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Foliar application of zinc its effect in plant growth and seed yield of green gram (*Vigna radiata* L.)

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Abstract
Ten treatment combination of zinc along with RDF dose applied in green gram were evaluated for study entitled "Foliar application with zinc on growth & yield parameter of Green gram [*Vigna radiata* (L.)]". The experiment was conducted in a Randomized Block Design with three replications during the *Kharif* season 2023 at Field experimentation centre, Department of Genetics and Plant Breeding, Naini Agriculture Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Naini, Prayagraj, U.P. the plant to plant distance was 10 cm and row to row distance was 30 cm. the data were recorded from randomly selected five plants for each treatments for each replications for fifteen characters viz. days to field emergence, days to 50% flowering, days to 50% pod setting, days to maturity, plant height (cm), number of primary branches, number of secondary branches, number of pods per plant, length of pod (cm), number of seeds per pod, 1000-seed weight (g), biological yield (g), harvest index, seed yield per plant (g/plant) and seed yield per hectare (kg/ha). Treatment combination comprise of T_0 (RDF + Water spray (Control)); T_1 (RDF + Zn @ 0.5%); T_2 (RDF + Zn @ 0.9%); T_3 (RDF + Zn @ 1%); T_5 (RDF + Zn @ 0.3%); T_5 (RDF + Zn @ 0.5%); T_6 (RDF + Zn @ 0.9%); T_7 (RDF + Zn @ 1.0%) and T_8 (RDF+ Zn @ 0.3%); T_9 (RDF + Zn @ 0.5%). From the present investigation it is concluded that among 10 treatment combination of foliar spray of nutrients applied in green gram, Treatment combination T_9 (RDF+ Zn @ 0.5%) performed best in terms of yield parameters like number of pods per plant, number of seeds per pod, seed yield per plant, seed index. It was second highest in harvest index and second most early in flowering and maturing. Therefore, combination used in T_9 i.e., RDF+ Zn @ 0.5% can be promoted to use to get better yield and overcome low productivity in green gram.

Keywords: *Vigna radiata*, foliar spray, zinc

Introduction
Pulses are an important part of profitable agriculture because a large section of population relies on them as they are low priced source of proteins (Usman *et al*., 2014) [17]. The protein from pulses is easily digestible, relatively cheaper and has higher biological values. The lysine rich protein of pulses are considered to supplement the deficiency of this amino acid in cereal dietaries and because of this pulses are called as "poor man's protein". (Ramamurthi *et al*., 2012) [14]. The per capita availability of pulses is decreased from 70 g in 1959 to 31.6 g capita-1 day-1 in 2011 as against the minimum requirement of 84 g capita^{-1} day-1 prescribed by Indian Council of Medical Research, which is causing malnutrition among the growing population (Anonymous, 2011) [2].

Green gram (*Vigna radiata* L.) originated in Indo-Burma and area of South East Asia. It is a high protein 23-24% legume, occupies 14 per cent of total pulses area and 7 per cent of total pulse production in India. It is also called as Golden gram. It belongs to family Leguminaceae and sub family Papilionaceae. Pulses are the most favoured crops in semi-arid tropics on account of their less input requirement, intrinsic capacity of biological nitrogen fixation, less water requirement deep rooting system and high temperature tolerance. Since prehistoric times, green gram (*Vigna radiata* L.) has been an important short season grain legume and staple diet of humans and livestock throughout S.E. Asia. *Vigna radiata*, commonly known as green gram or mung bean is the most widely distributed species among the six Asiatic Vigna species. It has diploid chromosomes no 2n=22. It is known differently in different Indian languages.

It is a rich source of calcium 68 mg 100-1 g seeds and phosphorous 300 mg 100^{-1} g seed and iron 7 mg 100-1 g seed. It is also rich in vitamin C and riboflavin. It is one of the predominant sources of protein and certain essential amino acids like lysine and tryptophan in vegetarian diets. It also provides 334-344 Kcal Energy.

Zinc efficiency can also adversely affect the quality of harvested products, plants susceptibility to injury by high light or temperature intensity and infection by fungal diseases can also increase. Its seems to affect the capacity for water uptake and transport in plants and also reduce the adverse effects of short periods of heat and salt stress. As zinc is required for the synthesis of tryptophan which is a precursor of IAA. It also had an active role in production of an essential growth hormone auxin. The zinc is required for integrity of cellular membranes to preserve the structural orientation of macromolecules and iron transport systems. Zinc sulphate is applied as basal as well as foliar. It is needed by plants in small amounts, but yet crucial to plant development. In plants, zinc is key constituent of many enzymes and proteins. It is essential in the formation of auxins, which help with growth regulation and stem elongation. Growth parameters were increased by zinc application regardless to its concentration and application method. Zinc application either through soil or foliar application, also increases the Zn content of shoot (Abbas and Zaynab, 2010) [1].

Materials and Methods

Location and climatic conditions of the experimental farm

The present investigation was carried out in the Field at Central Research Farm of Department of Genetics and Plant Breeding, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, U.P during *Kharif*- 2023. The University is situated on the left side of Prayagraj – Rewa National Highway, about 5 km away from Prayagraj City. Prayagraj falls in central plain sub-zone of Agro-climatic zone V (Source: Perspective and Strategic Plan (SPSP) for IWMP of Uttar Pradesh, Department of Land Development and Water Resources, Government of U.P.). Naini is situated between the parallels of 20° 33’ 40’’ to 21’’ .50’ N latitude and 73° 27’ 58’’ and 73° 56’ 36’’ E longitude.

Table 1: List of Treatments

Treatment	Concentration	Duration
T_0	RDF + Water SPRAY (Control)	-
T_1	RDF + Zn @ 0.5%	30 DAS
T_2	RDF + Zn @ 0.9%	30 DAS
T_3	RDF + Zn @ 1.0%	30 DAS
T_4	RDF + Zn @ 0.3%	30 DAS
T_5	RDF + Zn @ 0.5%	45 DAS
T_6	RDF + Zn @ 0.9%	45 DAS
T_7	RDF + Zn @ 1.0%	45 DAS
T_8	RDF + Zn @ 0.3%	45 DAS
T_9	RDF + Zn @ 0.5%	30 DAS + 45 DAS

The experiment was laid out in a Randomized Block Design with 10 treatments and replicated thrice. Data recorded on different aspects of crop, viz., growth, yield were subjected to statistically analysis by analysis of variance method. (Gomez and Gomez, 1976) and economic data analysis mathematical method.

Result and Discussion

Days to field emergence: The results pertaining to the effect of foliar spray of zinc on days to field emergence of green gram are presented in Table 2

There were significant differences observed statistically between different combinations of micronutrient doses applied in green gram. It was also found that T_9 (RDF + Zn @ 0.5%) took minimum days to field emergence (9.44 days) followed by T_7 (RDF + Zn @ 0.1%) with 10.56 days. While maximum days to field emergence was taken by T_0 (RDF + Water spray (Control)) with 15.24 days.

The earlier germination and field emergence of green gram treated with a combination of Recommended Dose of Fertilizers (RDF) and a zinc at 0.5% can be attributed to several factors. The RDF ensures that the plants receive an optimal balance of essential macronutrients, such as nitrogen, phosphorus, and potassium, which are critical for initial growth stages. The addition of a micronutrient mixture provides essential trace elements like zinc, which play vital roles in enzyme function, photosynthesis, and hormonal activity. This combination creates a nutrient-rich environment that supports robust seedling development. Enhanced nutrient availability accelerates metabolic processes and promotes root growth, leading to quicker water and nutrient uptake. As a result, seeds treated with RDF and zinc at 0.5% exhibit improved vigour and resilience, resulting in faster and more uniform germination and field emergence compared to other treatments lacking this balanced nutrient support. Similar findings were reported by Dash and Rautary (2017) [5]; in green gram.

Plant height

The results pertaining to the effect of foliar spray of zinc on plant height of green gram are presented in Table 2.

There were significant differences observed statistically between different combinations of zinc doses applied in green gram. Among various combinations applied, T_9 (RDF+ zinc @ 0.5%) had tallest height of plant (32.87 cm) followed by T_7 (RDF + Zn @ 0.1%) with 31.00 cm. While minimum plant height was observed in T_0 (RDF + Water spray (Control)) with 24.92 cm.

Green gram plants treated with a combination of the Recommended Dose of Fertilizers (RDF) and a mixture of all zinc at 0.5% exhibit increased height due to the synergistic effect of comprehensive nutrient provision. The RDF supplies essential macronutrients (nitrogen, phosphorus, potassium), crucial for cell division and elongation, while the micronutrient mixture zinc supports critical physiological processes like enzyme function and photosynthesis. This balanced nutrient environment fosters robust vegetative growth, leading to taller plants. Additionally, other treatment combinations, which might include partial or varied nutrient applications, still performed better than the control treatment. This improvement is because even partial nutrient supplementation enhances plant growth processes compared to the control, which lacks additional nutrient inputs. The control treatment likely suffers from nutrient deficiencies, limiting its growth potential. Therefore, any nutrient addition, particularly the comprehensive RDF + zinc combination, significantly boosts plant height by addressing both macronutrient and zinc needs. Similar findings were reported by Debroy *et al*., (2013) [6]; Muthal *et al*., (2016) [13] in green gram.

Number of primary branches per plant

The results pertaining to the effect of foliar spray of micronutrients on number of primary branches per plant of green gram are presented in Table 2.

There were significant differences observed statistically between different combinations of micronutrient doses applied in green

gram. Among various combinations applied, T_9 (RDF+ zinc @ 0.5%) had maximum number of primary branches per plant (5.16 branches) followed by T_7 (RDF + Zn @ 0.1%) with 4.92 branches. While minimum number of primary branches per plant was observed in T_0 (RDF + Water spray (Control)) with 3.28 branches.

Green gram plants treated with a combination of the Recommended Dose of Fertilizers (RDF) and a mixture of all zinc at 0.5% develop more primary branches due to the optimal supply of both macronutrients and micronutrients. The RDF provides essential macronutrients (nitrogen, phosphorus, potassium), which are critical for overall plant growth, including branching. The added zinc enhance specific physiological processes like hormonal balance and enzyme activities, which are vital for the development of lateral shoots. Other treatments, although not as comprehensive as the RDF + zinc, still improve the number of primary branches compared to the control treatment. This improvement is because any additional nutrient supply supports better growth than the control, which likely suffers from nutrient deficiencies. The control plants, lacking these inputs, exhibit restricted growth and fewer branches. Thus, the balanced and enriched nutrient environment provided by the RDF and zinc@ 0.5% significantly promotes the formation of primary branches by addressing all the nutritional needs of the plants. Findings were in accordance with findings of Divyashree *et al*., (2017) [8]; Kavya *et al*., (2021) [10] in green gram.

Number of secondary branches per plant

Table 2 present the results of the study on the impact of foliar spraying micronutrients on the number of secondary branches per plant of green gram. Significant statistical differences were found between the various combinations of micronutrient doses applied in green gram.

T_9 (RDF + zinc @0.5%) had highest number of secondary branches per plant among the different combinations applied, with 7.51 branches, followed by T_7 (RDF + Zn @0.1%), which had 7.49 branches. T_0 (RDF + Water spray (Control)) had the fewest secondary branches per plant, with 4.95 branches.

Because of the ideal supply of macro nutrients and micro nutrients, green gram plants treated with a combination of the Recommended Dose of Fertilizers (RDF) and a zinc at 0.5% develop more secondary branches. Nitrogen, phosphorus, and potassium are essential macro nutrients that the RDF supplies and are necessary for the general growth of plants, including branching. The supplementary zinc improve particular physiological functions, such as enzyme activity and hormonal balance, which are essential for the growth of lateral shoots. Compared to the control treatment, other treatments increase the number of secondary branches even though they are not as thorough as the RDF + zinc. This is an improvement because, in comparison to the control, which most likely has nutrient deficiencies, any additional nutrient supply promotes better growth. Without these inputs, the control plants grow more slowly and have fewer branches. Therefore, by meeting all of the plants' nutritional needs, the balanced and enriched nutrient environment that the RDF and zinc at 0.5% provide greatly encourages the formation of secondary branches. Results in green gram were consistent with those of Kumar *et al*. (2020) [11], and Boradkar *et al*., (2023) [4].

Days to 50% flowering

Table 2 present the results of the study on the impact of foliar spraying zinc on the days to 50% flowering of green gram. Significant statistical differences were found between the various combinations of micronutrient doses applied in green gram.

T_9 (RDF + Zn @ 0.5%) took minimum days to 50% flowering (40.17 days) among the different combinations applied followed by T_7 (RDF+ zinc @ 0.1%), (44.04) which had days. T_0 (RDF + Water spray (Control)) took maximum days to 50% flowering (51.92 days).

The earliness in flowering of green gram plants treated with a combination of the Recommended Dose of Fertilizers (RDF) and zinc (Zn) at 0.5% is due to the optimal supply of both macronutrients and the critical micronutrient zinc. RDF provides essential macronutrients (nitrogen, phosphorus, potassium), which are fundamental for vegetative and reproductive growth. Zinc, specifically, plays a crucial role in the synthesis of plant hormones such as auxins, which regulate flowering and other growth processes. This combination ensures that plants have a balanced nutrient profile, promoting quicker transition from vegetative growth to the flowering stage. Enhanced nutrient availability accelerates metabolic processes, leading to earlier flowering compared to other treatments. Additionally, all other nutrient treatments showed earlier flowering than the control due to the alleviation of nutrient deficiencies that hinder growth and development. The control treatment, lacking these supplementary nutrients, exhibits delayed flowering. Therefore, the combination of RDF and zinc at 0.5% significantly advances flowering time by addressing both macronutrient and micronutrient needs efficiently. Results in green gram were consistent with those of Muindi *et al*., (2021) [12], Dhaliwal *et al*., (2023) [7].

Days to 50% pod setting

Table 2 present the results of the study on the impact of foliar spraying micronutrients on the days to 50% pod setting of green gram. Significant statistical differences were found between the various combinations of micronutrient doses applied in green gram.

T_9 (RDF + Zn @ 0.5%) took minimum days to 50% pod setting (55.17 days) among the different combinations applied followed by T_7 (RDF+ zinc@ 0.1%), which had 59.04 days. T_0 (RDF + Water spray (Control)) took maximum days to 50% pod setting (66.92 days). The earliness in pod setting of green gram plants treated with a combination of the Recommended Dose of Fertilizers (RDF) and zinc (Zn) at 0.5% is due to the optimal supply of both macronutrients and the critical micronutrient zinc. RDF provides essential macronutrients (nitrogen, phosphorus, potassium), which are fundamental for vegetative and reproductive growth. Zinc, specifically, plays a crucial role in the synthesis of plant hormones such as auxins, which regulate pod setting and other growth processes. This combination ensures that plants have a balanced nutrient profile, promoting quicker transition from vegetative growth to the pod setting stage. Enhanced nutrient availability accelerates metabolic processes, leading to earlier pod setting compared to other treatments. Additionally, all other nutrient treatments showed earlier pod setting than the control due to the alleviation of nutrient deficiencies that hinder growth and development. The control treatment, lacking these supplementary nutrients, exhibits delayed pod setting. Therefore, the combination of RDF and zinc at 0.5% significantly advances pod setting time by addressing both macronutrient and micronutrient needs efficiently. Results in green gram were consistent with those of Dash and Rautary (2017) [5], Begum *et al*. (2018) [3].

B) Post-harvest parameters

Number of pods per plant

The study on the effect of foliar spraying zinc on the number of pods per plant of green gram is presented in Table 2. There were notable variations in the statistical analysis of the different combinations of micronutrient doses applied in green gram.

T_9 (RDF+ zinc @ 0.5%) had highest number of pods per plant (9.62 pods) among the different combinations applied followed by T_7 (RDF + Zn @ 0.1%), which had 9.37 pods. T_0 (RDF + Water spray (Control)) had lowest number of pods per plant (7.75 pods).

Green gram plants treated with a combination of the Recommended Dose of Fertilizers (RDF) and a zinc at 0.5% produce more pods per plant due to the comprehensive nutrient support provided. RDF supplies essential macronutrients (nitrogen, phosphorus, potassium), which are crucial for overall plant growth and reproductive development. The addition of a mixture of micronutrients zinc addresses specific deficiencies that could limit pod formation. These micronutrients play critical roles in enzyme function, hormone regulation, and photosynthesis, all of which are vital for flowering and pod setting. The balanced and adequate nutrient supply enhances metabolic activities and improves the plant's ability to produce and support more pods. Additionally, other treatments, although not as comprehensive as the RDF + zinc, still outperform the control treatment in terms of pod production. This is because even partial nutrient supplementation improves plant health and reproductive capacity compared to the control, which likely suffers from nutrient deficiencies that limit pod formation. Thus, the combination of RDF and zinc at 0.5% significantly boosts the number of pods per plant by providing a well-rounded nutrient profile. The outcomes in the green gram aligned with the findings of Muindi *et al*., (2020) [12].

Number of seeds per pod

The study on the effect of foliar spraying micronutrients on the number of seeds per pod of green gram is presented in Table 2. There were notable variations in the statistical analysis of the different combinations of micronutrient doses applied in green gram.

T_9 (RDF+ zinc @ 0.5%) had highest number of seeds per pod (9.86 seeds) among the different combinations applied at par with T_7 (RDF + Zn @ 0.1%), which had 9.55 seeds. T_0 (RDF + Water spray (Control)) had lowest number of seeds per pod (7.33 seeds).

Green gram plants treated with a combination of the Recommended Dose of Fertilizers (RDF) and a zinc at 0.5% produce more seeds per pod due to the comprehensive and balanced nutrient support provided. The RDF supplies essential macronutrients (nitrogen, phosphorus, potassium), which are critical for robust plant growth and reproductive development. The inclusion of a full spectrum of micronutrients zinc ensures that the plants have all the necessary elements to support complex physiological processes like photosynthesis, enzyme activity, and hormone regulation, which are essential for seed development. This nutrient combination optimizes the plant's metabolic functions, leading to better fertilization and seed formation within each pod. Other treatments, while not as complete as the RDF + zinc, still improve seed production per pod compared to the control, which lacks additional nutrients and thus faces deficiencies that hinder optimal seed development. Consequently, plants receiving RDF and zinc at 0.5% produce the highest number of seeds per pod due to the enhanced and balanced nutritional environment. The outcomes in the green gram aligned with the findings of Begum *et al*., (2018) [3], Kavya *et al*., (2021) [10].

Length of pod

The study on the effect of foliar spraying zinc on the length of pod of green gram is presented in Table 3. There were notable variations in the statistical analysis of the different combinations of micronutrient doses applied in green gram.

T_9 (RDF+ zinc@ 0.5%) had maximum length of pod (8.81 cm) among the different combinations applied at par with T_7 (RDF + Zn @ 0.1%), which had 8.57 cm. T_0 (RDF + Water spray (Control)) had minimum length of pod (6.15 cm).

Green gram plants treated with a combination of the Recommended Dose of Fertilizers (RDF) and a mixture of all zinc at 0.5% produce longer pods due to the optimal and balanced nutrient provision. RDF supplies essential macronutrients (nitrogen, phosphorus, potassium) critical for overall plant growth and reproductive development. The added micronutrients, zinc are vital for various physiological processes such as cell division, elongation, and photosynthesis, which directly influence pod development. The synergistic effect of this comprehensive nutrient mix enhances the plant's metabolic functions, leading to better growth and elongation of pods. Adequate nutrient supply ensures that the plants can sustain prolonged growth phases, resulting in longer pods. Compared to other treatment combinations, which may lack some essential nutrients or provide them in less optimal ratios, the RDF + zinc ensures that no nutrient deficiencies limit pod growth. This comprehensive nutrient support allows the plants to maximize their genetic potential for pod length, resulting in significantly longer pods than those produced with other treatments. The outcomes in the green gram aligned with the findings of Muindi *et al*., (2020) [12], Kavya *et al*., (2021) [10], and Dhaliwal *et al*., (2023) [7].

Biological yield

The study on the effect of foliar spraying micronutrients on the biological yield of green gram is presented in Table 3. There were notable variations in the statistical analysis of the different combinations of micronutrient doses applied in green gram.

T_9 (RDF+ zinc @ 0.5%) had maximum biological yield (2862.70 grams) among the different combinations applied at par with T_7 (RDF + Zn @ 0.1%), which had 2679.39 grams. T_0 (RDF + Water spray (Control)) had minimum biological yield (1699.04 grams).

The superior biological yield observed in the treatment combination of Recommended Dose of Fertilizers (RDF) along with a 0.5% application of a zinc in green gram can be attributed to several factors. Firstly, the RDF ensures the provision of essential macronutrients, promoting overall plant health and vigour, thus laying a strong foundation for growth. Additionally, the supplementation of zinc at the optimal concentration facilitates enhanced enzymatic activities crucial for metabolic processes, leading to improved nutrient uptake, photosynthesis, and ultimately, biomass production. This comprehensive nutrient approach addresses potential deficiencies, maximizing the plant's physiological efficiency and resilience against stressors. Consequently, the treatment combination fosters robust plant development, culminating in a significant increase in biological yield compared to other micronutrient treatments and the control group. The outcomes in the green gram aligned with the findings of Muthal *et al*., (2016) [13].

1000-seed weight

The study on the effect of foliar spraying zinc on the 1000-seed weight of green gram is presented in Table 3. There were notable variations in the statistical analysis of the different combinations of micronutrient doses applied in green gram.

Maximum 1000-seed weight was recorded in T_9 (RDF+ zinc@ 0.5%) having (39.95 grams) followed by T_8 (RDF + Zn @ 0.3%) having 38.64 grams whereas the minimum 1000-seed weight was observed in treatment T_0 (Control) with 33.68 grams.

The enhanced 1000-seed weight observed in the treatment combination of Recommended Dose of Fertilizers (RDF) alongside a 0.5% application of a zinc in green gram is attributable to several factors. Firstly, the RDF ensures optimal provision of essential macro-nutrients, vital for robust seed development and filling. Concurrently, the addition of micronutrients at the prescribed concentration augments crucial physiological processes, including enzyme activation and nutrient transport, thereby optimizing seed filling and weight accumulation. This comprehensive nutrient strategy addresses potential deficiencies, ensuring unhindered seed development. Consequently, the treatment synergy promotes a more efficient utilization of resources, leading to larger and heavier seeds compared to alternative zinc treatments and the control group. This signifies a significant improvement in seed quality and yield potential, pivotal for agricultural productivity and sustainability. The outcomes in the green gram aligned with the findings of Debroy *et al*., (2013) [6], Muindi *et al*., (2020) [12], and Boradkar *et al*., (2023) [4].

Harvest index

The study on the effect of foliar spraying zinc on the harvest index of green gram is presented in Table 3. There were notable variations in the statistical analysis of the different combinations of micronutrient doses applied in green gram.

Highest harvest index percentage was recorded in T_9 (RDF + zinc @ 0.5%) having (33.99%) followed by T_8 (RDF+ zinc@ 0.3%) having 32.24% whereas the minimum biological yield was observed in treatment T_0 (Control) with 32.43%.

The improved harvest index witnessed in the treatment blend of Recommended Dose of Fertilizers (RDF) combined with a 0.5% application of a comprehensive mixture of micronutrients in green gram stems from a synergistic optimization of plant growth and resource allocation. Firstly, the RDF ensures the adequate supply of essential macro-nutrients, fostering robust vegetative growth while simultaneously supporting reproductive processes. Concurrently, the balanced application of zinc at the specified concentration facilitates enhanced physiological functions crucial for reproductive development, such as pollination, flower retention, and seed filling. This integrated nutrient management approach optimizes the conversion of assimilates into harvestable yield, thereby improving the harvest index. Consequently, compared to alternative micronutrient treatments and the control group, this treatment combination promotes more efficient resource utilization, culminating in a higher proportion of harvested yield relative to total biomass, indicative of enhanced agronomic efficiency and productivity. The outcomes in the green gram aligned with the findings of Kavya *et al*., (2021) [10], and Dhaliwal *et al*., (2023) [7].

Days to physiological maturity

Table 3. present the results of the study on the impact of foliar spraying zinc on the days to maturity of green gram. Significant statistical differences were found between the various combinations of micronutrient doses applied in green gram.

T_9 (RDF + Zn @ 0.5%) took minimum days to maturity (65.17 days) among the different combinations applied followed by T_8 (RDF+ zinc@ 0.3%), which had 71.94 days. T_0 (RDF + Water spray (Control)) took maximum days to maturity (79.92 days).

Due to an ideal supply of both macronutrients and the important micronutrient zinc, green gram plants treated with a combination of the Recommended Dose of Fertilisers (RDF) and zinc (Zn) at 0.5% reached maturity earlier than other plants. The macronutrients nitrogen, phosphorus, and potassium that are necessary for both vegetative and reproductive growth are found in RDF. Particularly zinc is essential for the production of plant hormones like auxins, which control maturation and other aspects of growth. By ensuring that plants have a balanced nutrient profile, this combination helps them reach maturity more quickly from the vegetative stage. Enhanced nutrient availability accelerates metabolic processes, leading to earlier maturity compared to other treatments. Additionally, all other nutrient treatments showed earlier maturity than the control due to the alleviation of nutrient deficiencies that hinder growth and development. The control treatment, lacking these supplementary nutrients, exhibits delayed maturity. Therefore, the combination of RDF and zinc at 0.5% significantly advances maturity time by addressing both macronutrient and micronutrient needs efficiently. Results in green gram were consistent with those of Soni and Kushwaha (2020).

Seed yield per plant

The study on the effect of foliar spraying zinc on the seed yield per plant of green gram is presented in Table 3. There were notable variations in the statistical analysis of the different combinations of micronutrient doses applied in green gram.

Among the various combinations used, T_9 (RDF + zinc @0.5%) had the highest seed yield per plant (94.87 g/plant), followed by T_8 (RDF + Zn @ 0.3%), which had 82.07 g/plant. The seed yield per plant for T_0 (RDF + Water spray (Control)) was the lowest at 57 g/plant.

A complex optimisation of plant growth and reproductive processes can be responsible for the higher seed yield per plant seen in the treatment combination of Recommended Dose of Fertilisers (RDF) along with a 0.5% application of a comprehensive zinc in green gramme. First and foremost, the RDF guarantees the availability of vital macronutrients, encouraging rapid vegetative growth and offering a solid basis for the development of reproductive organs. Simultaneously, the administration of zinc in a balanced manner at the designated concentration promotes improved metabolic activities that are essential for reproductive processes like pollination, flower initiation, and seed filling. By optimising the plants' reproductive potential, this integrated approach to nutrient management increases the number of seeds produced by each plant. In contrast to the control group and other zinc treatments, this combination of treatments promotes better resource utilisation, which leads to a higher quantity of seeds produced per individual plant, indicative of enhanced crop productivity and yield. The outcomes in the green gram aligned with the findings of Kavya *et al*., (2021) [10], and Dhaliwal *et al*., (2023) [7].

Seed yield per hectare

The study on the effect of foliar spraying zinc on the seed yield per hectare of green gram is presented in Table 3. There were notable variations in the statistical analysis of the different combinations of micronutrient doses applied in green gram.

Among the various combinations used, T_9 (RDF + zinc @0.5%)

had the highest seed yield per hectare (1470.20 kg/ha), followed by T_8 (RDF + Zn @ 0.3%), which had 1225.60 kg/ha. The seed yield per hectare for T_0 (RDF + Water spray (Control)) was the lowest at 801.41 kg/ha.

A complex optimisation of plant growth and reproductive processes can be responsible for the higher seed yield per hectare seen in the treatment combination of Recommended Dose of Fertilisers (RDF) along with a 0.5% application of a comprehensive mixture of zinc in green gramme. First and foremost, the RDF guarantees the availability of vital macronutrients, encouraging rapid vegetative growth and offering a solid basis for the development of reproductive organs. Simultaneously, the administration of zinc in a balanced manner at the designated concentration promotes improved metabolic activities that are essential for reproductive processes like pollination, flower initiation, and seed filling. By optimising the plants' reproductive potential, this integrated approach to nutrient management increases the number of seeds produced by each plant. In contrast to the control group and other micronutrient treatments, this combination of treatments promotes better resource utilisation, which leads to a higher quantity of seeds produced per individual plant, indicative of enhanced crop productivity and yield. The outcomes in the green gram aligned with the findings of Gidaganti *et al*. (2019) [9], Kavya *et al*., (2021) [10], and Dhaliwal *et al*., (2023) [7].

Economic

The study on the effect of foliar spraying zinc on the economics of green gram is presented in Table 4. There were notable variations in the statistical analysis of the different combinations of micro nutrient doses applied in green gram.

Cost of Cultivation (INR/ha)

The lowest cost of cultivation was found in the control plot (INR 27500/ha) and the highest cost of cultivation was observed RDF + Zn @ 0.5%.

Gross returns (INR/ha)

The higher gross return (INR 95562.78/ha) was obtained in the RDF + Zn @ 0.5%

Net Return (INR/ha)

The higher net return (INR 68062/ha) was obtained in the RDF + Zn @ 0.5%

Benefit Cost Ratio

Higher B:C ratio (2.47) was found in RDF + Zn @ 0.5% in Treatment 9.

Higher benefit cost ratio was recorded with the application of Zinc (0.5%) might be due to higher grain and strove yield which resulted in increases the gross return, ultimately increases the benefit ratio Gidaganti *et al*. (2019) [9].

Table 2: Effect of different foliar spray of zinc on green gram for growth and yield attributes

Treatments	Concentration	Field Emergence	Plant height (cm)	Number primary branches per plant	Number of secondary branches per plant	Days to 50% pod flowering	Days to 50% pod formation	Number of pods per plant	Number of seeds per pod
T_0	RDF + Water SPRAY (Control)	15.24	24.92	3.28	4.95	51.92	66.92	7.75	7.33
T_1	RDF + Zn @ 0.5%	14.56	25.40	3.61	5.64	50.99	65.99	8.07	8.04
T_2	RDF + Zn @ 0.9%	13.61	26.69	3.64	6.28	49.74	64.74	8.33	8.25
T_3	RDF + Zn @ 1.0%	11.79	30.65	4.83	6.92	45.92	60.92	9.21	9.33
T_4	RDF + Zn @ 0.3%	13.67	27.17	4.28	6.29	48.12	63.12	8.35	8.58
T_5	RDF + Zn @ 0.5%	12.82	28.98	4.34	6.34	48.70	63.70	8.50	8.77
T_6	RDF + Zn @ 0.9%	12.75	29.60	4.54	6.54	47.99	62.99	8.80	8.86
T_7	RDF + Zn @ 1.0%	10.56	31.00	4.92	7.49	44.04	59.04	9.37	9.55
T_8	RDF + Zn @ 0.3%	11.79	30.59	4.62	6.83	46.94	61.94	8.98	9.11
T_9	RDF + Zn @ 0.5%	9.44	32.87	5.16	7.51	40.17	55.17	9.62	9.86
	F-test	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
	SEm(±)	0.43	1.16	0.39	0.49	2.15	2.15	2.15	2.15
	CD (p=0.05)	1.28	3.45	1.15	1.45	6.38	6.38	6.38	6.38

Table 3: Effect of different foliar spray of zinc on green gram for yield attributes and yield

Treatments	Concentration	Length of the Pod (cm)	Biological yield (kg)	1000 grain weight (g)	Harvest Index (%)	Days to physiological maturity	Seed yield per plant (gm)	Seed yield per hectare (kg/ha)
T_0	RDF + Water SPRAY (Control)	6.15	1699.04	33.68	32.43	76.92	57.00	801.41
T_1	RDF + Zn @ 0.5%	6.52	1776.99	35.26	32.41	75.99	64.92	852.04
T_2	RDF + Zn @ 0.9%	6.85	1886.30	36.98	33.56	74.74	68.88	955.97
T_3	RDF + Zn @ 1.0%	8.37	2736.78	38.86	32.14	70.92	86.15	1296.03
T_4	RDF + Zn @ 0.3%	7.15	2123.22	37.21	32.75	73.12	71.59	1031.89
T_5	RDF + Zn @ 0.5%	7.40	2313.12	37.81	32.14	73.70	74.87	1093.72
T_6	RDF + Zn @ 0.9%	7.88	2480.49	38.11	31.71	72.99	78.37	1152.90
T_7	RDF + Zn @ 1.0%	8.57	2679.39	39.77	34.08	69.04	88.98	1379.47
T_8	RDF + Zn @ 0.3%	7.86	2574.96	38.64	32.24	71.94	82.07	1225.60
T_9	RDF + Zn @ 0.5%	8.81	2862.70	39.95	33.99	65.17	94.87	1470.20
	F-test	S	S	**S**	NS	S	S	S
	SEm(±)	0.22	115.35	1.07	1.65	2.15	4.83	38.66
	CD (p=0.05)	0.65	342.68	3.18	4.91	6.38	14.36	114.85

Table 4: Effect of different foliar spray of zinc on green gram for economics

Treatment	Concentration	Cost of cultivation	Gross return	Net return	B:C
T_0	RDF + Water SPRAY (Control)	26500	52091.43	25591.43	0.97
T_1	RDF + Zn @ 0.5%	27000	55382.81	28382.81	1.05
T_2	RDF + Zn @ 0.9%	27400	62137.84	34737.84	1.27
T_3	RDF + Zn @ 1.0%	27500	84241.73	56741.73	2.06
T_4	RDF + Zn @ 0.3%	26800	67073.06	40273.06	1.5
T_5	RDF + Zn @ 0.5%	27000	71091.58	44091.58	1.63
T_6	RDF + Zn @ 0.9%	27400	74938.28	47538.28	1.73
T_7	RDF + Zn @ 1.0%	27500	89665.55	62165.55	2.26
T_8	RDF + Zn @ 0.3%	26800	79664.22	52864.22	1.97
T_9	RDF + Zn @ 0.5%	27500	95562.78	68062.78	2.47

Conclusion

From the present investigation it is concluded that among 10 treatment combination of foliar spray of zinc applied in green gram, Treatment combination T_9 (RDF+ Zn @ 0.5%) performed best in terms of yield parameters like number of pods per plant, number of seeds per pod, seed yield per plant, seed index. It was second highest in harvest index and second most early in flowering and maturing. Therefore, combination used in T_9 i.e., RDF+ Zn @ 0.5% can be promoted to use to get better yield and overcome low productivity in green gram.

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