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To investigate the impact of zinc on the growth and yield of green gram (*Vigna radiata* L.) cultivated in zinc-deficient soil

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Abstract

During the Kharif season of 2024-2025, a field experiment was done at the research farm of the Department of Soil Science at the College of Agriculture in Latur. The experiment looked at the "Effect of zinc application on yield, nutrient uptake and quality of green gram (*Vigna radiata* L.) grown on zinc-deficient soil." The experiment utilized a randomized block design with three replications and eight treatments featuring the green gram variety BM-2003-2.

In summary, the results showed that the growth and yield of green gram were significantly affected by the application of zinc along with the recommended dose of fertilizer (RDF). The treatment involving RDF combined with S.A. Grade-I micronutrient at 25 kg ha^{-1} and F.A. Grade-II micronutrient at 0.5% applied at 25 and 40 days after sowing (T8) led to a notable improvement in growth parameters such as plant height, leaf area, and number of nodules per plant. These growth improvements were similar to those observed in treatments T5 (RDF + S.A. of $ZnSO_4$ at 25 kg ha^{-1} + F.A. of $ZnSO_4$ at 0.5% applied at 25 and 40 DAS) and T3 (RDF + S.A. of $ZnSO_4$ at 25 kg ha^{-1}).

The application of RDF combined with S.A. Grade-I micronutrient at 25 kg ha^{-1} and F.A. Grade-II micronutrient at 0.5% applied at 25 and 40 days after sowing (T8) led to a significantly higher number of pods per plant, grains per pod, seed yield per plot, seed yield per hectare, straw yield per plot and straw yield per hectare. These results were also comparable to those observed in treatments T5 (RDF + S.A. of $ZnSO_4$ at 25 kg ha^{-1} + F.A. of $ZnSO_4$ at 0.5% applied at 25 and 40 DAS) and T3 (RDF + S.A. of $ZnSO_4$ at 25 kg ha^{-1}).

Keywords: Green gram, $ZnSO_4$, grade-I, grade-II, growth and yield

Introduction

The green gram (*Vigna radiata* L.) is known as Mung in Hindi and Mung bean in English. It is considered the most resilient among all pulse crops. Belonging to the Leguminosae family, green gram originated primarily in India and is mainly grown across East Asia, Southeast Asia, and the Indian subcontinent. In India, it ranks third in importance for pulse crops, following pigeon pea and chickpea, based on both production and cultivation area. (Singh *et al*. 2017). India is the world's largest producer of green gram, accounting for over 70% of the global crop and approximately 65% of the global area and 54% of the global production. Green gram is cultivated across almost all Indian states, with major growing regions including Andhra Pradesh, Maharashtra, Orissa, Rajasthan, Gujarat, Punjab, and Uttar Pradesh. In India, green gram is grown on 3.57 million hectares, yielding a total production of 17.89 metric tonnes with a productivity of 500 kg per hectare. (Anonymous, 2021) [4]. Green gram is an short-duration legume crop with a notable amount of riboflavin and thiamine, as well as 25 per cent protein with excellent digestion (Lokhande *et al*. 2018) [9].

Zinc is a critical micronutrient essential for plant growth, acting as a foundation of nutrition. Soil zinc levels in pasture and forage are often low (20-30 mg kg^{-1}). Zinc is vital for enzyme function, including dehydrogenases and superoxide dismutase, and its deficiency impairs RNA and protein production, leading to low plant protein content. Foliar spraying of zinc is considered essential for enhancing green gram growth and quality. Zinc regulates plant metabolic reactions, such as chlorophyll formation, and influences plant growth hormone production, including the biosynthesis of IAA, which can increase crop yield. It also contributes to protein, nucleic acid, and seed synthesis, and regulates the balance of carbonic acid, water, and CO_2 in plant metabolism (Ranpariya *et al*. 2017) [11].

Zinc efficiency can negatively impact the quality of harvested crops. It may also increase the plant's vulnerability to damage caused by intense light, high temperatures and fungal infections. Additionally, zinc appears to influence the plant's ability to absorb and transport water, as well as lessen the harmful effects of brief periods of heat and salt stress. The correct structure of macromolecules, iron transport systems, and cell membrane integrity all depend on zinc. Zinc sulfate can be sprayed on leaves or applied to the soil as a basal dose. Zinc is essential for the growth and development of plants, despite being needed in trace amounts. Auxins, which control growth and encourage stem elongation, are produced using it, and it is an essential part of many proteins and enzymes. It has been demonstrated that applying zinc improves growth parameters, irrespective of the dosage or technique. Zinc also increases the concentration of zinc in plant shoots when it is sprayed on leaves or incorporated into the soil (Abbas *et al.* 2010) [1].

Material and Methods

The field experiment was conducted at the research field of the Department of Soil Science at the College of Agriculture, Latur, during the *Kharif* season of 2024-2025. to investigate the "effect of zinc application on yield, nutrient uptake and quality of green gram (*Vigna radiata* L.) grown on zinc-deficient soil." The field topography was uniformly leveled, well-drained and conducive to the best possible crop growth. The experimental soil had a clayey texture, a slightly alkaline reaction, low levels of available nitrogen (228.33 kg ha^{-1}), available phosphorous (14.02 kg ha^{-1}) and high levels of available potassium (418.14 kg ha^{-1}). It was also deficient in DTPA-Zn (0.50 mg kg^{-1}). According to this data, the average temperature for the crop-growing season is 35.2°C at its highest point and 16.10°C at its lowest. The mean humidity during morning is 98.00% while mean humidity during evening is 30.86 %.

The experiment was conducted using a randomized block design with three replications and eight different treatments. The treatments were as follows: T1 - (Control), T2 - (RDF), T3 - (RDF combined with soil application (S.A.) of $ZnSO_4$ at 25 kg ha^{-1}), T4 - (RDF with foliar application (F.A.) of $ZnSO_4$ at 0.5% concentration applied at 25 and 40 days after sowing (DAS), T5 - (RDF with both soil application of $ZnSO_4$ at 25 kg ha^{-1} and foliar application at 0.5% at 25 and 40 DAS), T6 - (RDF with soil application of Grade-I micronutrient at 25 kg ha^{-1}), T7-(RDF with foliar application of Grade-II micronutrient at 0.5% at 25 and 40 DAS) and T8 - (RDF with both soil application of Grade-I micronutrient at 25 kg ha^{-1} and foliar application of Grade-II micronutrient at 0.5% at 25 and 40 DAS).

Each experimental unit measured 3.9 m by 4.0 m. Sowing was carried out using the drilling method on July 25, 2024, with a spacing of 30 cm between rows and 10 cm between plants. Recommended agronomic practices and plant protection measures were followed throughout the experiment. A fertilizer dose of 25:50:25 NPK kg ha^{-1} was applied according to the respective treatments. Prior to sowing, seeds were treated with rhizobium biofertilizer and SAAF fungicide, and foliar sprays of zinc and multi-micronutrients were applied as per the treatment requirements.

The crop was harvested on September 8, 2024.

Result and Discussion

Growth Parameters

Plant height

The data revealed that the application of zinc at key growth stages had a significant effect on the plant height of green gram at 30 DAS, 45 DAS, and at harvest. Plant height varied from 29.16 to 43.40 cm at 30 DAS, 34.59 to 49.63 cm at 45 DAS, and from 38.45 to 53.12 cm at the time of harvest.

The maximum plant height in green gram was observed under treatment T8, which involved the application of the recommended dose of fertilizers (RDF) along with soil application (S.A.) of Grade-I micronutrients at 25 kg ha^{-1} and foliar application (F.A.) of Grade-II micronutrients at 0.5% concentration at 25 and 40 days after sowing (DAS). This treatment resulted in plant heights of 43.40 cm at 30 DAS, 49.63 cm at 45 DAS, and 53.12 cm at harvest. These values were statistically on par with treatment T5 (RDF + S.A. of $ZnSO_4$ @ 25 kg ha^{-1} + F.A. of $ZnSO_4$ @ 0.5% at 25 and 40 DAS) and treatment T3 (RDF + S.A. of $ZnSO_4$ @ 25 kg ha^{-1}), and significantly superior to all other treatments. In contrast, the lowest plant height was recorded in the control (T1), with measurements of 29.16 cm at 30 DAS, 34.59 cm at 45 DAS, and 38.45 cm at harvest. The results are confirmative with the finding of Ajjannavar *et al.* (2021) [2], Boradkar *et al.* (2023) [5] and Almad *et al.* (2020) [3].

Number of nodulations at flowering

The data on the number of nodules per plant in green gram, as affected by zinc application and recorded during the flowering stage, are presented. During this stage, the number of nodules $plant^{-1}$ ranged from 15.02 to 19.82.

The highest number of nodules $plant^{-1}$ (19.82) was recorded in treatment T8, which included RDF along with soil application of Grade-I micronutrients at 25 kg ha^{-1} and foliar application of Grade-II micronutrients at 0.5% at 25 and 40 DAS. This result was statistically similar to treatments T5 (RDF + soil application of $ZnSO_4$ at 25 kg ha^{-1} + foliar application of $ZnSO_4$ at 0.5% at 25 and 40 DAS) and T3 (RDF + soil application of $ZnSO_4$ at 25 kg ha^{-1}), and significantly better than the other treatments. The lowest number of nodules $plant^{-1}$ (15.02) was observed in the control treatment (T1). Similar findings were reported by Kumar *et al.* (2020) [8], Boradkar *et al.* (2023) [5] and Meena *et al.* (2013) [10].

Leaf area

Data showed that leaf area of green gram was varied from 380.47 to 518.23 cm^2 at 30 DAS and 402.27 to 554.20 cm^2 at 45 DAS.

The highest leaf area, measuring 518.23 cm^2 and 554.20 cm^2 $plant^{-1}$ at 30 and 45 days after sowing (DAS), respectively, was observed in treatment T8 (RDF combined with soil application of Grade-I micronutrients at 25 kg ha^{-1} and foliar application of Grade-II micronutrients at 0.5% at 25 and 40 DAS). This treatment was statistically on par with T5 (RDF + soil application of $ZnSO_4$ at 25 kg ha^{-1} + foliar application of $ZnSO_4$ at 0.5% at 25 and 40 DAS) and T3 (RDF + soil application of $ZnSO_4$ at 25 kg ha^{-1}) and significantly outperformed the other treatments. In contrast, the lowest leaf area, 380.47 cm^2 and 402.27 cm^2 $plant^{-1}$ at 30 and 45 DAS, respectively, was recorded in the control treatment (T1). Similar result was reported by Almad *et al.* (2020) [3], Boradkar *et al.* (2023) [5] and Gowda *et al.* (2014) [7].

Yield and yield attributes

Number of pods plant^{-1} and Number of grains pod^{-1}

The data revealed that the highest number of pods plant^{-1} (29.95) was observed in treatment T8 (RDF + soil application of Grade-I micronutrient at 25 kg ha^{-1} + foliar application of Grade-II micronutrient at 0.5% at 25 and 40 DAS). This was statistically on par with treatment T5 (RDF + soil application of $ZnSO_4$ at 25 kg ha^{-1} + foliar application of $ZnSO_4$ at 0.5% at 25 and 40 DAS) and treatment T3 (RDF + soil application of $ZnSO_4$ at 25 kg ha^{-1}) and significantly better than the remaining treatments. The lowest number of pods plant^{-1} (25.08) was recorded in treatment T1 (Control).

Likewise, the highest number of seeds pod^{-1} (13.85) was recorded in treatment T8 (RDF + soil application of Grade-I micronutrient at 25 kg ha^{-1} + foliar application of Grade-II micronutrient at 0.5% at 25 and 40 DAS). This value was comparable to that in treatment T5 (RDF + soil application of $ZnSO_4$ at 25 kg ha^{-1} + foliar application of $ZnSO_4$ at 0.5% at 25 and 40 DAS) and treatment T3 (RDF + soil application of $ZnSO_4$ at 25 kg ha^{-1}), and significantly higher than in the other treatments. The lowest number of seeds per pod (10.72) was found in treatment T1 (Control) in green gram. Similar findings were reported by Gidaganti *et al.* (2019) [6], Banoth *et al.* (2022) and Boradkar *et al.* (2023) [5].

Seed yield (kg ha-1)

It was clearly noted that application of zinc showed beneficial effect on grain yield as compared to control. The seed yield of green gram ranged between 865.38 kg ha^{-1} to 1408.12 kg ha^{-1}. The highest seed yield (1408.12 kg ha^{-1}) was achieved with treatment T8, which involved the application of RDF along with soil application of Grade-I micronutrients at 25 kg ha^{-1} and foliar application of Grade-II micronutrients at 0.5% at 25 and 40 days after sowing (DAS). This yield was statistically on par with treatment T5 (RDF + soil application of $ZnSO_4$ at 25 kg ha^{-1} + foliar application of $ZnSO_4$ at 0.5% at 25 and 40 DAS) and treatment T3 (RDF + soil application of $ZnSO_4$ at 25 kg ha^{-1}) and significantly higher than all other treatments. In contrast, the lowest seed yield (865.38 kg ha^{-1}) was observed under treatment T1 (Control). These results are in line with Gidaganti *et al.* (2019) [6], Ajjannavar *et al.* (2021) [2] and Boradkar *et al.* (2023) [5].

Straw yield (kg ha^{-1})

The data showed that the straw yield of the green gram crop increased with the application of zinc, ranging from 1371.79 to 1976.50 kg ha^{-1}.

The highest straw yield (1976.50 kg ha^{-1}) was observed in treatment T8 (RDF combined with S.A. Grade-I micronutrient at 25 kg ha^{-1} and F.A. Grade-II micronutrient at 0.5% applied at 25 and 40 DAS). This yield was statistically similar to treatment T5 (RDF with S.A. of ZnSO4 at 25 kg ha^{-1} and F.A. of ZnSO4 at 0.5% applied at 25 and 40 DAS) and treatment T3 (RDF with S.A. of ZnSO4 at 25 kg ha^{-1}), but significantly higher than all other treatments. In contrast, the lowest straw yield (1371.79 kg ha^{-1}) was recorded in treatment T1 (Control). The results explained above are in close conformity with the findings of Almad *et al.* (2020) [3], Meena *et al.* (2013) [10] and Boradkar *et al.* (2023) [5].

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Conclusion

1. Green gram crops fertilized with RDF combined with S.A. Grade-I micronutrient at 25 kg ha^{-1} and F.A. Grade-II micronutrient at 0.5% applied at 25 and 40 days after sowing showed improved growth parameters such as plant height, leaf area and number of nodules plant^{-1}. This treatment was found to be comparable to the application of RDF with S.A. of $ZnSO_4$ at 25 kg ha^{-1} plus F.A. of $ZnSO_4$ at 0.5% at 25 and 40 DAS, as well as RDF with S.A. of $ZnSO_4$ at 25 kg ha^{-1}.
2. The application of RDF combined with S.A. Grade-I micronutrient at 25 kg ha^{-1} and F.A. Grade-II micronutrient at 0.5% at 25 and 40 days after sowing resulted in a significantly higher number of pods plant^{-1}, grains pod^{-1}, seed yield plot^{-1}, seed yield hectre^{-1}, straw yield plot^{-1} and straw yield hectare^{-1}. This treatment was found to be comparable to the RDF + S.A. of $ZnSO_4$ at 25 kg ha^{-1} + F.A. of $ZnSO_4$ at 0.5% applied at 25 and 40 DAS, as well as RDF + S.A. of $ZnSO_4$ at 25 kg ha^{-1} alone.

Table 1: Effect of zinc application on plant height (cm) of green gram at 30, 45 DAS and at harvest.

Treatments	**Plant height** (cm)		
	30 DAS	**45 DAS**	**At harvest**
T1: Control	29.16	34.59	38.45
T2: RDF	32.75	36.27	41.80
T3: RDF + S.A. of $ZnSO_4$ @ 25 kg ha^{-1}.	41.79	46.85	50.71
T4: RDF + F.A. of $ZnSO_4$ @ 0.5 % at 25 and 40 DAS.	39.30	44.68	48.20
T5: RDF + S.A. of $ZnSO_4$ @ 25 kg ha^{-1} + F.A. of $ZnSO_4$ @ 0.5 % at 25 and 40 DAS.	42.59	47.51	51.39
T6: RDF + S.A. Grade-I micro-nutrient @ 25 kg ha^{-1}.	37.77	43.36	47.14
T7: RDF + F.A. Grade-II micro-nutrient @ 0.5 % at 25 and 40 DAS.	36.56	42.06	46.10
T8: RDF + S.A. Grade-I micro-nutrient @ 25 kg ha^{-1} + F.A. Grade-II micro-nutrient @ 0.5 % at 25 and 40 DAS.	43.40	49.63	53.12
SE (m) ±	0.63	1.03	0.95
CD at 5%	1.91	3.13	2.88

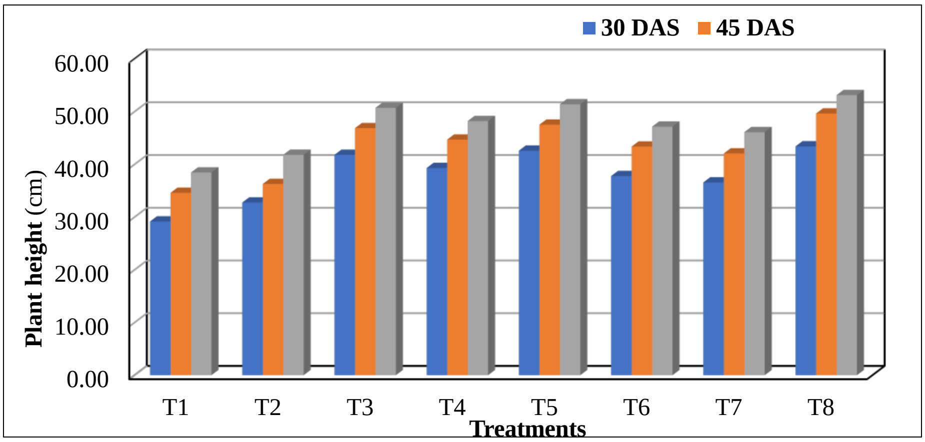


Table 2: Effect of zinc application on leaf area (cm² plant⁻¹) of green gram.

Treatments	Leaf Area (cm² plant⁻¹)	
	30 DAS	45 DAS
T1: Control	380.47	402.27
T2: RDF	405.13	424.22
T3: RDF + S.A. of $ZnSO_4$ @ 25 kg ha^{-1}.	501.72	533.65
T4: RDF + F.A. of $ZnSO_4$ @ 0.5 % at 25 and 40 DAS.	485.50	510.80
T5: RDF + S.A. of $ZnSO_4$ @ 25 kg ha^{-1} + F.A. of $ZnSO_4$ @ 0.5 % at 25 and 40 DAS.	509.87	539.98
T6: RDF + S.A. Grade-I micro-nutrient @ 25 kg ha^{-1}.	448.46	472.51
T7: RDF + F.A. Grade-II micro-nutrient @ 0.5 % at 25 and 40 DAS.	427.15	447.54
T8: RDF + S.A. Grade-I micro-nutrient @ 25 kg ha^{-1} + F.A. Grade-II micro-nutrient @ 0.5 % at 25 and 40 DAS.	518.23	554.20
SE (m) ±	6.73	7.53
CD at 5%	20.43	22.83

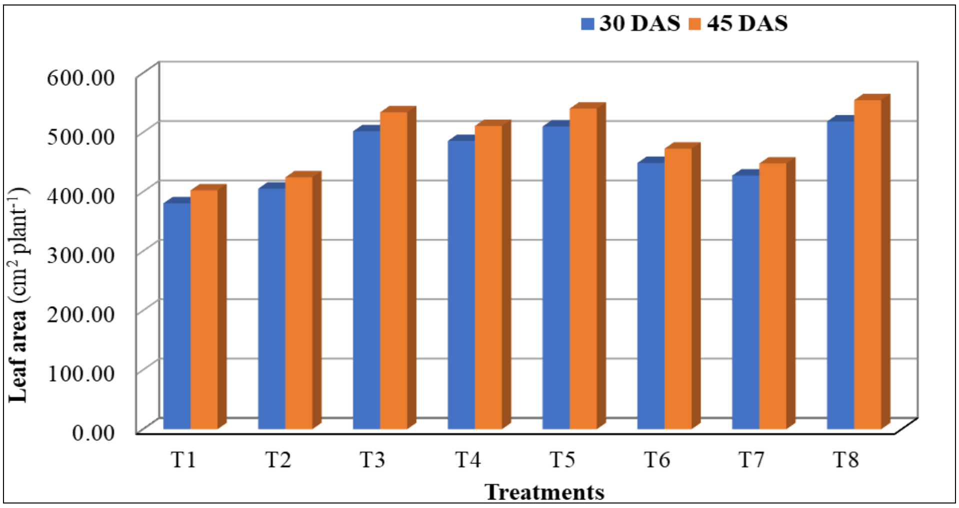


Table 3: Effect of zinc application on nodulation of green gram.

Treatments	Root nodules at flowering stage (plant⁻¹)
T1: Control	15.02
T2: RDF	16.28
T3: RDF + S.A. of $ZnSO_4$ @ 25 kg ha^{-1}.	19.48
T4: RDF + F.A. of $ZnSO_4$ @ 0.5 % at 25 and 40 DAS.	18.58
T5: RDF + S.A. of $ZnSO_4$ @ 25 kg ha^{-1} + F.A. of $ZnSO_4$ @ 0.5 % at 25 and 40 DAS.	19.69
T6: RDF + S.A. Grade-I micro-nutrient @ 25 kg ha^{-1}.	18.43
T7: RDF + F.A. Grade-II micro-nutrient @ 0.5 % at 25 and 40 DAS.	17.93
T8: RDF + S.A. Grade-I micro-nutrient @ 25 kg ha^{-1} + F.A. Grade-II micro-nutrient @ 0.5 % at 25 and 40 DAS.	19.82
SE (m) ±	0.36
CD at 5%	1.10

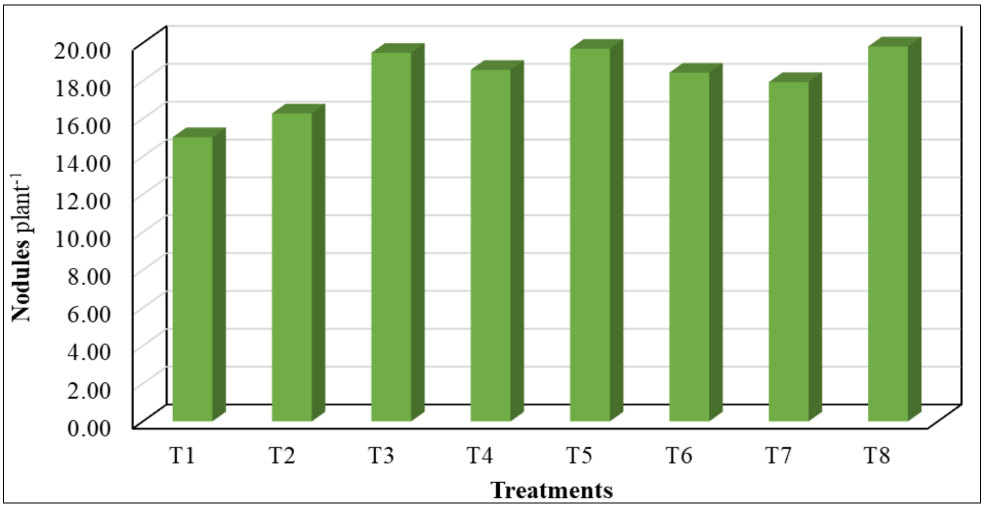


Table 4: Effect of zinc application on number of pods (plant^{-1}) and number of grains (pod^{-1}) of green gram.

Treatments	No. of pods (plant^{-1})	No. of grains (pod^{-1})
T1: Control	25.08	10.72
T2: RDF	25.75	11.25
T3: RDF + S.A. of $ZnSO_4$ @ 25 kg ha^{-1}.	29.56	13.32
T4: RDF + F.A. of $ZnSO_4$ @ 0.5 % at 25 and 40 DAS.	28.40	12.71
T5: RDF + S.A. of $ZnSO_4$ @ 25 kg ha^{-1} + F.A. of $ZnSO_4$ @ 0.5 % at 25 and 40 DAS.	29.71	13.65
T6: RDF + S.A. Grade-I micro-nutrient @ 25 kg ha^{-1}.	27.95	12.25
T7: RDF + F.A. Grade-II micro-nutrient @ 0.5 % at 25 and 40 DAS.	27.47	11.70
T8: RDF + S.A. Grade-I micro-nutrient @ 25 kg ha^{-1} + F.A. Grade-II micro-nutrient @ 0.5 % at 25 and 40 DAS..	29.95	13.85
SE (m) ±	0.47	0.24
CD at 5%	1.44	0.73

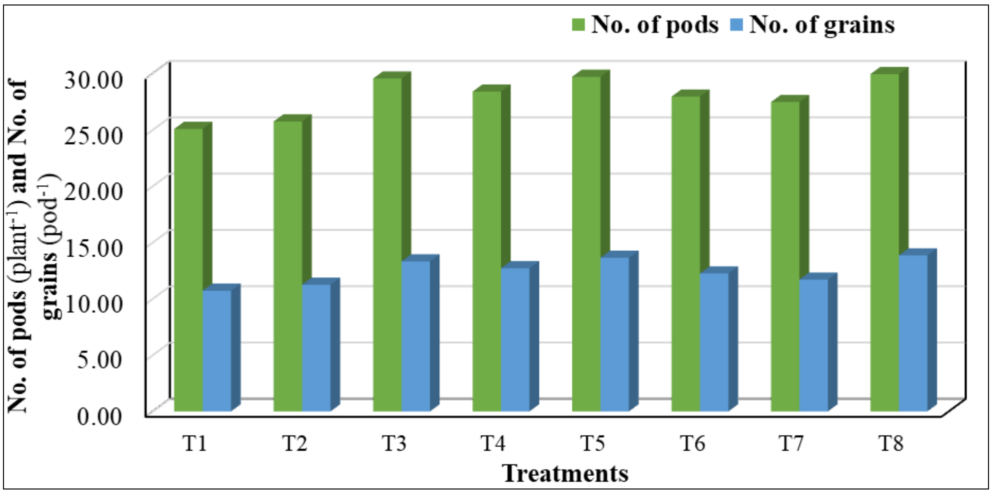
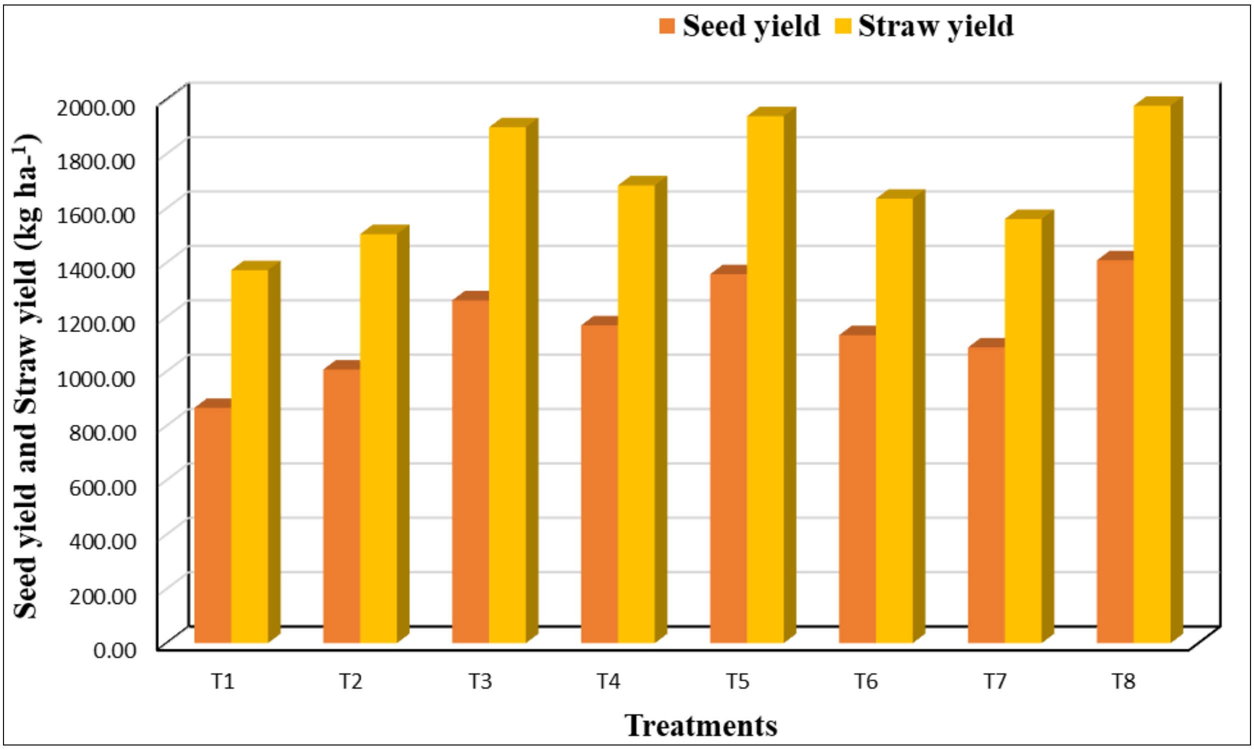


Table 5: Effect of zinc application on grain yield (g plot^{-1}) and straw yield (kg ha^{-1}) of green gram.

Treatments	**Seed yield** (kg ha^{-1})	**Straw yield** (kg ha^{-1})
T1: Control	865.38	1371.79
T2: RDF	1006.41	1504.27
T3: RDF + S.A. of $ZnSO_4$ @ 25 kg ha^{-1}.	1260.68	1897.44
T4: RDF + F.A. of $ZnSO_4$ @ 0.5 % at 25 and 40 DAS.	1168.80	1683.76
T5: RDF + S.A. of $ZnSO_4$ @ 25 kg ha^{-1} + F.A. of $ZnSO_4$ @ 0.5 % at 25 and 40 DAS.	1356.84	1938.03
T6: RDF + S.A. Grade-I micro-nutrient @ 25 kg ha^{-1}.	1132.48	1634.62
T7: RDF + F.A. Grade-II micro-nutrient @ 0.5 % at 25 and 40 DAS.	1087.61	1559.83
T8: RDF + S.A. Grade-I micro-nutrient @ 25 kg ha^{-1} + F.A. Grade-II micro-nutrient @ 0.5 % at 25 and 40 DAS.	1408.12	1976.50
SE (m) ±	57.60	67.93
CD at 5%	174.72	206.05



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