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Influence of foliar zinc nutrition on yield and economic viability of coloured rice (*Oryza sativa* L.) genotypes

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Abstract

Zinc is one of the most essential micronutrients for proper growth and development of the plant. The study examined the impact of zinc fertilizer on pigmented rice varieties at Agricultural College Farm in Bapatla, India, in order to ascertain the impact of zinc foliar fertilization at different growth stages on rice yield and economic viability during the Kharif, 2023. The experiment was carried out with 4 main plots (pigmented rice varieties) and 4 sub plots (zinc foliar fertilization @0.2% at different growth stages) and replicated thrice in Split plot design (SPD). The experiment revealed that grain, straw yield and economics was significantly enhanced by the addition of zinc at different growth stages of rice over control. The application of ZnSO₄ @ 0.2% at tillering, PI and booting stages in kujipatalia variety resulted in significantly higher value for yield and economic returns. Based on the study, it is concluded that the foliar zinc application at different growth stages was found to be effective in enhancing crop productivity and economic returns of pigmented rice varieties tested.

Keywords: Zinc sulphate, pigmented rice, foliar fertilization, rice yield

Introduction

Rice (*Oryza sativa* L.) crop provides food for almost half of the world's population, accounting for over 21% of human caloric requirement and upto 76% of caloric intake of southeast-Asian inhabitants (Zhao *et al.*, 2020) [21]. It is considered as the staple food of our country with its cultivation, the primary economic activity and main source of income for many Indian rural-households. It is the staple food for more than 65% of the country's population. India is the second-largest rice-producing country in the world and the crop contributes over 42% to the annual food grain production of the country (Vijayakumar *et al.*, 2021a) [17]. As per 3rd advance estimates of 2025-26 in India, rice cultivation covers an extensive area of 528.32 lakh hectares, resulting in an annual production and productivity of 1540.24 lakh tonnes and 2915 kg ha⁻¹ respectively. An area of 26.51 lakh hectares in Andhra Pradesh cultivates rice, yielding an annual production of 105.85 lakh tonnes and a productivity of 3993 kilograms per hectare [DA & FW, 2026] [3]. For people who rely on it as their main source of sustenance, the quality of rice is critical. In the past few years, the demand for high-quality rice has risen as a result of social progress and improved living conditions. Moreover, interest of researchers on traditional or specialty rice has increased in recent years, red and black rice are one such type. Black rice is a medium-grain, non-glutinous heirloom rice with a deep purple hue and a nutty, slightly sweet flavour. The dark colour of the grain is due to anthocyanin, a powerful antioxidant. Black rice has a deep black colour and usually turns deep purple when cooked. It is suitable for creating porridge, dessert, cake, bread, kheer, noodles and many other dishes (Saha *et al.*, 2022) [13]. The demand for black rice has been increasing in today's world because of its superior nutritional quality due to the presence of antioxidants and phenolic compounds. It is also rich in beneficial amino acids like lysine and tryptophan which possess health benefits. Historically, the nobility and affluent enjoyed red rice as an exclusive type is due to its exceptional nutritional content and distinct flavour. Additionally, it possesses a more pronounced nutty taste and a slightly resilient consistency, rendering it a preferred option in numerous customary recipes. The composition of this substance includes anthocyanins, proanthocyanidins, GABA (Gamma-Aminobutyric acid) and phytosterols.

Conversely, rice has a naturally low content of micronutrients, such as zinc. In India, zinc deficiency remains a major factor limiting crop productivity among all the micronutrients. Although crops require only small amounts of zinc for normal growth, their extremely low fertilizer usage efficiency ranging from 1-3% for soil application and 5-8% for foliar application necessitates a considerable application rate. Around 50% of farmed soils worldwide have low Zn concentrations during cereal-growing seasons [Prasad *et al.*, 2014] ^[12]. Zn deficiency in plants is characterised by decreased membrane integrity, increased vulnerability to thermal stress, and decreased synthesis of auxin, chlorophyll, cytochromes, carbohydrates, and nucleotides. A few of the Zn-containing enzymes that are inhibited include alkaline phosphatase, carbonic anhydrase, Cu-Zn-superoxide dismutase, phospholipase, carboxypeptidase, and RNA polymerase [Marschner 1995] ^[9]. Zinc interacts with more than 500 different kinds of proteins. Zinc sulphate heptahydrate, applied as a foliar fertilizer and in the soil, increased the zinc content of plant parts like hull, bran, white rice kernels, and straw [Stein *et al.*, 2007] ^[16]. Foliar fertilization has a stronger effect on raising Zn concentration in rice than soil application, according to the rice crop's immediate response to nutrient treatment. The production of cereal and straw from different types of rice differed substantially when Zn was applied and when it wasn't. Also, Zn is considered the most sustainable strategy for achieving optimal yield and agronomic biofortification [Chattha *et al.*, 2017] ^[2]. These factors were taken into consideration as the current study, "Foliar application of zinc on growth and yield in different pigmented varieties of rice (*Oryza sativa* L.), was carried out at the kharif season of 2023 at the Agricultural College Farm, Bapatla.

Materials and Methods

The present experiment was conducted during *kharif*, 2023 in Agricultural college farm, Bapatla (80.30°E longitude and 15.54° N latitude with an altitude of 5.49 m Amsl), Andhra Pradesh. The soil of the experimental field was sandy clay loam, neutral in pH (7.2), normal in EC (0.21 dS/m), medium in organic carbon, low in available nitrogen, medium in available phosphorus and available potassium and low in available zinc. The mean maximum temperature during the cropping period was 33.2°C and mean minimum temperature was 23.7°C. The total rainfall received during the cropping period was 900.8mm, during the cropping period. The experiment was laid out in a split-plot design (SPD) with 3 replications. In the main plot, – coloured rice varieties: M₁- Navara; M₂- BPT-2858; M₃- BPT-2841 and M₄-Kujipatalia and in sub-plots, – application of ZnSO₄ @ 0.2% at different stages: S₁- no zinc; S₂- application of ZnSO₄ @ 0.2% at tillering stage; S₃- application of ZnSO₄ @ 0.2% at tillering and panicle initiation stages and S₄- application of ZnSO₄ @ 0.2% at tillering, panicle initiation and booting stages were tested. The varieties are having the duration of (M₁)120, (M₂)130, (M₃)130-135 and (M₄)120-130 days.

Statistical Analysis

Statistical significance was tested by applying F-test at 0.05 level of probability. Critical differences at 0.05 level were worked out for the effects, which were significant.

Results and Discussion

Effect on zinc fertilization on yield of coloured rice varieties

Grain yield (kg ha⁻¹)

The grain yield was significantly influenced by coloured rice

varieties and zinc fertilization, presented in (table 1) and interaction effect was also significantly effected by varieties and zinc fertilization. Data reveals that, kujipatalia variety (4480 kg ha⁻¹), recorded significantly the highest grain yield which was on par with BPT-2841 variety (4187 kg ha⁻¹), while significantly the minimum grain yield was recorded with navara variety (3318 kg ha⁻¹). The maximum grain yield was recorded with the application of ZnSO₄ @ 0.2% at tillering, panicle initiation and booting stages (4328 kg ha⁻¹) which was found to be on par with the application of ZnSO₄ @ 0.2% at tillering, panicle initiation (4172 kg ha⁻¹). The foliar application of Zn significantly improved grain yield by increasing number of spikelets per spike, filled grain rate and 1000 grain weight stated by (Wang *et al.*, 2023) ^[18]. The similar findings were noted with those conducted by (Xia *et al.*, 2018) ^[19] and (Chen *et al.*, 2022). Significantly the minimum grain yield (3484 kg ha⁻¹) was noticed with no zinc application. Application of Zn might increase the plant nutrient availability throughout the crop growth period which promotes the various physiological activities. Higher grain yield due to combined application (soil and foliar) of Zn is attributed to involvement of Zn in many metallic enzymes in plant system, and auxin production, which enhances the carbohydrates synthesis and transport to the grain production site (Pedda Babu *et al.*, 2007) ^[11]. These results are in agreement with the findings of Shivay (2015) ^[14] and Kadam (2018) ^[7]. The yield qualities improved when assimilates were directed more towards reproductive organs. Transferring nutrients to reproductive sinks is necessary for seed development. The availability and utilization of assimilates might have an effect on seed set and filling [Anshuman and Rao, 2021] ^[1]. Among the interaction, the highest grain yield was recorded with kujipatalia variety coupled with application of ZnSO₄ @ 0.2% at tillering, panicle initiation and booting stages and the lowest grain yield was recorded with navara variety combined with no zinc application. Zn treatments may have contributed to the enhanced grain output of rice by starting the early emergence of panicles, which may have allowed for more assimilate storage in rice grains. [Khan and others 2003] ^[8]. Additionally, the extended yield characteristics are likely the result of an extended boom and improvement parameters, which ultimately led to an extended grain. These outcomes are in line with [Yatheesh Kumar *et al.*, 2022] ^[20].

Straw yield (kg ha⁻¹)

The straw yield was influenced significantly with coloured rice varieties and zinc fertilization. Data (Table 1) shows that significantly the maximum straw yield was recorded with kujipatalia variety (5374 kg ha⁻¹) followed by BPT-2841 (5255 kg ha⁻¹) variety. Significantly the lowest straw yield (4116 kg ha⁻¹) was recorded with navara variety. Among the zinc fertilization stages, the maximum straw yield was attained with the application of ZnSO₄ @ 0.2% at tillering, panicle initiation and booting stages (5221 kg ha⁻¹) which was significantly highest than the yield with the application of ZnSO₄ @ 0.2% at tillering, panicle initiation (5071 kg ha⁻¹) stages. While, significantly the lower straw yield was noticed with no zinc application (4559 kg ha⁻¹). (Singh *et al.*, 2021) ^[15] stated that Zn application is positively and closely related to the vegetative growth of the plants by enhancing the growth parameters viz., plant height, number of tillers, leaf area and drymatter accumulation have been resulted in higher straw yield. This may have occurred as a result of Zn's involvement in metabolic, hormonal, and photosynthetic processes. Higher straw yield was obtained as a result of stimulating vegetative growth. [Ghatak *et al.*, 2005] ^[5]. In interaction, the highest straw yield was recorded with kujipatalia variety coupled with application of

ZnSO₄ @ 0.2% at tillering, panicle initiation and booting stages while the lowest was recorded with navara variety combined with no zinc application. The research by [Padmavathi 1995]^[10] also supports the idea that hybrid rice has the capacity to use more nitrogen through the expression of superior growth brought about by the favourable influence on nutrient uptake and physiological growth increase straw yield [Fatma *et al.*, 2021; Imran *et al.*, 2021]^[4, 6].

Economics

Gross returns and net returns were worked out for rice crop effected by zinc fertilization on coloured rice varieties. A perusal of the data showed that the economics of rice crop were influenced significantly by varieties and zinc fertilization.

Gross Returns

Significantly the highest gross returns were obtained with kujipatalia variety (229386 Rs. ha⁻¹) which was found to be on par with BPT-2841 variety (214468 Rs. ha⁻¹) and significantly the lowest was recorded with navara variety (151108 Rs. ha⁻¹). Data pertaining to zinc fertilization stages, application of ZnSO₄ @ 0.2% at tillering, panicle initiation and booting stages (221634 Rs. ha⁻¹) recorded significantly superior gross returns and no zinc applied treatment recorded significantly the lower gross returns (172234 Rs. ha⁻¹). The interaction effect on gross returns of coloured rice revealed that the highest gross returns were recorded with kujipatalia variety combined with application of ZnSO₄ @ 0.2% at tillering, panicle initiation and booting stages. The

economic viability of crop cultivation is closely linked to the productivity of the crop, which in turn influences key economic attributes such as net returns and benefit-cost ratio (BCR). Despite the higher cost of cultivation associated with the application of 100% Recommended Dose of Fertilizers (RDF) with soil application of Zn, foliar spray of Zn @ 0.2% during active tillering and panicle initiation and booting stages has shown higher result of gross return and net return. This can be attributed to the significantly higher grain yield and straw yield achieved with this treatment. The increased yield not only offset the additional input costs but also resulted in substantially higher net income and BCR.

Net Returns

Significantly the highest net returns were obtained with kujipatalia variety (154954 Rs. ha⁻¹) followed by BPT-2841 variety (140035 Rs. ha⁻¹) and navara variety (76675 Rs. ha⁻¹) recorded significantly the lowest net returns. Among the zinc fertilization stages, application of ZnSO₄ @ 0.2% at tillering, panicle initiation and booting stages (147759 Rs. ha⁻¹) recorded significantly superior net returns over the rest of the treatments tested and no zinc application (98359 Rs. ha⁻¹) recorded significantly the lowest. The highest and lowest with regard to interaction were recorded with kujipatalia variety coupled with application of ZnSO₄ @ 0.2% at tillering, panicle initiation and booting stages and navara variety combined with no zinc application respectively.

Table 1: Yield and Economics of coloured rice varieties influenced by zinc fertilization

Treatments	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Gross returns (Rs ha ⁻¹)	Net returns (Rs ha ⁻¹)
Coloured rice varieties				
M ₁ : Navara	3318	4116	151108	76675
M ₂ : BPT-2858	3868	4801	198180	123748
M ₃ : BPT-2841	4187	5255	214468	140035
M ₄ : Kujipatalia	4480	5374	229386	154954
SEm (±)	100.9	94.6	5055.30	5055.3
CD (P=0.05)	349	327	17494	17494
CV (%)	8.8	8.9	8.8	14.1
Foliar application of ZnSO₄ @ 0.2%				
S ₁ : No zinc	3484	4559	172234	98359
S ₂ : Tillering stage	3869	4695	197021	122403
S ₃ : Tillering and PI stages	4172	5071	202253	126892
S ₄ : Tillering, PI and booting stages	4328	5221	221634	147759
SEm (±)	103.3	98.9	5204.07	5204.0
CD (P=0.05)	302	289	15190	15190
CV (%)	9.0	9.2	9.1	14.6
Interaction				
SEm (±)	178.0	169.4	8949.99	8949.9
CD (P=0.05)	493	470	24808	24808

Conclusion

The study evaluated how the zinc foliar fertilization influenced the yield and economic viability of pigmented rice varieties. It was determined that the variety kujipatalia performed well after receiving Zinc sulphate@ 0.2% application at tillering, PI and booting stages which enhanced growth and yield characteristics under the agro-climatic conditions of Bapatla. These results suggest that Zn treatment in plants through foliar spray can be helpful to combat the several syndromes caused due to Zn deficiency and foliar feeding of rice at different reproductive stages of rice is beneficial for enhancing the yield and economics of rice.

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