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Study on Zinc Fertilization on Growth Dynamics and Yield Attributes of Green Gram (*Vigna radiata* L.)

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ABSTRACT

Background: Green gram is an essential legume crop extensively cultivated across India. Its high protein content and ability to enhance soil fertility through nitrogen fixation make it a valuable crop. Particularly, a deficiency of the micronutrient zinc can disrupt various physiological and biochemical processes, ultimately limiting yields. Foliar application of zinc sulphate ($ZnSO_4$), along with the recommended fertilizer dose (RDF), has been shown to boost crop performance during critical growth stages. This study aimed to evaluate the influence of soil and foliar-applied zinc sulphate on the growth and yield attributes of green gram.

Methods: A field experiment was conducted during the summer season of 2024 at the Crop Research Farm of Kalia-awash, SGT University, Gurugram (Haryana). The experiment consisted of seven treatments and three replications, in a randomized block design (RBD). The soil was sandy loam, slightly alkaline and deficient in available nitrogen, phosphorus, potassium, sulphur and micronutrients. Treatments included RDF alone and combinations of soil and foliar applications of $ZnSO_4$. Treatment T_7 involved RDF + 0.5% $ZnSO_4$ foliar application at branching and flowering stages.

Result: Among the treatments, T_7 showed highest value for different growth and yield parameters, like plant height (38.73 cm), number of branches per plant (14.73), number of trifoliate leaves (27.07), number of pods per plant (15.67), number of grains per pod (10.07), test weight (34.18 g), seed yield (13.60 q ha^{-1}) and biological yield (38.19 q ha^{-1}) were recorded.

Key words: Foliar application, Green gram, Pod yield, Zinc sulphate.

INTRODUCTION

Pulses are one of the important segments of Indian agriculture after cereals in production. Green gram (*Vigna radiata* L.) is one of the major pulse crops belongs to the family Leguminosae. Among the pulses, green gram is one of the most important and extensively cultivated crops in India, it is the third most important pulse crop after pigeon pea and chickpea (Udhaya *et al*., 2023). Green grams have many local names “mung bean, mash or golden gram”. Its seed is more palatable, nutritive, digestible and non-flatulent than other pulses grown in country. It contains about 25% protein, which is almost three times that of cereals (Angmo *et al*., 2022). The nutrient profile of the seed includes the amounts of protein (18-25%), carbohydrate, (50%), fat (3%), ash (4-5%), fibre (3-4.5%), phosphorus (367 mg) and calcium (132 mg) per hundred-gram seed (Dhinagaran *et al*., 2021). The crop cultivated in the arid and semi-arid regions of the country has the ability to fix atmospheric nitrogen, thereby enhancing soil fertility through the addition of (25-40 kg N/ha). These short duration crops also exhibit broader adaptability, enabling their cultivation during both the summer and kharif growing seasons (Tomar *et al*., 2023). Mung bean plants thrive in loamy, well-drained, or sandy loam soils experiencing average temperatures between 20-40°C. These crop plants exhibit an upright or semi-upright growth habit, with the upper branches bearing paired leaves that display a trifoliate morphology characterized by elongated petioles (Kalasare *et al*., 2022). According to the All India Coordinated Research Project on Pulses Annual Report (2022-23) on *Kharif* pulses Rajasthan (46% and 45%) leads the states contributing the most to both the area and production of mung beans, followed by Madhya Pradesh (9% and 14%), Maharashtra (9% and 8%), Karnataka (9% and 6%), Odisha (5% and 4%), Bihar (4% and 5%), Tamil Nadu (4% and 3%), Gujarat (3% and 4%), Andhra Pradesh (3% for both) and Telangana (2% for both), respectively. In the state of Haryana, green gram was cultivated over an area of 20.17 thousand hectares during the 2019-20 growing season, resulting in a total production of 12.00 thousand tones and an average yield of 595 kilograms per hectare (Kumar *et al.,* 2023). FYM application has a

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significant influence on the yield and nutritional quality of green gram. FYM plays a crucial role in improving soil fertility and productivity through its positive effects on the physical, chemical and biological properties of the soil, as well as by promoting balanced plant nutrition. The application of well- decomposed FYM not only supplies a range of nutrients but also enhances the physical properties of the soil and encourages beneficial soil microbial activity (Rao *et al*., 2021). Increased nitrogen application has been shown to result in higher grain yields, fodder yields and net returns from legume crops, as well as improved nitrogen usage efficiency. Similarly, research on mung beans has demonstrated that applying starting phosphorus increases plant height, nodule count and the availability of nitrogen, phosphorus and potassium in the subsequent crop, thereby enhancing overall crop productivity and nutrient utilization (Muindi *et al*., 2020).

As an essential micronutrient, zinc plays a critical role in plant growth, serving as a component of various enzyme systems involved in energy production, protein synthesis and growth regulation. It is also implicated in auxin formation, activation of dehydrogenase enzymes and stabilization of ribosomal fractions. Zinc deficiency in plants manifests as delayed maturity, with symptoms including shortened internodes and reduced leaf size. In Indian soils, particularly in intensively cultivated and alkaline areas, zinc deficiency is widespread, resulting in reduced crop yields and diminished grain quality. Zinc can be applied through foliar, soil, pelleting, or seed dressing methods. Foliar application, which involves the direct spraying of dissolved zinc sulfate onto plant leaves and stems, allows for absorption by the leaf epidermis. The zinc is then remobilized and transported to the grain via the phloem, facilitated by Zn-regulating transporter proteins. (Muindi *et al.,* 2020). The application of micronutrients, such as foliar sprays of manganese, iron and zinc, has been found to significantly improve the growth and yield-related characteristics of mung bean plants (Hussain *et al.,* 2021).

MATERIALS AND METHODS

A field experiment was conducted during the summer season of 2024 at the crop research centre (CRC) of Kaliawash, SGT University, Gurugram (Haryana), located at 28.47' North latitude and 76.90' East longitude and at an altitude of 217 m above mean sea level. The crop research centre is located in the north- western zone of Haryana. The experimental site was hot and dry during the crop season, with 35.2 mm of total rainfall; zinc sulfate heptahydrate ($ZnSO_4 \cdot 7H_2O$) was used in the experiment. In order to determine the Physiochemical properties of the soil, soil samples were collected randomly from the plot of different treatment of the experimental field at a depth of 0-15 cm. A representative composite sample was then analysed to assess the physio-chemical properties of the soil using standard methods. The analytical results revealed that the soil of the experimental field was sandy loam in texture, slightly alkaline in reaction (pH 7.87) and (EC 0.32 dS m^{-1}) were measured using the pH meter (Jackson 1973), had low levels of available nitrogen was determined by the alkaline $KMnO_4$ method (Subbiah and Asija, 1956), medium in available phosphorus by the Olsen's method (Jackson, 1973), potassium by the 1 N ammonium acetate extraction method (Jackson, 1973), sulphur by the $CaCl_2$ extraction (Chesnin and Yien,1950) and micronutrients as per DTPA extraction by (Lindsay and Norvell 1978). The experiment was laid out with seven treatments of zinc sulphate, viz. Control T_1: Recommended dose of fertilizer N: P: K (20: 40: 40 kg ha^{-1}), T_2: RDF + soil application of $ZnSO_4$ @ 20 kg, T_3: RDF + soil application of $ZnSO_4$ @ 25 kg, T_4: RDF + Soil application of $ZnSO_4$ @ 30 kg, T_5: RDF + foliar application of $ZnSO_4$ @ 0.5% at branching stage, T_6: RDF + foliar application of $ZnSO_4$ @ 0.5% at flowering stage, T_7: RDF + foliar application of $ZnSO_4$ @ 0.5% at branching and flowering stage, in randomized block design (RBD) with three replications. Green gram variety (MH 1142) with plant geometry (30 cm × 25 cm) were sowed in mid-April 2024. The data on growth parameters like plant height, number of branches, total number of leave, number of pods and number of nodules were recorded from 5 randomly selected plants. Harvested plant samples were sun dried for 4-5 days and biological yield was recorded, threshing was done manually and weight of grain was subtracted from biological yield to get straw yield and calculation of economics.

RESULTS AND DISCUSSION

The data related to different growth yield parameters like plant height, number of branches, number of trifoliate leaves and number of nodules, number of pods $plant^{-1}$ number of grains pod^{-1} test weight, biological yield and yield (q ha^{-1}) as influenced by the application soil and foliar application of zinc sulphate is shown below.

Plant height

The combination of foliar treatments significantly increased the plant height of green gram, as shown in Table 1. The highest plant height at branching (19.10cm) was observed in treatment T_3: RDF + soil application of $ZnSO_4$ @ 25 kg, which was found to be at par with treatments T_6 and T_7 and significantly superior to the other treatments. The highest plant height at harvest (38.73 cm) was recorded with treatment T_7: RDF + foliar application of 0.5% $ZnSO_4$ at branching and flowering stage. This was found to be statically at par with treatments T_5 and T_6 and significantly higher than the other treatments. Treatment T_1 (RDF) recorded the lowest plant heights of 14.46 cm and 29.4 cm at branching and at harvest, respectively. Muindi *et al*., (2020) and Soni *et al*., (2020) reported similar result that under zinc treatment increased the plant height of mung bean.

Number of branches per plant

The data regarding the number of branches per plant of green gram, as affected by the application of treatments,

recorded at two growth stages (At branching and at harvest), are presented in Table 1. The maximum number of branches per plant (5.05 at branching) was observed in treatment T_3: RDF + soil application of $ZnSO_4$ @ 25 kg, which was found to be at par with treatments T_2 and T_4 and significantly superior to the other treatments. The maximum number of branches per plant (14.73 at harvest) was observed in treatment T_7: RDF + foliar application of 0.5% $ZnSO_4$ at branching and flowering stage, respectively and was found to be at par with treatments T_3 and T_6, significantly superior to the other treatments. The minimum number of branches per plant (2.33 at branching and 4.6 at harvest) was observed in treatment T_1 (RDF). Similar results were found by Tribhuwan *et al*., (2024) in green gram.

Number of trifoliate leaves per plant

The data regarding the number of trifoliate leaves per plant, as affected by the application of treatments, recorded at two growth stages (At branching and at harvest), are presented in Table 1. The highest number of trifoliate leaves per plant (13.70 at branching) was recorded with treatment T_3: RDF + soil application of $ZnSO_4$ @ 25 kg, which was found to be at par with treatments T_6 and T_7 and significantly superior to the rest of the treatments in green gram. The highest number of leaves per plant (27.07 at harvest) was recorded with treatment T_7: RDF + foliar application of 0.5% $ZnSO_4$ at branching and flowering stage, respectively. This was found to be at par with treatments T_3 and T_6 and significantly superior to the rest of the treatments in green gram. The lowest number of leaves per plant (7.67 at 30 DAS and 13.97 at 60 DAS) was recorded with treatment T_1 (RDF). Similar results were found by Krishna *et al*., (2022).

Nodulation

As per experiment data on the number of nodules per plant at the flowering stage are presented in Table 1. The maximum number of nodules per plant was obtained under treatment T_7: RDF + foliar application of 0.5% $ZnSO_4$ at branching and flowering stage, which was 12.05 and was found to be at par with treatments T_3 and T_5 and significantly superior to the rest of the treatments. The minimum number of nodules per plant was obtained under treatment T_1 (RDF). Similar findings were observed by Banoth *et al.* (2022).

Number of pods plant^{-1}

Represented data indicated that Zinc fertilization significantly increased the number of pod per plant for green gram. Treatment T_7: RDF + foliar application of 0.5% $ZnSO_4$ at branching and flowering stage resulted in the highest number of pods per plant at harvest (15.67), which was comparable to treatments T_2 and T_6, which produced (12.57) and (13.73) pods per plant, respec-tively. Similar result reported by Gidaganti *et al.* (2019).

Number of grains pod $^{-1}$

The quantity of grains per pod at the harvesting stage was not substantially impacted by the treatments, as shown in Table 2. Treatment T_7: RDF + foliar application of 0.5% $ZnSO_4$ at branching and flowering stage showed the highest number of grains per pod (10.07), whereas treatment T_1 (RDF) had the lowest number of grains per pod (7.26). Similar result reported by Hussain *et al.* (2021).

Test weight

The data test weight presented in Table 2 revealed that the highest test weight (34.18 g) was recorded with T_7: RDF + foliar application of 0.5% $ZnSO_4$ at branching and flowering stage, which was significance to majority of the treatments. However, treatments T_3 (33.26 g), T_5 (32.91 g) and T_2 (31.15 g) were found to be statistically at par with treatment T_7 (34.18 g). Similar findings were observed by Gidaganti *et al.* (2019).

Table 1: Effect of treatment on growth parameters of green gram at deferent growth stages.

Treatments	Plant height (cm)		Number of branches (plant^{-1})		Number of trifoliate (plant^{-1})		Nodules at flowering stage (plant^{-1})
	At Branching	At Harvest	At Branching	At Harvest	At Branching	At Harvest	
T_1- RDF NPK (20:40:40)	14.46	29.4	2.33	4.6	7.67	13.97	4.13
T_2- RDF + (SA) $ZnSO_4$ @ 20 Kg	16.86	31.6	4.23	9.27	9.28	20.05	9.07
T_3- RDF + (SA) $ZnSO_4$ @ 25 Kg	19.10	33.26	5.05	12.17	13.70	25.34	10.02
T_4- RDF + (SA) $ZnSO_4$ @ 30 Kg	17.05	28.00	4.37	5.03	8.13	15.19	4.63
T_5- RDF+ (FA) $ZnSO_4$ @ 0.5% atbranching stage	18.04	36.33	3.17	11.07	9.68	18.41	11.06
T_6- RDF+ (FA) $ZnSO_4$ @ 0.5% atflowering stage	19.00	37.13	2.86	11.57	12.22	25.00	9.68
T_7- RDF+ (FA) $ZnSO_4$ @ 0.5% at branching and flowering stage	18.08	38.73	3.03	14.73	12.00	27.07	12.05
SEm±	0.65	1.76	0.21	0.98	0.44	0.97	0.58
CD (5%)	2.03	5.48	0.67	3.06	1.38	3.05	1.81

*RDF-Recommended dose of fertilizer *SA- Soil application, *FA- Foliar application.

Table 2: Effect of treatment on yield and yield parameters of green gram at deferent growth stages.

Treatments	Number of pods/ plants	Test weight (g)	Number of grains/ pod	Biological yield (q ha^{-1})	Yield (q ha^{-1})	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net returns (Rs/ha)	B:C
T_1- RDF NPK (20:40:40)	10.23	30.08	7.26	24.29	10.12	43726.48	87861.84	44135.36	2.01
T_2- RDF + (SA) $ZnSO_4$ @ 20 Kg	12.57	31.15	8.13	32.54	12.68	45976.48	110087.76	64111.28	2.39
T_3- RDF + (SA) $ZnSO_4$ @ 25 Kg	12.08	33.26	8.43	36.44	13.17	46538.98	114341.94	67802.96	2.46
T_4- RDF + (SA) $ZnSO_4$ @ 30 Kg	11.57	29.18	6.07	23.80	9.30	47101.48	80742.6	33641.12	1.71
T_5- RDF+ (FA) $ZnSO_4$ @ 0.5% atbranching stage	12.3	30.99	8.67	31.78	11.90	43739.98	103315.8	59575.82	2.36
T_6- RDF+ (FA) $ZnSO_4$ @ 0.5% atflowering stage	13.73	32.91	7.63	32.29	12.70	43739.98	110261.4	66521.42	2.52
T_7- RDF+ (FA) $ZnSO_4$ @ 0.5% at branching and flowering stage	15.67	34.18	10.07	38.19	13.60	43753.48	118075.2	74321.72	2.71
SEm±	0.98	0.95	0.66	1.17	0.37				
CD (5%)	3.05	2.97	2.05	3.65	1.16				

*RDF-Recommended dose of fertilizer *FA- Foliar application *SA- Soil application.

Biological yield

Data of research showed (Table 2) that Zinc fertilization markedly influenced the biological yield, ranging from 24.29 q ha^{-1} to 38.19 q ha^{-1}. The maximum biological yield (38.19 q ha^{-1}) was recorded under the treatment T_7: RDF + foliar application of 0.5% $ZnSO_„$ at branching and flowering stage, which was found to be at par with treatments T_2 and T_3 and significantly superior to the other treatments. The lowest biological yield (24.29 q ha^{-1}) was recorded in treatment T_1 (RDF). The similar results were found by Jamal *et al.,* (2018).

Grain yield

The grain yield of green gram ranged from 9.30 q ha^{-1} to 13.60 q ha^{-1}. The highest seed yield (13.60 q ha^{-1}) was recorded in treatment T_7: RDF + foliar application of 0.5% $ZnSO_4$ at branching and flowering stage, which was at par with treatments T_3 and T_6 and significantly superior to the other treatments. The lowest seed yield (9.30 q ha^{-1}) was recorded in treatment T3. Similar findings were observed by Gahlot *et al.* (2020) and Gram *et al.* (2020).

Effect of treatments on Benefit cost ratio (B:C) of green gram cultivation

Zinc nutrition significantly influenced (B:C) ratio in cultivation of green gram is described in Table 2. Maximum gross returns (Rs. 118075.2 ha^{-1}), net returns (Rs. 74321.72 ha^{-1}) and B:C ratio (2.71) was recorded under treatment T_7: RDF + foliar application of 0.5% $ZnSO_4$ at branching and flowering stage. With a greater magnitude of yield enhancement, the marginal increase in production costs relative to the other treatments resulted in better yields, gross returns and benefit-cost ratios.

CONCLUSION

The experimental study suggests that treatment combination T_7 *i.e.* recommended dose of fertilizers (NPK) combined with foliar application of 0.5% $ZnSO_4$ at branching and flowering stage after sowing was the most effective in enhancing the growth, yield and economic returns in green gram. The application of RDF along with foliar application of 0.5% $ZnSO_4$ at these critical growth stages resulted in significantly higher yield. Based on the results of this study, it is recommended that green gram cultivation with RDF and foliar application of 0.5% $ZnSO_4$ at branching and flowering stages to optimize yield potential. So, it can be concluded that the management practice of zinc fertilization through foliar spray would be beneficial for farmers regarding economic profitability in green gram cultivation.

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Disclaimers

The views and opinions expressed in this research paper are those of the author and do not necessarily reflect the official policy or position of any affiliated institutions, organizations or funding agencies. The authors are solely responsible for the content and accuracy of the data and analysis presented herein. Any errors or omissions are the responsibility of the author.

Informed consent

All participants voluntarily took part in this study after receiving detailed information about its purpose and procedures. Written informed consent was obtained and confidentiality was assured. Participants were free to withdraw at any time. The study adhered to ethical guidelines approved by the appropriate institutional ethics committee.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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