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Effect of micronutrients and different spacing on growth and yield of rice crop (*Oryza sativa* L.) Grown under SRI

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Abstract

The field experiment was entitled “Effect of Micronutrient and Different Spacing on Growth and Yield of Rice crop (*Oryza sativa* L.) Grown under SRI” was conducted during *Kharif* season of 2025-2026 at Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj, Uttar Pradesh. The experiment was laid out in Randomized Block Design with ten treatment combinations and three replications. The treatments consisted of three levels of micronutrients Zinc, Boron and Iron (10, 6 and 20 kg/ha) and three levels of Spacing (20 × 20, 25 × 25 and 30 × 30 cm) and a control (120-60-60 NPK kg/ha). The results revealed that among the various treatment combinations, Significantly higher plant height (105.47 cm) was recorded treatment (T₁) Zinc at 10 kg/ha + 20 × 20 cm, The highest tiller per hill (18.8) and dry weight recorded (170.7 g) were recorded in treatment (T₃) Zinc at 10 kg/ha + 30 × 30 cm. Yield attributes such as productive tillers (18.4), higher grain per panicle (299), panicle length (28.9 cm) and test weight (29.25 g) were significantly higher in treatment (T₆) Boron at 6 kg/ha + 30 × 30 cm, Meanwhile, maximum seed yield (10.63 t/ha) and highest harvest index (52.7%) were recorded in treatment (T₅) Boron at 6 kg/ha + 25 × 25 cm. The maximum stover yield (12.38 t/ha) was recorded in treatment (T₁) Zinc at 10 kg/ha + 20 × 20 cm in rice crop grown under SRI.

Keywords: System of Rice Intensification (SRI), micronutrients, plant spacing, growth, yield

1. Introduction

Rice, scientifically known as (*Oryza sativa* L.), originates from Asia and is predominantly cultivated in South East Asia and India. Often considered as the "global grain," it holds a pivotal position as a fundamental food source for humanity (Singh *et al.*, 2024) ^[18]. Rice (*Oryza sativa* L.) is the dominant staple food for more than half of the world's population. It provides 23% of all the calories consumed by the world's population, and 50–80% of the energy intake of the people in developing countries (Kumar *et al.*, 2017) ^[8].

India is currently ranked as the top producing country in the world, contributing approximately 28% of the total global rice output (USDA foreign Agriculture service report 2024-2025). Rice is grown in 51.27 M ha in India with the production level of 150.18 M t and the average productivity is about 2929 kg/ha. Major rice producing state are Uttar Pradesh, Telangana, West Bengal, Punjab and Chhattisgarh. Uttar Pradesh is the largest growing state of rice in the country. Rice crop production in Uttar Pradesh was 20.76 M t from an area of 7.35 M ha and productivity of 2824 kg/ha (Agricultural Statistics at a Glance, 2024-2025).

Micronutrients are essential elements required by plants in small quantities for their growth, development, and metabolic functions. micronutrients play a critical role in various physiological processes, such as photosynthesis, enzyme activation, and nutrient uptake (Thrupthi *et al.*, 2023) ^[21]. Micronutrient deficiencies include difficulty in the identification of field crop symptoms, variation in soil micronutrient status, soil pH, and intensity, and seasonal fluctuations in the levels and temperature regimes in the region (Das. S. k., 2014) ^[6].

Zinc plays multiple roles in basic bio-chemical 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. Zinc is an important nutrient for the healthy growth and development of plants (Kumar *et al.*,

2024) [9]. Boron (B) an important mineral nutrient stimulates a number of physiological processes in vascular plants. It is important for carbohydrate metabolism, translocation and development of cell wall and RNA metabolism. Boron has been found to play key role in pollen tube growth, stimulate the plasma membrane, anther development, floret fertility and seed development (Patel *et al.*, 2020) [13]. Iron is one of the basic metals required. Fe is the micronutrient that plants need the most of the seven. It helps in the production and breakdown of chlorophyll in addition to the synthesis of proteins and nucleic acids. Iron is a constituent of ferredoxins and iron porphyrins, both of which are essential elements in the light phase of photosynthesis. Iron also plays a significant part in respiration and growth of healthy, green leaves. Iron is also necessary for electron transport in photosynthesis (Thrupthi *et al.*, 2023) [21].

The system of rice intensification (SRI) is an alternative for conventional rice cultivation that saves the expensive external inputs, improves soil health/quality and protects the environment substantially. The SRI practices include transplanting of single and young seedlings preferably 8-12 days old in a widely spaced square pattern, weed management through manual or mechanical means and water application as intermittent irrigation resulting in 40–50% water saving, and produce yield increases in the range 10–42% (Ram *et al.*, 2014) [14]. SRI has eked tremendous interest of scientists and this technology has been widely experimented in rice growing countries of world. Impressive yield gains with this technology have been reported by not only scientists from their on-station and on farm trials but also by the farmers. Higher yield with fewer inputs, like water, fertilizers, seed, labour, etc. have made SRI attractive and rewarding, particularly for the resource-poor small and marginal rice farmers. It is also useful to resource-rich large farmers. With SRI, yields twice higher than the conventional transplanted rice yields have been frequently reported (Das *et al.*, 2015) [6].

2. Materials and Methods

The experiment was carried out during *Kharif* season of 2025 at the Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj, Uttar Pradesh, to study the “Effect of Micronutrients and Different Spacing on Growth and Yield of Rice Crop (*Oryza sativa* L.) grown under SRI”. The experimental field's soil had a sandy loam texture, a pH of 7.1, low organic carbon content (0.391%), available nitrogen (178.48 kg/ha), available phosphorus (27.2 kg/ha), and available potassium (219.4 kg/ha). The study used a Randomized Block Design featuring ten treatments and three replications. The treatment combinations are as follows: T₁: Zinc at 10 kg/ha + 20 × 20 cm, T₂: Zinc at 10 kg/ha + 25 × 25 cm, T₃: Zinc at 10 kg/ha + 30 × 30 cm, T₄: Boron at 6 kg/ha + 20 × 20 cm, T₅: Boron at 6 kg/ha + 25 × 25 cm, T₆: Boron at 6 kg/ha + 30 × 30 cm, T₇: Iron at 20 kg/ha + 20 × 20 cm, T₈: Iron at 20 kg/ha + 25 × 25 cm, T₉: Iron at 20 kg/ha + 30 × 30 cm and T₁₀: Control (NPK 120-60-60 kg/ha).

Rice seedlings were transplanted at 14 days after germination into net plots measuring 3m x 3m. Fertilizer was applied by broadcasting to fulfill the recommended dosage of 120-60-60 kg/ha N-P-K. The entire requirements of Phosphorus and Potassium was applied as a basal dose using along with a full dose of micronutrients (Zinc, Boron and Iron). Nitrogen application was integrated using both organic and inorganic sources: 50% of the total nitrogen was provided through vermicompost and 30% through an inorganic source as a basal application. The remaining nitrogen was split into two top-dressings of 15% each using urea, applied at the active tillering and flowering stages to ensure

optimal nutrient uptake throughout the crop cycle.

The observations on growth parameters i.e. Plant height(cm), Number of tillers per hill, Plant dry weight (g), were recorded at regular interval after germination. Yield attributing parameters i.e. number of productive tillers per hill, number of Grains per panicle, Panicle length (cm), Test Weight(g), Grain yield (t/ha), Stover yield (t/ha) and Harvest Index (%) were recorded. Seed and stover yield were taken for the net plot of 1m² and using this formula (economic yield /Biological yield) × 100 and calculate for 1 ha. The recorded data were analysed statically by ANOVA technique, and the significance of treatment differences was tested using the Critical Difference (CD) at a 5% probability level.

3. Results and Discussion

3.1 Growth parameters

Plant Height (cm)

At 100 DAT, significantly higher plant height (105.47 cm) was recorded with the application T₁ Zinc at 10 kg/ha + 20 × 20 cm, whereas the application of T₂ Zinc at 10 kg/ha + 25 × 25 cm (98.57 cm), T₄ Boron at 6 kg/ha + 20 × 20 cm (101.10 cm) and T₇ Iron at 20 kg/ha + 20 × 20 cm (97.00 cm) were found to be statistically at par with highest. The significantly higher plant height recorded with Zinc at 10 kg/ha + 20 × 20 cm spacing showed that combining zinc application with a closer spacing directly promoted stem elongation and plant height Zinc acts as a critical biochemical precursor for the biosynthesis of Indole-3-Acetic Acid (IAA), an auxin that promotes cell division and internodal elongation, specifically during the rapid vegetative surge observed after 40 DAT (Alloway, 2008) [2]. This vertical expansion was further facilitated by the 20 × 20 cm spacing, which (Das *et al.*, 2010) [5] identified as the "optimum spacing" for maximizing nutrient uptake (N, P and K) and overall physiological performance. Their research indicates that while closer spacing can lead to stunted growth due to intense intra-specific competition, the 20 × 20 cm geometry provides a sufficient plant density to encourage the plant to prioritize primary axis height for maximum light interception. Furthermore, the statistical parity observed among the Zinc, Boron and Iron treatments suggests that the 20 × 20 cm configuration established a superior micro-environment that enhanced the efficiency of all applied trace elements (Das *et al.*, 2010) [5].

Number of Tillers/Hill

At 100 DAT, significantly higher number of tillers per hill (18.8) were recorded with the application of T₃ Zinc at 10 kg/ha + 30 × 30 cm, whereas the application of T₅ Boron at 6 kg/ha + 25 × 25 cm (16.9), T₉ Boron at 6 kg/ha + 30 × 30 cm (18.7) and T₉ Iron at 20 kg/ha + 30 × 30 cm (18.1) were found to be statistically at par with the highest. The significantly higher number of tillers per hill recorded with Zn 10 kg/ha is primarily attributed to the essential role of Zinc in metabolic activities and protein synthesis, as it serves as a vital precursor for tryptophan and growth-promoting hormones like auxins. According to (Alloway, 2008) [2], maintaining sufficient Zinc levels is critical for the initiation and maintenance of lateral buds, which directly increases tiller production during the vegetative phase. This hormonal boost worked better because the superior tiller count observed with 30 × 30 cm² spacing from 40 DAT onwards resulted from a substantial reduction in intra-specific competition for solar radiation, moisture, and nutrients (N, P, and K). (Das *et al.*, 2010) [5] noted that while closer spacing might Favor vertical growth, wider spacing under intensified systems significantly enhances the number of tillers per hill by providing the necessary area for both root expansion and canopy spread. The observed peak in

tillering at 60 DAT (21.3), followed by a gradual decline toward 100 DAT (18.4), shows how the rice crop naturally sheds its weaker, late-forming tillers. The plant stops sending resources to these non-productive stalks so it can concentrate its energy entirely on filling grains and developing panicles (Alloway, 2008; Das *et al.*, 2010) [2, 5].

Plant Dry Weight (g/hill)

At 100 DAT, significantly higher dry weight (170.7 g) was recorded with the application of T₃ Zinc at 10 kg/ha + 30 × 30 cm, whereas the application of T₁ Zinc at 10 kg/ha + 20 × 20 cm (157 g), T₂ Zinc at 10 kg/ha + 25 × 25 cm (165.7 g), T₆ Boron at 6 kg/ha + 30 × 30 cm (160 g), T₈ Iron at 20 kg/ha + 25 × 25 cm (158 g) and T₉ Iron at 20 kg/ha + 30 × 30 cm (165 g) were

Table 1: Effect of micronutrient and Different Spacing on Growth Parameters of rice crop grown under SRI

S. No.	Treatment combinations	AT 100 DAT		
		Plant height (cm)	Tillers/hill	Dry weight (g)
1	Zinc at 10 kg/ha + 20 × 20 cm	105.47	13.7	157.0
2	Zinc at 10 kg/ha + 25 × 25 cm	98.57	15.7	165.7
3	Zinc at 10 kg/ha + 30 × 30 cm	92.73	18.8	170.7
4	Boron at 6 kg/ha + 20 × 20 cm	101.10	13.6	136.4
5	Boron at 6 kg/ha + 25 × 25 cm	88.60	16.9	147.0
6	Boron at 6 kg/ha + 30 × 30 cm	90.10	18.7	160.0
7	Iron at 20 kg/ha + 20 × 20 cm	97.00	14.7	135.7
8	Iron at 20 kg/ha + 25 × 25 cm	92.50	15.7	158.0
9	Iron at 20 kg/ha + 30 × 30 cm	83.70	18.1	165.0
10	Control (N-P-K 120-60-60 kg/ha)	93.87	14.9	132.3
	F-Test	S	S	S
	S.Em (±)	3.66	0.83	5.45
	C.D. (p=0.05)	10.88	2.46	16.20

found to be statistically at par with the highest. The significantly higher dry weight recorded with 10 kg Zn/ha is primarily attributed to the essential role of Zinc in regulating photosynthetic efficiency and nitrogen metabolism. Zinc serves as a fundamental structural component of enzymes such as carbonic anhydrase, which is required for CO₂ fixation, chlorophyll synthesis and

directly enhancing biomass production (Alloway, 2008) [2]. While closer spacing 20 × 20 cm showed higher initial dry weight at 20 DAT due to early-stage plant density, the shift to 30 × 30 cm² by 100 DAT (170 g) demonstrates the superiority of wider geometry in long-duration growth. According to (Das *et al.*, 2010) [5], wider spacing under intensified systems minimizes "mutual shading" and provides a larger "root-zone volume," allowing individual hills to maximize their genetic potential for nutrient uptake and dry matter partitioning without intense competition for resources. is required for CO₂ fixation and chlorophyll synthesis, directly enhancing biomass production (Alloway, 2008) [2]. While closer spacing 20 × 20 cm showed higher initial dry weight at 20 DAT due to early-stage plant density, the shift to 30 × 30 cm² by 100 DAT (170 g) demonstrates the superiority of wider geometry in long-duration growth. According to (Das *et al.*, 2010) [5], wider spacing under intensified systems minimizes "mutual shading" and provides a larger "root-zone volume," allowing individual hills to maximize their genetic potential for nutrient uptake and dry matter partitioning without intense competition for resources.

3.2 Yield parameters

Number of productive tillers/hill

Significantly highest number of productive tillers per hill (18.4) were recorded with the application of T₆ Boron at 6 kg/ha + 30 × 30 cm, whereas the application of Zinc at 10 kg/ha + 30 × 30 cm (17.9), T₅ Boron at 6 kg/ha + 25 × 25 cm (16.6) and T₉ Iron at 20 kg/ha + 30 × 30 cm (17.9) were statistically at par with the highest. Significantly highest number of productive tillers per hill (18.4) recorded under T₆ (T₆ Boron at 6 kg/ha + 30 × 30 cm) Boron's critical role in minimizing grain sterility and sustaining active vegetative structures, as a deficiency in this essential micronutrient directly causes a decrement in the number of productive tillers (Laik *et al.*, 2021) [10]. Furthermore, the wider 30 × 30 cm plant geometry maximizes this nutritional benefit by reducing resource competition, allowing the crop to express its full phenotypic capacity for structural growth. The statistical equivalence observed with the Zinc and Iron treatments at the same wider spacing indicates that balancing overall micronutrient limitations is a primary prerequisite for maximizing productive tillering in intensive agriculture systems (Alloway, 2008) [2].

Table 2: Effect of Micronutrient and Different Spacing on yield of Rice Crop grown under SRI

S. No.	Treatment combinations	Number productive tillers/ hill	No. of grains/panicle	Panicle length(cm)	Test weight (g)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest Index (%)
1	Zinc at 10 kg/ha + 20 × 20 cm	13.0	219.5	23.4	21.72	6.31	12.38	33.9
2	Zinc at 10 kg/ha + 25 × 25 cm	15.2	232.5	27.4	23.04	7.57	10.43	42.2
3	Zinc at 10 kg/ha + 30 × 30 cm	17.9	239.8	28.5	25.02	7.07	9.56	42.5
4	Boron at 6 kg/ha + 20 × 20 cm	12.9	261.2	24.4	23.65	6.02	11.35	34.7
5	Boron at 6 kg/ha + 25 × 25 cm	16.6	286.5	28.1	26.42	10.63	9.57	52.7
6	Boron at 6 kg/ha + 30 × 30 cm	18.4	299.0	28.9	29.25	8.04	8.18	50.0
7	Iron at 20 kg/ha + 20 × 20 cm	14.1	203.2	24.9	22.26	7.32	11.13	39.7
8	Iron at 20 kg/ha + 25 × 25 cm	15.2	266.5	25.3	24.94	8.72	10.37	45.7
9	Iron at 20 kg/ha + 30 × 30 cm	17.9	278.8	25.9	25.91	7.29	8.90	45.1
10	Control (N-P-K 120-60-60 kg/ha)	14.2	216.5	22.8	15.72	5.42	8.40	39.9
	F-Test	S	S	S	S	S	S	S
	S.Em (±)	0.79	12.52	0.79	1.44	0.23	0.83	1.98
	C.D. (p=0.05)	2.36	37.20	2.33	4.29	0.68	2.45	5.89

Number of Grains/Panicle

Significantly maximum number of grains/panicle (299) were recorded in T₆ Boron at 6 kg/ha + 30 × 30 cm, whereas the application of T₅ Boron at 6 kg/ha + 25 × 25 cm (286.5), T₈ Iron at 20 kg/ha + 25 × 25 cm (266.5) and T₉ Iron at 20 kg/ha + 30 × 30 cm (278.8) were found to be statistically at par with the

highest. The superiority of Boron at this dosage is attributed to its fundamental role in pollen germination and pollen tube elongation, which directly reduces spikelet sterility and enhances grain filling (Rehman *et al.*, 2012) [15] and the wider 30 × 30 cm² geometry likely facilitated higher light interception and reduced inter-plant competition, providing a physiological advantage for

individual hills to accumulate more biomass and divert it toward reproductive sinks. This is supported by (Srivastava *et al.*, 2014)^[19].

Panicle length

Significantly higher panicle length (28.9 cm) was recorded in T₆ Boron at 6 kg/ha + 30 × 30 cm, whereas the application of T₅ Boron at 6 kg/ha + 25 × 25 cm (28.1 cm), T₂ Zinc at 10 kg/ha + 25 × 25 cm (27.4 cm) and T₃ Zinc at 10 kg/ha + 30 × 30 cm (28.5 cm) were found to be statistically at par with the highest. Boron application significantly enhances key growth parameters, including tiller and panicle development per plant, by ensuring robust nutrient availability throughout the crop cycle (Saleem *et al.*, 2011)^[17]. The significantly higher panicle length (28.9 cm) observed under T₆ (Boron + 30 × 30 cm) and its statistical parity with T₃ (30 × 30 cm) confirms that a wider planting geometry increases individual resource allocation. This open configuration minimizes mutual canopy shading and improves the interception of sunlight per hill, boosting photosynthesis and directing more carbohydrates toward panicle growth (M. Monjurul, 2013)^[11]. Concurrently, the parity maintained by T₅ and T₂ demonstrates that balancing nutritional demands with Boron or Zinc at a narrower spacing (25 × 25 cm) can successfully alleviate localized root-zone competition and resource limitations (Rex Immanuel, 2021)^[16].

Test weight

Significantly maximum test weight (29.25 g) was recorded in T₆ Boron at 6 kg/ha + 30 × 30 cm, whereas the application of T₃ Zinc at 10 kg/ha + 30 × 30 cm (25.02 g), T₅ Boron at 6 kg/ha + 25 × 25 cm (26.42 g) and T₃ Iron at 20 kg/ha + 30 × 30 cm (25.91 g) were found to be statistically at par with the highest. The superiority of Boron at this dosage is attributed to its fundamental role in pollen germination and pollen tube elongation, which directly reduces spikelet sterility and enhances grain filling (Rehman *et al.*, 2012)^[15]. Furthermore, the wider 30 × 30 cm² geometry likely facilitated higher light interception and reduced inter-plant competition, providing a physiological advantage for individual hills to accumulate more biomass and divert it toward reproductive sinks. This is supported by (Srivastava *et al.*, 2014)^[20].

Straw yield (t/ha)

Straw yield (12.38 t/ha) were significantly highest in T₂ Zinc at 10 kg/ha + 20 × 20 cm, whereas the application of Zinc at 10 kg/ha + 25 × 25 cm (10.43 t/ha), T₄ Boron at 6 kg/ha + 20 × 20 cm (11.35 t/ha), T₇ Iron at 20 kg/ha + 20 × 20 cm (11.13 t/ha) and T₈ Iron at 20 kg/ha + 25 × 25 cm (10.37 t/ha) were found to be statistically at par with the highest. The significantly maximum straw yield (12.38 t/ha) recorded under T₂ (Zinc @ 10 kg/ha + 20 × 20 cm) is primarily due to the closer planting layout, which increases the total plant population per unit area and directly drives up cumulative vegetative biomass and dry matter accumulation per hectare (Amanullah *et al.*, 2020)^[3]. This elevated crop density was benefited directly from Zinc fertilization, which is involved in protein synthesis, and hormone production that enhance vegetative crop growth (Chauhan *et al.*, 2017)^[4]. At the same time, the similar values seen with treatments under a wider layout (25 × 25 cm) or alternative micronutrients (T₄ Boron and T₇ Iron under 20 × 20 cm) suggests that balanced micronutrient management can effectively enhance individual plant growth and vegetative structural weight. This nutritional optimization serves to fully compensate for lower localized plant populations by boosting individual hill phenotypic performance.

Grain yield (t/ha)

Grain yield (10.63 t/ha) was recorded maximum with application of T₅ Boron at 6 kg/ha + 25 × 25 cm, which was found to be statistically at par with all treatments.

Harvest Index

Significantly higher harvest index (52.7%) was recorded in T₅ Boron at 6 kg/ha + 25 × 25 cm, which was found to be statistically at par with all treatments.

while the 30 × 30 cm² spacing excelled in individual plant performance, the maximum grain yield (10.63 t/ha) and Harvest Index (52.7%) were recorded with Boron at 6 kg/ha at a slightly denser spacing of 25 × 25 cm. This suggests that while wider spacing improves individual plant parameters, the 25 × 25 cm configuration provides an optimal plant population per unit area (16 hills/m² compared to 11.11 hills/m²), balancing individual productivity with overall community yield. This finding is strongly validated by (Ram *et al.*, 2014)^[14], observed that wider spacing 30 × 30 cm gave significantly more tillers/hill and grains/panicle. however, the yield was significantly higher in the closer spacing of 25 cm × 25 cm. The significant increase in Harvest Index at 25 × 25 cm indicates a more efficient partitioning of dry matter into the grain. Conversely, the highest straw yield (12.38 t/ha) was associated with Zinc at 10 kg/ha, likely due to Zinc's role in auxin synthesis and vegetative elongation (Midya *et al.*, 2021)^[12].

4. Conclusion

It is concluded that Application of Treatment T₅ (Boron at 6 kg/ha + 25 × 25 cm spacing) recorded highest Yield and B:C ratio in rice crop grown under the system of Rice Intensification (SRI).

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Competing Interests

The authors have declared that no competing interests exist.

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