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A Review on Foliar Nutrition in Chickpea: Implications for Growth, Yield and Nutrient Use Efficiency

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Review Article

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Abstract

Pulses play a crucial role in global food and nutritional security because of their high protein content and contribution to sustainable agriculture. Among pulse crops, chickpea (*Cicer arietinum* L.) is one of the most widely cultivated and economically important food legumes in the semi-arid and subtropical regions of the world. It is a major source of dietary protein, essential amino acids, vitamins and minerals, particularly for vegetarian populations in developing countries such as India. In addition to its nutritional importance, chickpea contributes to soil fertility through biological nitrogen fixation, thereby improving soil health and supporting sustainable cropping systems. Despite its importance, chickpea productivity remains relatively low in many regions because of nutrient deficiencies, moisture stress, poor soil fertility, pest and disease incidence, and inadequate crop-management practices. Efficient nutrient-management strategies are therefore essential for enhancing crop productivity and sustainability. In recent years, foliar nutrition has emerged as an

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effective supplement to conventional soil fertilisation because it enables rapid nutrient absorption and the correction of deficiencies during critical growth stages. The development of water-soluble fertilisers and speciality nutrient formulations has further improved the efficiency of foliar feeding. Several studies have reported that the foliar application of macro- and micronutrients during key growth stages can improve plant growth, flower retention, pod formation, nutrient uptake and seed yield in chickpea. Integrated nutrient-management approaches that combine soil fertilisation with foliar nutrient application have also shown promise for enhancing productivity and nutrient-use efficiency. This review compiles and critically analyses the available literature on nutrient-management strategies, particularly foliar fertilisation, for improving chickpea growth, yield attributes, nutrient uptake and overall productivity. The findings may inform the development of efficient nutrient-management practices for sustainable chickpea production.

Keywords: Chickpea; Foliar nutrition; Nutrient management; Water-soluble fertilizers; Pulse crops; Yield improvement; Nutrient uptake; Sustainable agriculture; Integrated nutrient management.

1. Introduction

Pulses play a vital role in global food and nutritional security, particularly in developing countries where plant-based diets predominate. As members of the family Fabaceae, pulses are essential components of sustainable agricultural systems because of their high nutritional value and ecological benefits (Kocoń, 2010; Chtouki et al., 2022). They are major sources of dietary protein, complex carbohydrates, vitamins and minerals, making them indispensable for human nutrition. In countries such as India, where a large proportion of the population follows a vegetarian diet, pulses constitute one of the most affordable sources of protein (Kachave & Kausadikar, 2018). In addition to protein, pulses provide essential micronutrients such as iron, calcium, phosphorus and zinc, together with important amino acids required for balanced nutrition. Therefore, increasing pulse production is critical for addressing malnutrition and ensuring food and nutritional security in many parts of the world (Shivay et al., 2015).

Among pulse crops, chickpea (*Cicer arietinum* L.) is one of the most important food legumes cultivated worldwide. It is predominantly grown during the rabi season in semi-arid and subtropical regions and plays a key role in cropping systems because of its adaptability to diverse agroclimatic conditions and relatively low input requirements. Chickpea contributes significantly to the global pulse economy and occupies a prominent position in terms of cultivated area and production (Venkatesh & Basu, 2011; Pal et al., 2019).

India is the largest producer and consumer of chickpea in the world and accounts for a major share of the global area and production (Lusiba et al., 2018). The crop is widely cultivated in major chickpea-growing states such as Madhya Pradesh, Uttar Pradesh, Rajasthan, Maharashtra, Gujarat, Andhra Pradesh and Karnataka. Despite its importance, the average productivity of chickpea remains relatively low compared with its potential yield because of several agronomic and environmental constraints, including nutrient deficiencies, moisture stress and poor crop-management practices (Rahman et al., 2017).

Chickpea also plays an important role in sustainable agriculture because of its ability to improve soil fertility through biological nitrogen fixation. The crop forms a symbiotic association with nitrogen-fixing bacteria of the genus *Rhizobium*, which fix atmospheric nitrogen and improve soil fertility for subsequent crops. This characteristic makes chickpea an integral component of sustainable cropping systems, particularly in rainfed agriculture (Kumar et al., 2017). However, chickpea productivity in many regions has remained stagnant because of production constraints such as nutrient deficiencies, a low harvest index, pest and disease incidence, and the limited adoption of improved agronomic practices. Balanced fertilisation and efficient nutrient management are therefore essential for enhancing crop productivity and sustainability (Khan et al., 2018; Khan et al., 2021).

In recent years, foliar nutrition has gained considerable attention as an effective approach to improving nutrient-use efficiency and crop productivity. Foliar application allows nutrients to be absorbed directly through plant leaves, enabling the rapid correction of nutrient deficiencies and improving physiological processes during critical growth stages. Studies have reported that the foliar application of nutrients significantly improves growth parameters, yield attributes and seed yield in chickpea (Wen et al., 2023).

Furthermore, the application of micronutrients such as zinc and iron through soil and foliar methods has been shown to enhance chickpea growth, yield and grain quality. The combined application of $ZnSO_4$ and $FeSO_4$ significantly improved yield attributes, protein content and economic returns compared with untreated crops (Pathak et al., 2012; Rawat et al., 2023).

Recent studies have also highlighted the potential of foliar micronutrient fortification to improve the yield and nutritional quality of chickpea. For instance, the foliar application of micronutrient formulations significantly increased chickpea seed yield, straw yield and protein content under field conditions (Gupta et al., 2011; Hussain et al., 2022).

Similarly, integrated approaches that combine soil fertilisation with foliar nutrient sprays have been reported to enhance chickpea growth, nutrient uptake and productivity (Irshad et al., 2022).

Although several studies have demonstrated the beneficial effects of foliar nutrient application in chickpea, comprehensive information on the combined roles of soil fertilisation and the foliar application of water-soluble nutrients remains limited. Therefore, a systematic synthesis of the available research findings is necessary to clarify the role of foliar nutrition in improving chickpea growth, yield attributes, nutrient uptake and productivity (Drostkar et al., 2016). The present review aims to critically analyse the available literature on nutrient-management strategies, particularly foliar fertilisation, for improving chickpea productivity and sustainability.

2. Review

2.1 Importance of Foliar Fertilisation

Foliar fertilisation has gained increasing attention as an efficient nutrient-management strategy for improving crop growth, productivity and nutrient-use efficiency. Unlike soil fertilisation, foliar application allows nutrients to be absorbed directly through the leaf surface, enabling the rapid correction of nutrient deficiencies and improved nutrient utilisation during critical growth stages. Early studies demonstrated that foliar feeding with water-soluble fertilisers significantly enhanced plant growth, yield attributes and quality parameters in several crops. The method is particularly beneficial when soil nutrient availability is limited or nutrient uptake by plant roots is constrained.

In cropping systems such as rice-fallow pulses, basal fertiliser application is often difficult because pulse crops are sown before the preceding rice crop is harvested. Under such conditions, the soil incorporation of fertilisers becomes impractical, and foliar fertilisation provides a convenient and effective alternative for supplying essential nutrients. Moreover, nutrient application through foliar sprays during critical growth stages improves nutrient-use efficiency and enhances crop performance.

Recent studies have further highlighted the importance of foliar nutrition in pulse-production systems. The foliar application of nutrients has been shown to improve physiological efficiency, enhance nutrient translocation and increase crop productivity under both irrigated and rainfed conditions. In addition, foliar feeding has become increasingly important in modern agriculture because it reduces nutrient losses through leaching and fixation while providing a rapid plant response.

2.2 Effect of the Foliar Application of Water-Soluble Fertilisers on Growth and Yield Parameters

Balanced fertilisation plays a crucial role in achieving optimum crop growth and productivity. The application of nutrients in appropriate quantities and proportions and at suitable growth stages significantly influences crop performance. Several researchers have reported positive crop responses to the foliar application of nutrients.

Ganesa Raja (1990) reported that the application of higher levels of NP fertilisers (60:120 kg ha^{-1}), combined with foliar sprays of 2% diammonium phosphate (DAP) and 0.5% $ZnSO_4$ at flowering, significantly increased soybean grain yield compared with lower fertiliser levels. Similarly, Sarkar and Mukhopadhyay (1990) observed that the foliar application of 0.5% potassium nitrate (KNO_3) during flowering improved grain yield in rice cultivars.

In pulse crops, foliar fertilisation has shown promising results. For instance, Solaiappan and Ramiah (1990) reported that foliar spraying with 3% DAP resulted in a higher seed yield in pigeonpea than sprays of urea or single superphosphate. Similarly, Dwivedi and Tiwari (1991) found that the foliar application of 2% urea significantly increased the number of pods per plant in chickpea.

Foliar sprays of nutrients and growth regulators have also been shown to influence physiological growth parameters. Kalarani (1991) observed that the foliar application of 1% urea combined with 50 ppm naphthaleneacetic acid (NAA) improved the specific leaf area of soybean. Likewise, Baghel and Yadhav (1992) reported that NAA application enhanced growth parameters in blackgram.

Further studies demonstrated that the foliar application of 3% DAP at flowering and again 15 days later significantly increased the number of pods per plant, seed weight and grain yield in blackgram and greengram (Rajendran, 1991). These findings indicate that well-timed foliar nutrition can improve vegetative and reproductive growth in pulse crops.

Later studies confirmed the beneficial effects of foliar fertilisation on crop growth and productivity. Ramamoorthy et al. (1995) reported that foliar spraying with 1% potassium chloride during flowering and pod formation significantly increased plant height and grain yield in rainfed blackgram. Similarly, Yadav and Choudhary (2012) reported favourable crop responses to foliar nutrition in cowpea.

More recent studies have also confirmed the role of foliar fertilisation in improving the growth and yield of chickpea and other pulses. Mudalagiriyappa et al. (2016) reported that the foliar application of water-soluble fertilisers improved chickpea growth, yield and economic returns. Singh et al. (2021) similarly reported improvements in chickpea growth and yield following the foliar application of water-soluble fertilisers. Kumar et al. (2023) further reported improved growth attributes and yield in chickpea following the foliar application of zinc and boron.

Foliar fertilisation may also support crop performance under stressful production conditions. More recently, Singh et al. (2023) reported that foliar-applied urea improved the yield and monetary returns of irrigated chickpea.

2.3 Effect of Foliar Application on Nutrient Uptake

Foliar fertilisation plays an important role in improving nutrient-uptake efficiency in crops. Nutrients applied through foliar sprays penetrate the leaf cuticle or stomata and are rapidly translocated to different plant parts, resulting in efficient utilisation (Tisdale et al., 1993).

Several studies have reported increased nutrient uptake following foliar fertilisation. Chapagain and Wiesman (2004) reported increased concentrations of phosphorus, potassium, magnesium and iron in tomato leaves following the foliar application of monopotassium phosphate.

Comparable improvements in plant nutrient status have been reported following the foliar application of balanced fertilisers. Kocoń (2010) also found that foliar feeding with urea improved nitrogen uptake in faba bean.

Recent research further supports the positive effects of foliar fertilisation on nutrient uptake in pulse crops. Venkatesh and Basu (2011) reported an increased nitrogen concentration in chickpea leaves following repeated foliar sprays of urea. Likewise, Yadav and Choudhary (2012) observed enhanced nitrogen, phosphorus and potassium uptake in cowpea following the foliar application of DAP. More recently, Khan et al. (2021) reported that integrated nutrient-management practices improved nutrient uptake and nutrient-use efficiency in chickpea.

2.4 Effect of Foliar Fertilisation on Flower Retention

Flower drop is a major factor limiting yield in pulse crops. Foliar nutrition during reproductive stages can improve flower retention and pod formation by ensuring adequate nutrient availability during critical growth periods.

Ravindranath et al. (1985) observed reduced flower drop and increased yield in pigeonpea following the foliar application of potassium.

Recent studies have confirmed that foliar nutrition enhances reproductive growth in pulses. Ganapathy et al. (2008) reported that the foliar application of 2% DAP combined with plant growth regulators significantly increased flower formation and reduced flower shedding in rice-fallow pulses. Similarly, Singh et al. (2021) reported that foliar fertilisation improved the growth and yield of chickpea.

2.5 Effect of Foliar Fertilisation on Quality and Protein Content

In addition to improving yield, foliar fertilisation also enhances crop-quality parameters. Chapagain and Wiesman (2004) reported improved fruit-quality attributes in tomato, including higher total soluble solids and fewer physiological disorders, following foliar nutrient application.

Similarly, Chaurasia et al. (2005) observed improved total soluble solids in tomato following repeated foliar sprays of water-soluble fertilisers. Senthil Valavan and Kumaresan (2006) also reported improved capsaicin content in chilli when foliar fertilisation was combined with soil fertilisation.

In chickpea, the foliar application of nitrogen sources such as urea has been reported to increase grain protein content by improving nitrogen availability during seed filling (Venkatesh & Basu, 2011). Similar improvements in protein content have been reported in mungbean and soybean following foliar nutrient application (Khalilzadeh et al., 2012; Sohrabi et al., 2012). More recent evidence also indicates that foliar-applied urea can improve chickpea yield and associated quality-related traits (Singh et al., 2023).

2.6 Effect of Foliar Fertilisation on Economics

Foliar fertilisation not only enhances crop productivity but also improves economic returns for farmers. Ramamoorthy et al. (1995) reported favourable crop responses in rainfed blackgram following foliar potassium application combined with basal fertilisation.

Similarly, Parasuraman (2001) reported increased net returns in cowpea when recommended fertilisers were combined with foliar sprays of DAP. Chaurasia et al. (2005) also reported higher net returns from tomato following repeated foliar sprays of water-soluble fertilisers.

Table 1. Foliar Nutrients, Dose, Stage, and Crop Response in Chickpea

Foliar Nutrient	Dose /Concentration	Growth Stage of Application	Crop Response
Zinc sulphate ($ZnSO_4$)	0.5%	Pre-flowering / Flowering	Increased plant height, pods per plant, and seed yield
Iron sulphate ($FeSO_4$)	0.5%	Vegetative / Flowering	Improved chlorophyll content and photosynthesis
Urea	2%	Flowering / Pod filling	Enhanced nitrogen availability and seed yield
NPK (19:19:19)	1–2%	Vegetative / Flowering	Improved overall growth and yield attributes
Boron (B)	0.2%	Flower initiation	Better flower retention and pod setting
Micronutrient mixture	0.5%	Critical growth stages	Increased yield, protein content, and nutrient uptake

Recent studies further highlight the economic advantages of foliar fertilisation. Mudalagiriyappa et al. (2016) reported higher economic returns in chickpea following the foliar application of water-soluble fertilisers. Similarly, Singh et al. (2023) reported that foliar-applied urea improved chickpea yield and monetary returns.

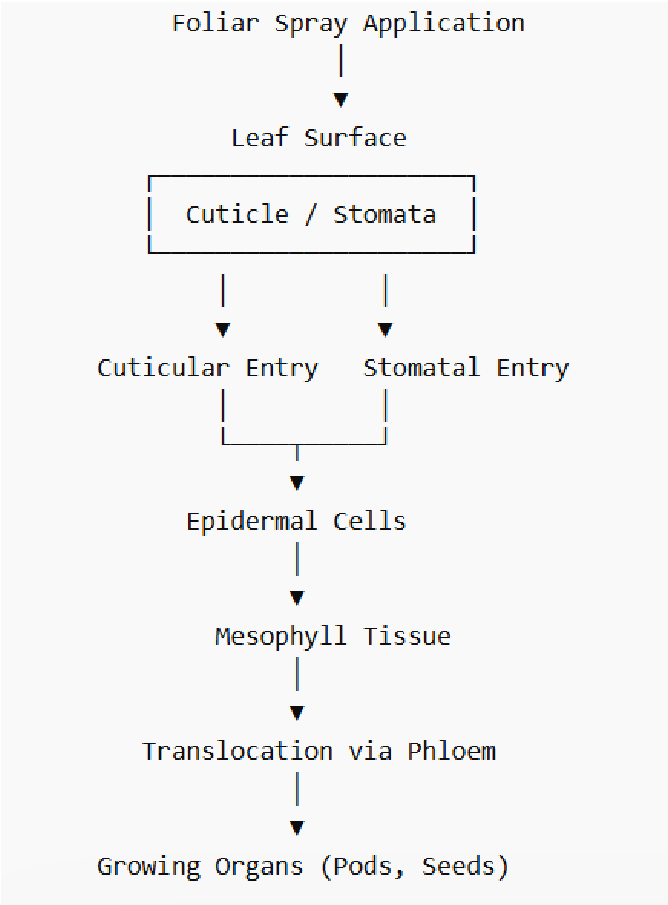

Fig. 1. Foliar nutrient uptake pathway

3. Conclusion

Chickpea (*Cicer arietinum* L.) contributes substantially to nutritional security and sustainable cropping systems, but its productivity is often limited by nutrient deficiencies, poor soil fertility and suboptimal crop management, particularly under rainfed conditions. The literature reviewed indicates that foliar fertilisation can serve as an effective supplement to soil-applied nutrients by supplying nutrients rapidly during critical stages of crop development. Applications of urea, diammonium phosphate, balanced NPK formulations and selected micronutrients have been associated with improvements in vegetative growth, flower retention, pod formation, nutrient uptake, seed filling, yield, protein content and economic returns. However, the effectiveness of foliar nutrition depends on the nutrient source, concentration, timing, frequency of application and production environment. Its greatest value is therefore likely to be realised when it is integrated with balanced soil fertilisation and other sound agronomic practices rather than used as a complete substitute for soil nutrient management. Location-specific validation and careful optimisation are required before broad recommendations are made. Properly designed foliar-nutrition strategies may improve nutrient-use efficiency, productivity and profitability while supporting more sustainable chickpea production.

4. Research Gaps and Future Prospects

Despite considerable research on nutrient management in chickpea (*Cicer arietinum* L.), several knowledge gaps remain that limit the wider adoption and optimisation of foliar fertilisation practices. Most available studies have focused on individual nutrients such as nitrogen or phosphorus, whereas limited attention has been given to the combined foliar application of macro- and micronutrients. Because chickpea productivity is influenced by multiple nutrient interactions, comprehensive studies are needed to evaluate balanced foliar nutrient formulations and their synergistic effects on growth, yield and nutrient uptake.

Another important research gap is the lack of location-specific recommendations for foliar fertilisation. Chickpea is cultivated across diverse agroecological regions, and variations in soil fertility, climate and cropping systems significantly influence crop responses to nutrient-management practices. Therefore, region-specific research is necessary to determine the optimal nutrient concentrations, application timing and frequency of foliar sprays for different environments.

Further research is also required to understand the physiological and biochemical mechanisms associated with foliar nutrient absorption, translocation and utilisation in chickpea plants. Such studies would help improve nutrient-use efficiency and support the development of advanced fertiliser formulations tailored to crop requirements. In addition, the role of foliar fertilisation in enhancing stress tolerance, particularly under drought and heat stress, requires further investigation because chickpea is often grown in rainfed and marginal environments.

The integration of foliar fertilisation with other sustainable nutrient-management approaches, such as biofertilisers, organic amendments and integrated nutrient-management systems, also requires greater attention. Long-term field experiments evaluating the combined effects of these practices on soil health, crop productivity and environmental sustainability would provide valuable insights into sustainable chickpea production.

From a practical perspective, future research should also focus on developing farmer-friendly foliar nutrient technologies, including ready-to-use water-soluble fertiliser formulations and precision nutrient-management tools. The use of digital agriculture, remote sensing and precision-farming techniques could further improve the efficiency of foliar nutrient application and support farmers' decision-making.

Overall, addressing these research gaps will help to develop more efficient, sustainable and economically viable nutrient-management strategies for chickpea cultivation. Such advances will contribute to improved productivity, enhanced resource-use efficiency and greater resilience of pulse-based cropping systems under changing climatic conditions.

5. Limitations

This review is limited by the heterogeneity of the cited studies in crop varieties, soil conditions, climates, nutrient formulations, concentrations, application schedules and measured outcomes. Several findings were derived from crops other than chickpea, which restricts direct comparison and generalisation. The available evidence also provides limited information on long-term soil effects, environmental losses, physiological mechanisms and consistent economic performance across locations. Consequently, the reported benefits should be interpreted as context-dependent, and recommendations require validation through well-designed, multi-location and multi-season chickpea experiments.

Declaration of AI Use

This manuscript was prepared through the combined contributions of all author(s), including contributions to the study design, data, content development, results, interpretation, and related scholarly work. The author(s) acknowledge the use of Grammarly and ChatGPT to assist with grammar checking, language refinement, reference formatting. These AI-assisted tools were not used as authors and did not replace the intellectual contributions or scholarly judgment of the author(s). All AI-assisted outputs, including content, references, and interpretations, were carefully reviewed, revised, verified, and approved by the author(s). The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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