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Foliar Nutrition with Iron and Zinc for Improving Growth, Yield and Quality of Groundnut (*Arachis hypogaea* L.)

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Abstract

Groundnut (*Arachis hypogaea* L.) is an important oilseed crop valued for its high oil and protein content and its contribution to food and nutritional security. Iron (Fe) and zinc (Zn) are essential micronutrients involved in several physiological and biochemical processes, and their inadequate availability may restrict crop growth and productivity. Foliar application provides an effective complementary approach for supplying micronutrients during critical stages of crop development. Recent studies have demonstrated beneficial effects of chelated Fe and Zn, particularly Fe-EDDHA and Zn-EDTA, on nutrient uptake, growth, yield and quality of groundnut when integrated with soil application. Fe-fortified humic substances and siderophore-producing bacteria have also shown potential for improving Fe nutrition. This article reviews recent findings on Fe and Zn nutrition in groundnut and discusses their implications for integrated micronutrient management and sustainable crop production.

Keywords: Foliar nutrition, Groundnut, Iron, Micronutrient management, Zinc

Introduction

Groundnut (*Arachis hypogaea* L.), commonly known as peanut, is an important oilseed and food legume cultivated extensively in tropical and semi-arid regions. The crop is valued for its edible seeds, high oil and protein content, and nutritionally important by-products used as livestock feed. Groundnut also contributes to agricultural sustainability through its role in crop rotation and biological nitrogen fixation. In India, it represents an important component of the agricultural economy and contributes to food and nutritional security.

Groundnut production is affected by several abiotic and biotic constraints, including irregular rainfall, pest and disease incidence, soil degradation and nutrient deficiencies. Among nutritional constraints, inadequate availability of micronutrients such as Fe and Zn may adversely affect plant growth, physiological processes and yield. Iron is associated with chlorophyll synthesis and nitrogen metabolism; whereas Zn participates in enzyme activation and several metabolic processes.

Conventional soil fertilization does not always ensure adequate micronutrient availability because nutrient fixation, soil characteristics and imbalanced fertilization can influence nutrient accessibility. Climate variability may further complicate nutrient availability and uptake. Consequently, foliar nutrition has received increasing attention as a complementary approach for supplying micronutrients directly to plant tissues during critical crop-growth stages.

Micronutrient Constraints in Groundnut Production

Groundnut is of considerable economic and nutritional significance and is an important source of edible oil, proteins, essential fatty acids, vitamins and minerals. Its inclusion in crop rotations also contributes to soil fertility through biological nitrogen fixation.

Several constraints can influence groundnut productivity. Continuous cultivation without balanced nutrient management may contribute to soil nutrient depletion. Deficiencies of Fe and Zn can result in poor plant growth, chlorosis and reduced yield. In addition, variations in rainfall can affect nutrient availability and uptake, while pest and disease infestations may further reduce yield potential.

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Rising temperatures and unpredictable weather patterns may intensify crop stress and influence nutrient-use efficiency.

These constraints emphasize the importance of integrated nutrient-management strategies that combine appropriate soil fertility management with targeted foliar application where required.

Foliar Nutrition with Chelated Iron and Zinc

Chelated micronutrient formulations have been investigated as potential sources of Fe and Zn for improving nutrient availability and crop performance. Among these, Fe-EDDHA and Zn-EDTA have been evaluated in groundnut production.

Hadole *et al.* (2024) investigated the effects of chelated Zn and Fe on nutrient uptake and quality parameters of summer groundnut. The study reported that soil application of Zn-EDTA and Fe-EDDHA combined with foliar sprays at 35 and 65 days after sowing (DAS) resulted in improved uptake of N, P and K as well as Fe and Zn. The treatment comprising 100% recommended dose of fertilizers (RDF), Zn-EDTA at 1.5 kg ha^{-1} and Fe-EDDHA at 1.5 kg ha^{-1}, supplemented with foliar application, recorded superior nutrient-uptake responses. The improved nutrient uptake was accompanied by enhanced plant height, dry-matter accumulation and branch formation, which contributed to improved yield performance.

These findings indicate the potential value of integrated soil and foliar micronutrient application. However, the results should not be interpreted as evidence that foliar application alone was responsible for all observed improvements because the reported treatment incorporated both soil and foliar applications.

Influence on Yield and Quality

Improved micronutrient uptake may contribute to enhanced vegetative development, yield formation and grain quality. Hadole *et al.* (2024) reported the highest pod and haulm yields under combined soil and foliar application of chelated Fe and Zn. The treatment also improved protein and oil content, indicating potential benefits for both productivity and nutritional quality.

Barman *et al.* (2023) evaluated foliar application of Fe-fortified humic substances and humic acid in groundnut grown on calcareous Vertisol. A treatment comprising 0.50% humic substances fortified with 500 ppm Fe produced superior growth and yield responses, including increased pod and kernel weights. The study also reported beneficial effects on nodulation. The findings suggest that the response to Fe nutrition may depend on soil characteristics and the form in which Fe is supplied. Consequently, treatment responses obtained under specific experimental conditions should be interpreted within their respective soil and environmental contexts.

Importance of Zinc Nutrition

Zinc is an essential micronutrient involved in several enzymatic and physiological functions in plants. In groundnut, Zn deficiency can adversely affect plant growth, nutrient uptake and yield. Radhika and Meena (2021) reviewed the effects of Zn nutrition on groundnut and emphasized its importance in improving growth, nutrient uptake, yield and quality. The review also highlighted the potential of foliar-applied chelated Zn, including Zn-EDTA, for improving yield and nutritional quality.

The magnitude of crop response to Zn application is, however, dependent on factors such as the severity of deficiency, soil characteristics, crop genotype and environmental conditions. Therefore, reported responses should be considered in relation to the conditions under which the respective studies were conducted.

Biological Approaches to Improving Iron Nutrition

Biological approaches may complement conventional micronutrient-management practices. Sarwar *et al.* (2022) investigated siderophore-producing bacterial strains (SPBs) for improving Fe nutrition and biofortification in groundnut. Siderophores are microbial compounds capable of binding Fe and thereby influencing its availability to plants. The study reported that combining SPBs with foliar-applied Fe increased total Fe uptake by 14.73% to 45.72%. This finding indicates the potential of microbial interventions to complement foliar Fe application and contribute to improved Fe nutrition and biofortification in groundnut.

Such biological approaches may be particularly relevant within integrated nutrient-management systems, although their effectiveness requires consideration of environmental conditions and the specific microbial strains used.

Practical Considerations for Integrated Micronutrient Management

The studies reviewed in the original article indicate that integrated soil and foliar application may provide beneficial responses in groundnut. Based on the findings of Hadole *et al.* (2024), foliar application at 35 and 65 DAS and soil application of Zn-EDTA and Fe-EDDHA at 1.5 kg ha^{-1} were associated with improved nutrient uptake and crop performance. He further suggested foliar application of 0.5% Zn-EDTA and 1.0% Fe-EDDHA, together with soil application of 1.5 kg ha^{-1} for both micronutrients. These values should be regarded as rates reported or proposed on the basis of the studies discussed and should not be considered universally optimum for all groundnut-growing environments.

Soil testing and assessment of crop nutrient status are therefore important for developing site-specific nutrient-management strategies. Factors such as soil properties, initial Fe and Zn availability, crop growth stage and environmental conditions should be considered when selecting micronutrient sources, rates and application schedules (Table 1).

Experimental and Research Considerations

Research on micronutrient management in groundnut has employed experimental approaches such as Factorial Randomized Block Design (FRBD) to evaluate the effects of different nutrient treatments and their interactions. Hadole *et al.* (2024) used such an approach to investigate chelated Fe and Zn and their effects on nutrient uptake and crop performance.

Table 1: Selected findings on Fe and Zn management in groundnut

Nutrient/ Approach	Application method	Rate/timing reported	Major response	References
Zn-EDTA+Fe-EDDHA	Soil+foliar	1.5 kg ha^{-1} each; foliar application at 35 and 65 DAS	Improved nutrient uptake, growth and yield.	Hadole *et al*. (2024)
Fe-fortified humic substances	Foliar	0.50% HS+500 ppm Fe	Improved growth, nodulation and pod/kernel weight.	Barman *et al*. (2023)
SPBs+Fe	Biological+foliar	Study-specific	14.73-45.72% increase in total Fe uptake.	Sarwar *et al*. (2022)
Zn nutrition	Soil/foliar approaches	Various treatments	Improved nutrient uptake, growth, yield and quality.	Radhika and Meena (2021)

Future research should place greater emphasis on multi-location and multi-season evaluation of Fe and Zn application strategies. The effectiveness of micronutrient application may vary with soil type, pH, nutrient status, cultivar, climate and crop-growth stage. Further investigations should also assess nutrient-use efficiency and the economic feasibility of foliar micronutrient application.

Integration of chemical and biological approaches, including siderophore-producing microorganisms and Fe-fortified humic substances, represents another potential area for research. Such approaches could contribute to improved nutrient-use efficiency and sustainable micronutrient management.

Conclusion

Fe and Zn are important micronutrients for maintaining normal growth, nutrient metabolism, productivity and quality of groundnut. Recent studies reviewed in this article demonstrate beneficial responses to chelated Fe and Zn, particularly when soil and foliar applications are integrated. Hadole *et al.* (2024) reported improved nutrient uptake, growth, yield and quality parameters with Zn-EDTA and Fe-EDDHA, while Barman *et al.* (2023) demonstrated beneficial responses to Fe-fortified humic substances under calcareous Vertisol conditions. Sarwar *et al.* (2022) further demonstrated the potential of siderophore-producing bacterial strains to enhance Fe uptake when combined with foliar Fe application.

Overall, foliar Fe and Zn nutrition represents a promising component of integrated micronutrient management in groundnut. However, application rates and timings should be selected according to crop and soil conditions and validated through appropriate field research. Soil testing, balanced fertilization and site-specific recommendations remain important for achieving efficient and sustainable micronutrient management.

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