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Impact of foliar application of zinc and iron on summer green gram (*Vigna radiata* L.)

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Abstract

Micronutrient malnutrition in soils, particularly iron & zinc deficiency, is a major inadequacy to pulse productivity in India. Summer greengram (*Vigna radiata* L.), an important fast-growing pulse crop, is highly sensitive to Zn and Fe deficiency, resulting in chlorosis, reduced nodulation, poor pod formation, and low grain yield. Foliar fertilization has emerged as an efficient strategy to correct micronutrient deficiencies during critical crop growth stages due to higher nutrient-use efficiency and rapid absorption. This review critically examines the physiological roles of Zn and Fe, mechanisms of foliar absorption, and their effects on yield, attributes, nutrient uptake, growth, grain excellence, and biofortification in green gram. Literature indicates that foliar use of ZnSO₄ (0.5%) and FeSO₄ (0.5%) put in at the flowering and pod initiation stages significantly improve chlorophyll content, height of plant, 100-seed weight, pods per plant, yield of grain, and seed micronutrient concentration (Rashid *et al.*, 2024; Farooq *et al.*, 2025). Combined foliar use of Fe and Zn shows synergistic effects compared to individual application. The review highlights research gaps and suggests future directions for optimizing foliar micronutrient management in green gram under Indian conditions.

Keywords: Green gram, foliar nutrition, zinc, iron, micronutrients, yield attributes, biofortification

1. Introduction

Green gram (*Vigna radiata* L.) is the key grain legumes cultivated extensively in India owing to its high protein content (20–25%), short term, and suitability in multiple cropping systems. Despite its importance, national productivity remains relatively low as compared to its genetic potential. Key reason for short production is widespread micronutrient deficiency, particularly zinc and iron (Singh and Sachdev, 2017) ^[23] nearly 48–50% of soils in India suffer from zinc deficiency (Alloway, 2009) ^[2]. Iron deficiency is commonly occur in calcareous and alkaline soils, leading to interveinal chlorosis and impaired physiological activity (Marschner, 2012) ^[18]. Micronutrient deficiency not only reduces yield but also lowers grain nutritional quality, contributing to hidden hunger among human populations (Cakmak *et al.*, 2017) ^[7] Foliar fertilization is increasingly recognized as a corrective and supplementary nutrient management strategy that enhances nutrient-use efficiency and minimizes soil-related losses (Fernández and Brown, 2013) ^[15].

Additionally, micronutrients are required for plant growth. Plant reproduction and the synthesis of growth-promoting hormones depend on zinc (Patel *et al.*, 2017) ^[19]. Zn is vital for the functioning of the many enzymes, including tryptophan synthases, dehydrogenases, and superoxide dismutase. Zinc deficiency leads to deficiencies in the production of RNA and proteins. Zinc-deficient plants therefore contain less protein (Singh *et al.*, 2018) ^[24]. Zinc fertilizer encourages root and shoot growth throughout the growing season, increasing seed yield, according to research by Rengel (2001) ^[22]. The method of micronutrient application was observed to positively influence plant growth and lead to the increase in seed yield. Most of the nation's agricultural lands suffer from zinc deficiency. Reduced leaves, delayed growth, chlorosis, and spikelet sterility are all symptoms of a zinc deficiency. These differences make plants more susceptible to different biotic and abiotic stressors. One of the micronutrients found in plants, zinc is necessary for a number of enzymatic functions. Usually, metals are used to activate

enzymes. It has been demonstrated that zinc increases crop productivity almost as much as major nutrients do. Zinc is involved in the synthesis of tryptophan, protein, and nucleic acid, among other aspects of auxin metabolism. Furthermore, it promotes nitrogen fixation and root nodulation in leguminous crops and helps plants absorb phosphate and nitrogen (Patel *et al.*, 2013) ^[20].

2. Physiological Role of Iron and Zinc in Green Gram

2.1 Role of Iron (Fe)

Iron plays a critical role in:

- Chlorophyll synthesis
- Electron transport chain (cytochromes, ferredoxin)
- Respiration and photosynthesis
- Nitrogen fixation in legumes
- Enzyme activation

Iron deficiency results in interveinal chlorosis of young leaves, reduced photosynthesis, and lower biomass production (Marschner, 2012) ^[18]. In legumes like green gram, iron is essential for nitrogenase enzyme activity in root nodules, thereby influencing biological nitrogen fixation (Fageria and Baligar, 2008) ^[12].

2.2 Role of Zinc (Zn)

Zinc is involved in:

- Auxin synthesis (IAA metabolism)
- Protein and nucleic acid synthesis
- Enzyme activation (dehydrogenases, carbonic anhydrase)
- Membrane integrity
- Carbohydrate metabolism

Zn deficiency causes stunted growth, small leaves, delayed maturity, and poor seed set (Broadley *et al.*, 2007) ^[5]. Zinc also improves nodulation and enhances nitrogen assimilation in pulses (Singh and Sachdev, 2017) ^[23].

3. Concept and Mechanism of Foliar Nutrition

Foliar fertilization denotes to the use of nutrient solutions directly onto plant leaves through spraying. Nutrient uptake occurs via:

- Cuticular penetration
- Stomatal absorption
- Diffusion across epidermal cells

Efficiency depends on spray concentration, environmental conditions (humidity, temperature), leaf age, and surfactants (Zhang and Brown, 1999) ^[31].

Advantages of Foliar Nutrition

- Rapid correction of deficiencies
- Higher nutrient-use efficiency
- Reduced fixation in soil
- Smaller nutrient doses required

Foliar fertilization is especially effective when root uptake is limited due to adverse soil conditions (Fernández and Brown, 2013) ^[15].

4. Impact of Foliar Zinc Practice on Growth and Yield

Foliar Zn application significantly improves:

- Height of plant
- Leaf area index

- Content of chlorophyll
- Dry matter accumulation

Angmo *et al.* (2022) ^[3] investigated the influence of zinc fertilization on green gram performance through an experiment involving four zinc levels: 0, 5, 10, and 15 kg/ha. They showed that applying zinc up to 10 kg/ha directed to a noticeable improvement in plant growth and yield. Plants grew taller and produced more pods per plant, while the 1000-seed weight also increased. These improvements ultimately resulted in higher yield of seed as well as greater stover yield.

Krishna *et al.* (2022) ^[16] conducted a study on green gram during Zaid season of 2021 at SHUATS, Prayagraj. The experiment included three zinc levels 10, 12, and 15 kg/ha. Among these, the use of zinc at 15 kg/ha produced the best growth by the time of harvest. Plants reached a height of 44.08 cm and developed about 6.04 branches/plant. The dry matter accumulation was also higher (6.20 g per plant), along with a greater no. of nodules (6.33 per plant). In addition, the crop growth rate was recorded at 2.62 g m⁻² day⁻¹ under this treatment.

Dhinakaran *et al.* (2021) ^[11] found that green gram achieved significantly higher pods per plant (28.46), seeds per pod (13.5), test weight (3.48 g), seed yield (950 kg/ha), and stover yield (1,520 kg/ha) when ZnSO₄ was applied to the soil at 25 kg/ha after incubating it with 125 kg vermicompost in a 1:5.

5. Effect of Foliar Iron Application

Foliar Fe sprays correct chlorosis and enhance chlorophyll synthesis. Dhayal *et al.* (2025) ^[10] described significant improvement in pods per plant and grain yield with foliar Fe application.

Iron improves:

- Nitrogen metabolism
- Photosynthetic efficiency
- Root nodulation
- Enzyme activity

Improved iron nutrition enhances vegetative growth and reproductive development (Marschner, 2012) ^[18].

Choudhary *et al.* (2018) ^[9] informed the effect of mungbean to foliar use of iron in Jobner condition and found that the grain yield was significantly increased (28.5%) with use of 0.5% FeSO₄ at branching with flowering over control, whereas straw yield was recorded 15.6% higher with 0.5% FeSO₄ at branching and 20.8% higher with the foliar practice same at branching + flowering stage over control

Soni *et al.* (2020) ^[27] performed an experiment at Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya in Chitrakoot, Satna (M.P.), Soni and colleagues examined how foliar sprays of zinc and iron influenced mung bean yields. Their findings showed no significant impact on height of plant, nodules per plant, or branches per plant.

Kumawat *et al.* (2006) ^[17] reported that soil application of iron at 25 kg FeSO₄ per hectare was statistically comparable to a foliar spray of 0.5% FeSO₄ combined with 0.1% citric acid applied at the branching and flowering stages. Both treatments produced significantly higher seed & straw yields of summer mungbean compared with the control.

Chaurasia *et al.* (2024) ^[8] showed that the improvements in growth parameters of greengram under combined input management, including micronutrients, indicating that iron may enhance nodulation and nitrogen fixation when integrated with biological inputs such as *Rhizobium*. Since iron supports the nitrogenase activity and energy transfer, adequate iron nutrition

contributes to stronger nodulation and better growth of plant. This supports the inclusion of parameters of growth such as crop height of crop, branches per plant, dry matter accumulation (DMA), and nodulation parameters when evaluating iron interventions in green gram.

6. Combined Foliar Practices of Zinc and Iron

Combined foliar usage of Zn and Fe produces synergistic effects. Farooq *et al.* (2025) ^[14] informed that combined application increased grain yield and micronutrient absorption more than single nutrient application.

Synergistic effects include:

- Improved enzyme activation
- Better chlorophyll formation
- Enhanced nutrient translocation
- Increased seed micronutrient density

Combined application supports agronomic biofortification (Welch and Graham, 2004; White and Broadley, 2009) ^[29, 30]

Barla *et al.* (2023) ^[4] performed an experiment to evaluate the impact of iron and zinc foliar and soil applications on summer mungbean output, nutritional content, and quality. They found that foliar spraying of 0.5% zinc sulfate and 0.5% iron sulfate at the start of flowering—combined with the standard fertilizer dose (RDF) and farmyard manure—delivered optimal results. This approach yielded the top seed production (521 kg/ha) and stover output (1307 kg/ha), plus the highest gross income (Rs 36,470/ha) and net income (Rs 8,020/ha), achieving a benefit-cost ratio of 1.28.

Soni *et al.* (2020) ^[27] investigated foliar zinc and iron applications impact on mungbean productivity at Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Chitrakoot, Satna (M.P.). Results showed significant gains in yield attributes, particularly pods per plant with a 0.5% FeSO₄ application at flowering initiation.

7. Effect on Yield Attributes

Foliar Fe and Zn significantly enhance:

- No. of pods per plant
- Seeds per pod
- 100-seed weight
- Grain yield
- Straw yield

Improvement is attributed to enhanced photosynthesis and carbohydrate translocation to developing pods (Fageria and Baligar, 2008) ^[12].

8. Effect on Nutrient Uptake and Biofortification

Foliar Zn and Fe increase micronutrient concentration in grains. Agronomic biofortification through foliar fertilization is considered an effective strategy to address micronutrient malnutrition (Cakmak, 2008) ^[6]. Higher Zn and Fe density in green gram seeds contributes to improved human nutrition (FAO, 2024) ^[12].

9. Factors Affecting Foliar Efficiency

- Stage of application (flowering stage most responsive)
- Concentration of spray solution
- Frequency of spraying
- Environmental conditions
- Use of surfactants Excess concentration may cause leaf scorching (Fernández and Brown, 2013) ^[15].

10. Economic Feasibility

Foliar application requires low quantities of micronutrients, making it cost-effective. Yield gains often outweigh the cost of micronutrient sprays, particularly under Zn-deficient soils.

11. Research Gaps and Future Directions

- Need for multi-location and long-term studies
- Standardization of dose and timing
- Interaction with abiotic stresses (drought, salinity)
- Integration with integrated nutrient management

12. Conclusion

Foliar application of zinc & iron significantly enhances growth of plant, yield attributes, grain yield and the micronutrient content of summer green gram. Combined use is more effective than individual sprays. Adoption of foliar micronutrient management can enhance productivity and contribute to nutritional security in India.

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