International Journal of Agriculture and Plant Science
www.agriculturejournal.in
Online ISSN: 2664-7664, Print ISSN: 2664-7656
Received: 20-05-2025, Accepted: 19-06-2025, Published: 04-07-2025
Volume 7, Issue 4, 2025, Page No. 10-11

Nutrient management in coffee cultivation under high rainfed conditions in India: A review

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Abstract
Coffee is a key plantation crop in the high rainfall tracts of southern India, especially in Karnataka, Kerala, and Tamil Nadu. Under rainfed conditions, nutrient dynamics in coffee cultivation are highly influenced by leaching, runoff, soil acidity, and organic matter dynamics. Efficient nutrient management is critical to sustaining yields, bean quality, and long-term soil health. This review discusses nutrient requirements of coffee, the challenges posed by high rainfall, recommended nutrient management strategies, and recent research advances, including site-specific nutrient management and organic amendments. Integrated approaches combining chemical fertilizers, organic manures, and biofertilizers are highlighted as sustainable options to address nutrient imbalances and improve productivity in rainfed coffee ecosystems.

Keywords: Coffee, Nutrient Management Rainfed Cultivation, Soil Fertility, Organic Amendments, India

Introduction
Coffee cultivation in India predominantly occurs in high rainfall zones receiving 2000-3000 mm annual precipitation. The Western Ghats region, covering parts of Karnataka, Kerala, and Tamil Nadu, contributes nearly 70% of India's coffee production. Under these conditions, nutrient management becomes challenging due to heavy leaching losses, soil erosion, and high organic matter turnover. Adequate nutrient supply is essential for vegetative growth, berry development, bean quality, and disease resistance. Understanding the nutrient dynamics and effective management practices is thus crucial for sustainable coffee production.

Material and Methods
The review was conducted by synthesizing published research articles, government reports, extension bulletins, and field experiment data related to nutrient management in rainfed coffee areas of India. Literature from 1990 to 2025 was reviewed, focusing on field trials, fertilizer recommendations, nutrient uptake studies, and integrated nutrient management practices in high rainfall coffee zones.

Results
Nutrient Requirements of Coffee
Coffee plants require 16 essential nutrients. Among macronutrients, nitrogen (N), phosphorus (P), and potassium (K) are critical. Secondary nutrients like calcium (Ca), magnesium (Mg), and sulfur (S), along with micronutrients zinc (Zn), boron (B), copper (Cu), and iron (Fe), also play vital roles in growth and productivity.

Challenges in High Rainfall Regions
High rainfall leads to substantial nutrient losses via leaching (especially N and K) and surface runoff. Soils tend to be acidic with low cation exchange capacity, reducing nutrient retention and availability. Organic matter decomposition rates are high, requiring continuous replenishment.

Recommended Fertilizer Practices
Research from the Central Coffee Research Institute suggests annual fertilizer recommendations of 120-140 kg N, 90-100 kg P2O5, and 120-140 kg K2O per hectare for Arabica coffee, split into pre- and post-monsoon applications. Micronutrient deficiencies, particularly zinc and boron, are increasingly reported, warranting periodic foliar applications.

Organic and Biofertilizer Amendments
Integration of farmyard manure (10-15 t/ha), composted coffee pulp, and biofertilizers (Azospirillum, phosphorus-solubilizing bacteria) has shown promise in improving nutrient availability, soil organic carbon, and coffee yields under rainfed conditions.

Recent Advances
Site-specific nutrient management using soil testing and plant tissue analysis has led to precise fertilizer application strategies, minimizing nutrient losses. Use of slow-release fertilizers and nano-fertilizers is under trial in some research stations with promising results on nutrient use efficiency.

Discussion
Nutrient management in rainfed coffee systems requires balancing chemical inputs with organic amendments to maintain soil health. Excessive rainfall necessitates split applications and the use of slow-release formulations to minimize leaching. Organic manures improve soil structure, moisture retention, and microbial activity, indirectly enhancing nutrient uptake. Integrated approaches combining judicious chemical fertilizer use with organics and biofertilizers offer sustainable solutions.
Several studies indicate that continuous application of chemical fertilizers alone can acidify soils and reduce long-term fertility. In contrast, blending organics (coffee pulp, compost, poultry manure) with recommended NPK fertilizers improves both yield and quality. Site-specific nutrient management tools using soil and leaf analysis help tailor recommendations to field conditions, enhancing efficiency and reducing environmental impacts.

Conclusion
Sustainable nutrient management in rainfed coffee cultivation in India involves understanding the unique challenges posed by high rainfall. Integrated nutrient management practices combining inorganic fertilizers,

organic manures, and biofertilizers are critical for sustaining yields, improving bean quality, and conserving soil health. Adoption of site-specific recommendations, slow-release fertilizers, and organic amendments will be vital to meet future productivity and sustainability goals in coffee agroecosystems.

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