of Annamalainagar was moderately warm with hot summer months. The weekly mean maximum temperature was 32.3 ºC and the weekly mean minimum temperature was 23.4 ºC and mean relative humidity was 64.2% during Navarai-2023. While in Kuruvai-2024, the mean maximum temperature was 36.1°C, mean minimum temperature was 21.7°C, mean relative humidity was 73%.

The soil of the experimental field was clay loam in texture with pH 7.79, EC 0.68 dS m^{-1}, Organic carbon 0.3%, available nitrogen 223 kg ha^{-1}, available phosphorus 54 kg ha^{-1} and potassium 285 kg ha^{-1}. The test variety used in the study was ADT 43 which was developed from a cross between IR 50×Improved White Ponni. It was a semi-dwarf variety with the total crop duration of 110 days. ADT 43 had an average yield potential of 5900 kg ha^{-1}, with a thousand grain weight of 15.5 g. The plant exhibited a light green leaf sheath, white ligule and white coloured rice grains. The panicle was characterized as moderately long and drooping.

The experiments were laid out in Randomized Block Design with three replications and eight treatments. The treatments included T_1-Control; T_2-Recommended dose of N and K only; T_3-T_2+Soil application of $ZnSO_4$ at 25 kg ha^{-1}; T_4-T_2+Bio-compost enriched with 1.0% $ZnSO_4$ on w/w basis; T_5-T_2+Bio-compost enriched with 1.5% $ZnSO_4$ on w/w basis; T_6-T_2+Bio-compost enriched with 2.0% $ZnSO_4$ on w/w basis; T_7-T_2+Bio-compost enriched with 2.5% $ZnSO_4$ on w/w basis and T_8-T_2+Bio-compost enriched with 3% $ZnSO_4$ on w/w basis.

2.2. Bio-compost preparation

The bio-compost was prepared from maize-stover+*Albizia* saman leaf litter+cowdung at 3:1:1 ratio and enriched with $ZnSO_4$ (0.0, 1.0, 1.5, 2.0, 2.5 and 3.0% on w/w basis)+bio-fertilizers (*Azospirillum*, *Pseudomonas*, *Phosphobacteria* and Zinc Solubilizing Bacteria each applied at 0.2%) which was incubated for 60 days. The quantity of bio-compost recommended for 1 ha area was 0.5 t ha^{-1}. The bio-compost was applied as basal dose during transplanting of seedlings. As the soil in the experimental field was rich in phosphorus, the application of phosphorus fertilizer was avoided in all the treatments. All the other agronomic practices were followed uniformly across treatments as per the standard packages of practices as mentioned in the crop production guide (Anonymous, 2020) for the Cauvery Delta Zone.

2.3. Observations and analysis

The growth parameters such as plant height, number of tillers hill^{-1} and dry matter production were recorded at different growth stages. Growth was analyzed by LAI and CCI at flowering stage of the crop. Yield parameters viz., number of productive tillers m^{-2}, number of filled grains panicle^{-1}, number of unfilled grains panicle^{-1}, thousand grain weight, grain and straw yield were recorded at the harvest stage of the crop and BCR was calculated for each treatment.

The different growth and yield parameters observed during the course of study were analyzed statistically as per the procedure suggested by Gomez and Gomez (1984). Wherever the results were found significant ('F' test), the critical differences (CD) were arrived at 5% probability level (p=0.05). Treatment differences that not significant were denoted by 'NS'.

3. RESULTS AND DISCUSSION

3.1. Effect on growth parameters

The application of zinc enriched bio-compost had significantly influenced the growth parameters (Table 1). At harvest, the maximum plant height (99.8 cm), more number of tillers hill^{-1} (10.9) and the highest dry matter production (12.5 t ha^{-1}) were recorded at treatment T_6 with the application of bio-compost enriched with 2% $ZnSO_4$ on w/w basis. This enhancement might be due to the role of zinc in accelerating enzymatic activity and auxin metabolism which was essential for cellular growth and differentiation (Dubey et al., 2021). The enhancing properties of the zinc-enriched bio-compost might likely improved the micronutrient solubilization and stimulated the beneficial microbial activity in the rhizosphere, while the gradual nutrient released from organic amendments contributed to enhanced root proliferation, vigorous tillering and overall crop development (Naeem et al., 2025; Sande et al., 2024). Notably, T_6 also outperformed the other treatments in exhibiting the maximum Chlorophyll Content Index (34.4) and Leaf Area Index (5.9) of the crop. These findings

Table 1: Effect of zinc-enriched bio-compost on the growth parameters, yield parameters, yield and economics of transplanted rice

Treatments	Plant height (Harvest) (cm)	No. of tillers hill^{-1} (Active tillering)	DMP (Harvest) (t ha^{-1})	LAI (Flowering)	CCI (Flowering)	Productive tillers m^{-2}	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	Test weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	BCR
T_1	67.2	5.6	5.2	2.9	13.6	240.8	68.92	33.7	15.50	1.9	4.1	0.90
T_2	80.7	8.1	7.4	4.0	20.1	305.2	90.60	24.1	15.52	3.3	5.3	1.41
T_3	85.3	8.9	8.8	4.3	23.5	322.9	94.00	20.8	15.55	3.8	6.4	1.58
T_4	88.5	9.4	9.7	4.7	25.4	338.5	99.13	17.3	15.58	4.2	7.1	1.79
T_5	91.6	9.9	10.6	5.1	28.7	354.0	104.03	14.6	15.60	4.8	7.5	2.02
T_6	99.8	10.9	12.5	5.9	34.4	388.8	115.50	7.5	15.65	6.0	8.5	2.50
T_7	95.9	10.5	11.7	5.6	31.5	374.5	111.20	10.2	15.63	5.5	8.1	2.29
T_8	95.2	10.3	11.4	5.4	30.8	369.1	109.17	10.9	15.62	5.3	7.9	2.20
S.Em±	0.91	0.14	0.12	0.09	0.28	4.21	1.14	0.28	0.17	0.09	0.10	-
CD (p=0.05)	2.75	0.36	0.35	0.28	0.87	12.97	3.52	0.84	NS	0.27	0.32	-

T_1-Control; T_2-Recommended dose of N and K only; T_3-T_2+Soil application of $ZnSO_4$ at 25 kg ha^{-1}; T_4-T_2+Bio-compost enriched with 1.0% $ZnSO_4$ on w/w basis; T_5-T_2+Bio-compost enriched with 1.5% $ZnSO_4$ on w/w basis; T_6-T_2+Bio-compost enriched with 2.0% $ZnSO_4$ on w/w basis; T_7-T_2+Bio-compost enriched with 2.5% $ZnSO_4$ on w/w basis and T_8-T_2+Bio-compost enriched with 3% $ZnSO_4$ on w/w basis aligned with those of Shehzadi et al. (2024), who observed that plants receiving sufficient zinc showed increased leaf area index, largely attributed to higher chlorophyll levels and faster plant growth. This treatment was followed by the treatments T_7 and T_8 which were statistically on par with each other. The lowest plant height (67.2 cm), number of tillers hill^{-1} (5.6) and DMP (5.2 t ha^{-1}) were observed with the control (T_1) which underscored the importance of supplementing organic inputs with essential micronutrients.

3.2. *Effect on yield parameters*

The data pertaining to number of productive tillers m^{-2}, number of filled grains panicle^{-1}, number of unfilled grains panicle^{-1} and test weight recorded at harvest stage of the rice crop were presented in the Table 1. The treatments were found to be exerted a significant impact on the yield parameters of the transplanted rice. Among the treatments, T_6 recorded with the highest number of productive tillers m^{-2} (388.8), more number of filled grains panicle^{-1} (115.50) and improved test weight (15.65). It also exhibited considerable reduction in the number of unfilled grains panicle^{-1} (7.5). This treatment was followed by the application of bio-compost enriched with 2.5% $ZnSO_4$ (T_7) and it was much comparable with the treatment T_8 with the application of bio-compost enriched with 3% $ZnSO_4$. This enhancement in yield parameters might be attributed to increased zinc availability which improved translocation from source to sink and it also stimulated the synthesis of indole-3-acetic acid (IAA) which promoted the initiation of primordia of reproductive parts and in turn supported efficient grain development. (Chaubey et al., 2021). The control treatment showed the poor performance in all the yield parameters.

3.3. *Effect on yield and economics*

The grain yield and straw yield were significantly affected by the application of zinc-enriched bio-compost and the data on yield and economics were presented in the Table 1. The treatment T_6 recorded the highest grain yield of 6.0 t ha^{-1} and straw yield of 8.5 t ha^{-1}. It was followed by the treatments T_7 and T_8 which were on par with each other. Improved chlorophyll production and photosynthesis directly correlated with higher yields (Athar et al., 2025). The grain and straw yield were increased by applying compost enriched with zinc and this increase might be due to the better availability of nutrients resulting in improved zinc uptake and better grain production. Similar results were reported by Abbas et al. (2021) and Naeem et al. (2025). From an economic standpoint, T_6 also achieved the maximum benefit-cost ratio (BCR) of 2.50, indicating the highest economic return unit^{-1} of investment. This superior BCR reflected the combined effect of increased productivity and optimized input utilization. The lowest grain yield, straw yield and BCR were recorded in the control treatment (T_1) with 1.9 t ha^{-1}, 4.1 t ha^{-1} and 0.90, respectively which highlighted the inefficacy of no fertilizer application.

4. CONCLUSION

The optimum growth, yield and economic performance of the crop were achieved in 0.5 t ha^{-1} of crop residue compost enriched with 2.0% $ZnSO_4$ (10 kg (0.5 t ha^{-1})$^{-1}$ of bio-compost) along with biofertilizers. These findings supported the recommendation of bio-compost enriched with 2.0% $ZnSO_4$ as a sustainable and economically viable strategy to increase the growth, productivity and profitability of transplanted rice.

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