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# Nutrient Management in Cropping Systems: A Way of Agricultural Sustainability

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Crops need nutrients for their optimum growth and productivity. However, only primary nutrients are applied to meet the crop needs, which is also in an imbalanced proportion. In the recent age where several technological developments took place, crop nutrient management can be adopted in an integrated way by including all essential nutrients to be supplied from different sources in a balanced and proportionate manner, even nano-materials. Further, the crop nutrient management for a single crop is not a wise practice; rather, it should be based on the cropping systems adopted to ensure the best efficiency of the applied nutrients. In the cropping system, both intercropping and sequential cropping are to be taken into consideration and crop rotation by inclusion of legumes is beneficial for nutrient management. The ultimate target is agricultural sustainability, which can be achieved through efficient nutrient management of the cropping system.

## Plants need nutrients

Crop productivity is directly influenced by effective nutrient management. Plant growth, development, and general health are optimised when the proper ratio of necessary nutrients, including macro- and micronutrients, is provided (Maitra *et al*. 2001; Maheswari *et al*., 2025). The practice of supplying the essential nutrients to plants in an ideal and balanced way to support their growth, development, and productivity is known as plant nutrition management (Krishna *et al*., 2024a; Ray and Sairam, 2024; Hemasree *et al*., 2024; Mahto *et al*., 2025). Sustainable nutrient management in cropping systems is crucial for maintaining soil health, increasing yields, and reducing the environmental impact of agriculture (Sairam *et al*., 2023; Krishna *et al*., 2024b). It involves providing crops cultivated in the cropping system with the right amount of nutrients at the right time and place, considering their specific requirements and the soil's fertility status (Sairam *et al*., 2024, 2025). In general, farmers provide nutrients mainly through chemical fertilisers and which are limited in the supply of primary nutrients. Recently, the application of sulphur as a nutrient has increased. Further, calcium and magnesium are also used to ameliorate problematic soils such as acidic, alkaline and saline soils. However, micronutrients are not applied unless soils or plants show a deficiency to them. Plants remove micronutrients also from the soil for their flourishing, and thus, the depletion of nutrients takes place (Ray *et al*., 2024).

In a cropping system, crops are grown in either sequence (sequential cropping) or simultaneously (intercropping); hence, the nutrient management practices are to be adopted based on their collective needs for the specific period. In a cropping system, if legumes are included, the nitrogen requirement will be reduced; however, phosphorus needs may be enhanced (Manasa *et al*., 2021; Maitra *et al*., 2024a; Ray *et al*., 2025). By ensuring that crops have access to the nutrients they need at different growth stages, nutrition management practices enable them to fulfil their maximum potential and reach higher productivity levels

(Maitra, 2020; Maitra and Gitari, 2020). The following practices are to be adopted for a sustainable nutrient management in cropping systems.

**Integrated nutrient management:** It is a strategy that enhances the use of nutrients in agriculture while reducing their negative effects on the environment. It involves crop rotation and integration of all possible sources of nutrients, namely, organic, green and brown manuring, chemical, biofertilizers and nanomaterials (Hossain *et al*., 2021; Mwadalu *et al*., 2022). INM seeks to improve soil fertility, nutrient use efficiency, and sustainability in agricultural systems (Midya *et al*., 2021a, b; Maitra and Zaman, 2017; Maitra *et al*., 2018).

**Precision nutrient management:** This method makes the best use of nutrients in farming. They include the administration of nutrients that are site-specific, variable in rate, timed according to crop growth stages, fertilisers with controlled releases, and sensor-based nutrient management (Sagar *et al*., 2023, 2024). Precision nutrient management minimises environmental impacts while increasing agricultural output, decreasing losses, and improving nutrient usage efficiency.

While practising nutrient management for a cropping system in a sustainable manner, some key points are to be considered. They are: (i) balanced supply of all essential nutrients from various sources, namely, organic, biofertilizer and chemical nutrients as per crop needs in a compatible manner; (ii) reduced adverse impacts on soil; (iii) optimal plant growth; (iv) enhanced nutrient use efficiency; (v) declined nutrients runoff and leaching and (vi) lowered greenhouse gas emission.

Further, the economic feasibility is important while managing nutrients for crops and in this regard, the foliar application of nutrients and fertigation techniques may be effective based on the crop species and planting geometry adopted (Maitra and Ray, 2019; Maitra *et al*., 2000, 2023; Santosh *et al*., 2023). Moreover, under the controlled-environment cultivation, the nutrient use efficiency is enhanced (Maitra *et al*., 2024b). At present, drone-based foliar nutrient spray has become popular. The inclusion of legumes is one of the crucial factors which not only improves the soil microbe's diversity but also fixes atmospheric nitrogen, provides nutrients to companion crops in an intercropping system and succeeding crops in a sequential cropping (Maitra *et al*., 2001b; Praharaj and Maitra, 2020; Hossain *et al*., 2022). The need-based and scientific water management are also essential for efficient nutrient management in a cropping system (Zaman *et al*., 2017).

**Sustainable nutrient management practices for cropping systems:** For an efficient nutrient management of a cropping system, it is obvious to use nutrients judiciously by applying the proper quantity at the appropriate time to meet crop needs with a reduced loss. Utilising all sources of nutrients enhances the reliance of cropping systems and reduces the application of synthetic fertilisers. The application of nutrients should be balanced to avoid water contamination, reduce GHG emissions and maintain ecosystem integrity (Gaikwad *et al*., 2022; Maitra *et al*., 2023b). Sustainable nutrient management is not merely a set of practices but a holistic approach that integrates traditional and modern techniques to create a resilient, productive, and environmentally sound cropping system for a more sustainable and secure food for the future.

## Conclusion

Understanding plant nutrient needs, determining soil's inherent fertility, and applying fertilisers to meet those needs of macro- and micronutrients are the fundamentals of plant nutrition management. However, it is always wise to plan for sustainable nutrient management for the cropping system. In the current context of several hazards associated with agricultural productivity, the plant nutrient management for a cropping system should be considered as a noteworthy approach to reach the paramount goal of agricultural sustainability.

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