A-6408
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RESEARCH ARTICLE
Indian Journal of Agricultural Research

Response of Iron Nutrition on the Growth and Yield of Green Gram (*Vigna radiata* L.) in Semi-arid Region of Haryana

Adarsh Pandey[1], Debabrata Dhar[1], Shakti Om Pathak[1], Sachin Kumar[1], Manjri[2]

10.18805/IJARe.A-6408

Abstract

Background: A field experiment was conducted during the summer season of 2024 at the Crop Research Center of Kaliawash, SGT University, Gurugram (Haryana). Different level of iron sulphate were applied to green gram through basal and foliar application to study the effect of iron nutrition on growth and yield of the plant as well as soil nutrient availability.

Methods: The experiment consisted of seven different treatments and three replications, in randomized block design. The soil of the experimental field was sandy loam in texture, slightly alkaline in reaction, had low levels of available N.P.K. Further lab analysis showed the deficiency of essential micronutrients like Zn, Fe, Cu and Mn.

Result: The results specified that the highest growth parameters such as plant height (44.24 cm), number of branches per plant (15.98), number of trifoliate leaves (31.62) and yield parameters like number of pods per plant (16.48), number of grains per pod (9.67), test weight (36.00 g), grain yield (12.10 q ha^{-1}) and stalk yield (34.98 q ha^{-1}), were recorded under the treatment combination of RDF + foliar application (F.A.) of 0.6% $FeSO_4$ at 30 and 45 DAS.

Key words: Foliar application, Green gram, Green manuring, Growth, Iron sulfate, Pod yield.

Introduction

Pulses, annual legume crops belonging to the Fabaceae family, are crucial for Indian agriculture due to their ability to grow on marginal land and provide a protein-rich diet for the poor and vegetarians (Ahmad *et al*., 2016). Green gram (*Vigna radiata* L.) is an important pulse crop in India, primarily grown during the kharif and zaid seasons. It is also cultivated in some regions during the rabi season as a post-wet season crop. Green gram contributes to soil nitrogen content and is used for green manuring. It can fix atmospheric nitrogen at a rate of 42 kg N ha^{-1} and helps prevent soil erosion through intensive crop rotation (Pandey *et al*., 2019).

A hundred grams of green gram seeds provide 234 calories, along with other nutrients such as calcium (0.08 g), phosphorus (0.045 g), protein (24.6%), fat (1.0%), fiber (2.2 g), carbohydrates (57.5%), vitamin B (300 mg), thiamin (0.525 mg) and iron (5-7 mg) (Salman *et al*., 2023).

The Indian Institute of Pulses Research in Kanpur (2024) reports that mung bean production in India is 7.21 quintals per hectare, with India and Myanmar accounting for 30% of global production. Other major producers include China, Indonesia, Thailand, Kenya and Tanzania. India imports mung bean primarily from Kenya (30%), Mozambique (24%), Tanzania (18%), Brazil (11%), the UAE (4%), Australia (3%), South Africa (2%), Uganda (2%) and Venezuela (2%). Key export destinations for mung beans include the USA (24%), Nepal (18%), the UK (18%), Canada (10%), Bangladesh (6%), Qatar (4%), the Netherlands (4%), Australia (2%), the UAE (2%) and Malaysia (2%) ICAR-IIPR (2024).

India is the world's largest producer and consumer of green gram, accounting for 10% to 12% of total pulse production. The crop is cultivated across 46 million hectares, yielding approximately 2.4 million metric tons. Over 90% of green gram production comes from Rajasthan, Madhya Pradesh, Maharashtra, Karnataka, Bihar, Odisha, Gujarat andhra Pradesh and Tamil Nadu (Kathiravan *et al*., 2023). According to the AICRPR's Annual Report (2022-23) on Kharif pulses, the states contributing the most to both the area and production of mung beans are led by Rajasthan (46%, 45%) followed by Madhya Pradesh (9%, 14%), Maharashtra (9%, 8%), Karnataka (9%, 6%), Odisha (5%, 4%), Bihar (4%, 5%), Tamil Nadu (4%, 3%), Gujarat (3%, 4%) andhra Pradesh (3%, 3%) and Telangana (2%, 2%) respectively. In Haryana, the average area under green gram is 13.6 hectares, with a productivity of 9.4 tons per hectare. In 2020-21, Haryana produced 19.6 thousand tons, yielding 6.88 quintals per hectare (Manjeet *et al*., 2023).

[1]Department of Natural Resources Management, Faculty of Agricultural Sciences, SGT University, Gurugram-122 505, Haryana, India.
[2]Department of Crop Improvement, Faculty of Agricultural Sciences, SGT University, Gurugram-122 505, Haryana, India.

Corresponding Author: Shakti Om Pathak, Department of Natural Resources Management, Faculty of Agricultural Sciences, SGT University, Gurugram-122 505, Haryana, India.
Email: shakti_fasc@sgtuniversity.org

How to cite this article: Pandey, A., Dhar, D., Pathak, S.O., Kumar, S. and Manjri. (2025). Response of Iron Nutrition on the Growth and Yield of Green Gram (*Vigna radiata* L.) in Semi-arid Region of Haryana. *Indian Journal of Agricultural Research*. 1-6. doi: 10.18805/IJARe.A-6408.

Submitted: 05-05-2025 **Accepted:** 16-09-2025 **Online:** 27-09-2025

The Ministry of Agriculture and Farmers Welfare predicts a new high in green gram production of 35.45 LMT in 2022-2023, with a total predicted pulse production of 278.10 LMT.

Cattle and other livestock dung is an essential supply of nutrients for small agricultural holdings and areas with high animal populations. Manure is considered a good soil supplement due to its variety of impacts on soil characteristics (Chaudhary *et al.,* 2023). Green gram can fix nitrogen from the atmosphere, which is essential for crops like pulses and legumes. Nitrogen enhances protein content, nutritional yield and growth, while phosphorus is crucial for growth, nutrient fixation and root development (Kapat *et al*., 2024). Phosphorus also helps plants thrive under moisture stress and supports ATP synthesis in legume crops (Patel *et al*., 2020). Potassium strengthens the stalk, promotes root growth and aids in sugar and starch synthesis. Increased nitrogen levels lead to higher grain and fodder yields, as well as improved nitrogen use efficiency (Timsina *et al*., 2024).

Micronutrient deficiencies in soil and crops are caused by factors such as increased demand, high-yield crop cultivation, marginal soils, low-nutrient fertilizers, decreased use of animal manure, acidic soils and both human and natural factors that restrict soil supply. Micronutrients like iron, zinc, manganese, copper, molybdenum and boron are essential for boosting legume output yet can also limit crop growth and production potential when deficient (Tribhuwan *et al*., 2024). Iron, in particular, is crucial for plant survival, growth and reproduction and is especially necessary for legumes like green gram. Foliar spraying of iron fertilizers is a common method for addressing iron deficiency. Balancing the fertilization of macro and micronutrients is vital for healthy growth and high-yield production (Suman *et al*., 2022).

While considerable research has focused on macronutrient fertilization in pulse crops, limited attention has been given to iron (Fe) nutrition particularly foliar application in improving the growth and yield of green gram under semi-arid conditions. Despite rising concerns about iron deficiency in Indian soils, especially in the sandy loam and alkaline soils of Haryana, most studies focus on NPK and overlook the optimization of iron application methods and timing. Additionally, the combined effect of soil and foliar iron application, its economic feasibility and its performance under Haryana's semi-arid conditions remain inadequately explored.

MATERIALS AND METHODS

A field experiment was conducted during the summer season of 2024 at the crop research center (CRC) of Kaliawash, SGT University, Gurugram (Haryana), location of the trail at 28.47°N latitude and 76.90°E longitude and at an altitude of 217 m above mean sea level. The crop research center (CRC) is located in the northwestern zone of Haryana. To analyze soil properties, random soil samples were collected 0-30 cm depth. A representative composite sample was analyzed 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 8.27), had low levels of available nitrogen, medium in available phosphorus and potassium. The experiment was laid out seven treatments with iron fertilization, *viz*. Control (T_1); Recommended dose of fertilizer N : P : K (20: 40: 40 kg ha^{-1}), T_2: RDF + soil application of 20 kg ha^{-1} $FeSO_4$, T_3: RDF + soil application of 25 kg ha^{-1} $FeSO_4$, T_4: RDF + foliar application of 0.3% $FeSO_4$ at 30 DAS, T_5: RDF + foliar application of 0.6% $FeSO_4$ at 45 DAS, T_6: RDF + foliar application of 0.3% $FeSO_4$ at 30 and 45 DAS, T_7: RDF + foliar application of 0.6% $FeSO_4$ at 30 and 45 DAS, in randomized block design with three replication. Green gram (MH 1142) with plant spacing (30 cm × 25 cm) was sowing on mid-March 2024. The study analyzed growth parameters of five randomly selected plants, including height, branches, leaves, pods and nodules. The height was measured from the soil surface to the tips of the full leaf, while the total branches, leaves and pods were counted. Grains from 10 selected pods were counted and averaged. The number of nodules per plant was counted at the flowering stage. The harvested plants were sun-dried for 4-5 days and the biological yield was recorded. The weight of the grain was subtracted from the biological yield to calculate the straw yield and economics returns.

RESULTS AND DISCUSSION

The data related to different growth parameters like plant height, number of branches, number of trifoliate leaves, number of nodules, pods plant^{-1}, number of grains pod^{-1}, test weight, biological yield and yield (q ha^{-1}) as influenced by the application of Iron sulfate sources with certain treatments is shown below:

Plant height

The foliar application of treatments combinations significantly affected the plant height of green gram, as represented in Table 1. At 30 DAS, as per recorded data, it was observed that treatment T_3: RDF + 25 kg $FeSO_4$ (granular) at sowing time showed highest plant height (27.12 cm) among all treatments. The treatment T_3 was significant over treatments like T_1, T_2, T_4, T_5, T_6 and T_7. At the harvesting stage, as per recorded data, it was observed that treatment T_7: RDF + 0.6% $FeSO_4$ at 30 DAS and 45 DAS showed higher plant height (44.24 cm) among all the treatments. The treatment T_7 was significant over the treatment combination T_2, T_5 and T_4 and statistically at par with the treatment T_3 and T_6. At all growth stage, the shortest plants height (16.40 cm at 30 DAS and 33.32 cm at harvest) were recorded in control T_1: NPK (20:40:40) (RDF). The increase in plant height may be attributed to the direct absorption of iron by the plant's stem and leaves during the foliar spray, which triggered metabolic activity. Similar findings were observed by Karthikeyan *et al*., (2022) and

Gahlot *et al*. (2020) in black gram and mung bean respectively.

Number of branches plant^{-1}

The data regarding the number of branches per plant of green gram, as affected with iron nutrition, recorded at two growth stages (30 DAS and at harvest), are presented in Table 1. The maximum number of branches per plant (5.60 at 30 DAS) was observed in treatment T_3: RDF + 25 kg $FeSO_4$, which was found to be significantly superior to the other treatments. Again, at harvest, maximum number of branches per plant (15.98) was observed in treatment T_7: RDF + foliar application of 0.6% $FeSO_4$ at 30 and 45 DAS and the treatment was found to be significantly superior to the other treatments. At all growth stages, the lowest number of branches per plant (2.16 at 30 DAS and 5.80 at harvest) was observed in control T_1: NPK (20:40:40) (RDF). Iron nutrition helps plant branches grow by encouraging the synthesis of chlorophyll, which is necessary for photosynthesis, providing the energy required for growth. It also supports enzyme function and overall metabolism, promoting healthy branch development and preventing issues like chlorosis and stunted growth. Adhithya *et al.,* (2022) and Maddila *et al*., (2020) reported similar results in green gram.

Number of trifoliate leaves plant^{-1}

The data regarding the number of trifoliate leaves per plant, as affected by the application of treatments, recorded at two growth stages (30 DAS and at harvest), are presented in Table 1. The highest number of leaves per plant (15.80 at 30 DAS) was recorded with treatment T_3: RDF + 25 kg $FeSO_4$, which was found to be statistically at par with treatments T_2 and significantly superior to the rest of the treatments. Again, at harvest highest number of leaves per plant (31.62) was recorded with treatment T_7: RDF + foliar application (F.A.) of 0.6% $FeSO_4$ at 30 and 45 DAS and the treatment was found to be statistically at par with T_3 and significantly superior to the rest of the treatments. At all the growth stage, the minimum number of leaves per plant (9.32 at 30 DAS and 20.86 at harvest) was recorded with control T_1: NPK (20:40:40) (RDF). Iron fertilizer promotes chlorophyll production, supporting photosynthesis, healthy leaf growth and preventing chlorosis for vibrant, strong leaves. Similar finding were observed by Kumar *et al*., (2017).

Nodulation

The 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 (F.A.) of 0.6% FeSO„ at 30 and 45 DAS, which was 12.34 and was found to be statistically at par with treatments T_3 and significantly superior to the rest of the treatments. The minimum number of nodules per plant was observed under control T_1: NPK (20:40:40) (RDF), which was 8.68. Iron fertilizer boosts enzyme activity and nitrogen fixation, promoting healthy nodule development and efficient nutrient uptake. Karthikeyan *et al*., (2022) and Tribhuwan *et al.,* (2024) reported similar finding in green gram.

Number of pods plant^{-1}

The data regarding the number of pods per plant, as affected by the application of treatments, are presented in Table 1. As per recorded data number of pods plant^{-1} (Table-2). Treatment T_7: RDF + foliar application (F.A.) of 0.6% $FeSO_4$ at 30 and 45 DAS resulted in the highest number of pods per plant at harvest (16.48), which was statistically at par with treatment combinations like T_3, T_2, T_4 and T_6 and statistically significantly superior to the rest of the treatments. Iron is crucial for green gram pod formation, supporting key processes like photosynthesis, respiration and cell division, while a deficiency leads to chlorosis, reduced energy production and impaired pod development. Teja *et al*., (2022) reported similar finding.

Number of grains pod^{-1}

The quantity of grains per pod at the harvest stage was significantly influenced with iron fertilization, as shown in Table 2. Treatment T_7: RDF + foliar application (F.A.) of 0.6% $FeSO_4$ at 30 and 45 DAS had the highest number of grains per pod (8.98), which was statistically at par with the treatment combination of T_3 and T_2 and statistically significantly

Table 1: Effect of treatments application on growth attributes of green gram at deferent growth stages.

Treatments	Plant height (cm)		Number of branches (plant^{-1})		Number of leaves (plant^{-1})		Nodules at flowering stage (plant^{-1})
	30 DAS	At harvest	30 DAS	At harvest	30 DAS	At harvest	
T1- NPK (20:40:40)	16.40	33.32	2.16	5.80	9.32	20.86	8.68
T2- RDF + 20Kg $FeSO_4$	24.26	37.94	4.98	11.20	14	26.78	9.76
T3- RDF + 25Kg $FeSO_4$	27.12	41.30	5.60	13.86	15.8	29.18	12.02
T4- RDF + 0.3% $FeSO_4$ at 30 DAS	19.88	34.46	3.80	10.12	11.12	22.12	7.48
T5- RDF + 0.6% $FeSO_4$ at 45 DAS	20.19	37.36	3.60	9.96	10.72	21.04	9.22
T6- RDF + 0.3% $FeSO_4$ at 30 and 45 DAS	21.00	42.16	3.90	12.32	12.12	24.86	10.58
T7- RDF + 0.6% $FeSO_4$ at 30 and 45 DAS	20.68	44.24	4.12	15.98	12.38	31.62	12.34
SEm±	0.89	1.68	0.18	0.61	0.61	1.14	0.62
CD (5%)	2.76	5.18	0.56	1.87	1.89	3.50	1.92

• RDF - Recommended dose of fertilizers *Significant at $P \leq 0.05$; NS- Non significant at $P > 0.05$.

Table 2: Effect of treatments on yield, yield parameters and economics of green gram.

Treatments	Number of pods plant^{-1}	Number of grains Pod^{-1}	Test weight (g)	Biological yield (q ha^{-1})	Yield (q ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
T1- NPK (20:40:40)	12.32	8.18	33.26	24.29	9.13	63141	71152	8011	1.13
T2- RDF + 20Kg $FeSO_4$	15.26	8.70	33.48	26.80	10.12	69541	87862	18321	1.26
T3- RDF + 25Kg $FeSO_4$	16.23	8.80	35.42	29.36	11.20	71141	97238	26097	1.37
T4- RDF + 0.3% $FeSO_4$ at 30 DAS	14.66	8.18	33.86	25.00	9.46	63525	82132	18607	1.29
T5- RDF + 0.6% $FeSO_4$ at 45 DAS	13.06	7.98	34.00	25.50	9.68	63909	84042	20133	1.31
T6- RDF + 0.3% $FeSO_4$ at 30 and 45 DAS	14.6	7.87	35.30	29.84	11.30	63909	98106	34197	1.53
T7- RDF + 0.6% $FeSO_4$ at 30 and 45 DAS	16.48	8.98	36.00	30.98	12.10	64677	105052	40375	1.62
SEm±	0.63	0.25	1.25	0.93	0.38				
CD (5%)	1.94	0.76	3.85	2.86	1.17				

• RDF - Recommended dose of fertilizers *Significant at $P \leq 0.05$; NS- Non Significant at $P > 0.05$.

superior to the rest of the treatments. Whereas treatment T_1 (RDF) had the lowest number of grains per pod (7.87). NPK and iron fertilizers enhances the overall growth and productivity of green gram by plant metabolism, improving photosynthesis and other physiological processes, leading to better grain filling in the pods. Roy *et al*., (2024) reported similar results.

Test weight

The data presented in Table 2 revealed that the highest test weight (36.00 g) was recorded with T_7: RDF + foliar application (F.A.) of 0.6% $FeSO_4$ at 30 and 45 DAS, which was significantly higher than the majority of the treatment combinations. The treatment T_7 was significant over the treatment combination like T_5, T_4 and T_2 and statistically at par with the treatments like T_3 and T_6. The minimum test weight was observed under treatment T_1: NPK (20:40:40) (RDF), which was (33.26 g). Gahlot *et al*., (2020) reported similar results.

Biological yield

Effect of different treatments on biological yield of green gram presented in Table 2 the treatment combination consisting of RDF + foliar application (F.A.) of 0.6% $FeSO_4$ at 30 and 45 DAS (T_7) produced a significantly higher biological yield (30.98 q ha^{-1}) than other treatment combinations. The treatment T_7 was significantly superior the treatment combinations like T_5, T_4 and T_2 and statistically at par with the treatments like T_6 and T_3. Minimum biological yield of (24.29 q ha^{-1}) significantly lower than the rest of treatments was found in T_1 (RDF). NPK (Nitrogen, Phosphorus, Potassium) and Iron (Fe) fertilizers significantly boost the biological yield of green gram. NPK promotes healthy growth, root development and pod formation, while Iron supports photosynthesis, nitrogen fixation and overall plant metabolism. Rehaman *et al.,* 2024 reported similar results.

Grain yield

Considering the effect of treatment combinations on grain yield it was observed that the grain yield of green gram varied from (9.13 q ha{ ¹ to 12.10 q ha^{-1}). The highest grain yield (12.10 q ha^{-1}) was recorded in treatment T_7 which was statistically at par with treatments T_6 and T_3 and significantly superior to the other treatments. The lowest seed yield (9.13 q ha^{-1}) was recorded in treatment T_1 (RDF). The combination of RDF and $FeSO_4$ significantly enhanced pod development and grain yield in green gram, supporting our findings that treatment T7 significantly increased overall crop performance compared to other treatments. Dhaliwal *et al*., (2022) and Karthikeyan *et al*., (2022) reported similar results.

Effect of treatments on Economics of green gram

The effect of iron fertilization on the economics of green gram is presented in Table 2. Maximum gross returns (Rs. 105,052 ha^{-1}), net returns (Rs. 40,375 ha^{-1}) as well as highest B: C ratio (1.62) were recorded in treatment T_7:

RDF + foliar application (F.A.) of 0.6% $FeSO_4$ at 30 and 45 DAS. Due to enhanced yields, the marginal increase in production costs relative to the other treatments resulted in better yields, gross returns, net returns and B: C ratio.

CONCLUSION

As per research study, it can be concluded that combination of RDF and foliar application of 0.6% $FeSO_4$ at 30 and 45 DAS was effective for the growth, yield and economics of green gram. The green gram crop fertilized with RDF+ foliar application (F.A.) of 0.6% $FeSO_4$ at 30 and 45 DAS produced higher yields. Based on the experiment, it can be concluded that apply foliar application of Fe @ 0.6% at 30 and 45 DAS during green gram cultivation is would be benificial to enhance yield and profitability under semi-arid conditions.

ACKNOWLEDGEMENT

I would like to express my heartfelt gratitude to my research supervisor for their invaluable guidance, constant support and encouragement throughout the course of this research work. Their insightful feedback and expertise greatly contributed to the development and completion of this study. I also extend my sincere thanks to my department and institution for providing the resources and environment necessary for my research. Special appreciation goes to my peers and colleagues for their helpful discussions and moral support. Lastly, I thank my family and friends for their unwavering encouragement, patience and belief in me during the entire research journey.

Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal care and handling techniques were approved by the University of Animal Care 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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