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Nitrogen Management for High-Yield and High-Capsaicin Chili Production

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Abstract Chili pepper (*Capsicum* spp.) is an important economic crop, and its yield and capsaicin content are directly related to product quality and industrial value. Nitrogen is a key nutrient affecting chili growth, development, and secondary metabolism. Its application rate and form not only determine yield level, but also play a crucial role in regulating capsaicin synthesis. This paper systematically reviews the dynamics of nitrogen in chili cultivation systems, its uptake mechanisms, and its effects on plant growth, yield formation, and nitrogen use efficiency. It focuses on the metabolic pathways, key enzyme activities, and gene expression mechanisms involved in nitrogen-regulated capsaicin biosynthesis. Studies show that an appropriate nitrogen supply and a reasonable NH_4^+:NO_3^- ratio can promote plant growth and increase yield while enhancing the accumulation of capsaicin and related metabolites. In contrast, both excessive and insufficient nitrogen disrupt the balance between yield and quality. In addition, practices such as integrated water–fertilizer management, controlled-release fertilizers, split application, and multi-nutrient coordinated management can improve nitrogen use efficiency and reduce environmental risks. In the future, combining precision agriculture technologies with genetic improvement strategies will help achieve coordinated development of high yield, high quality, and ecological sustainability in chili production.
Keywords Chili pepper; Nitrogen management; Capsaicin; Yield; Nitrogen use efficiency

1 Introduction

Chili pepper (*Capsicum* spp.) is an important vegetable and spice crop widely cultivated around the world. Its main characteristics include pungency, color, flavor, and health-promoting functions (Duranova et al., 2022). In addition to its traditional food value, chili has become a key raw material in multiple industries such as food, nutraceuticals, pharmaceuticals, and cosmetics. The demand for high yield and stable pungency is increasing.

Chili fruits are rich in various vitamins (A, C, E, B6, and K), minerals, carotenoids, flavonoids, polyphenols, and capsaicinoids, which give them high nutritional value and functional properties (Bal et al., 2022; Ali et al., 2025). Capsaicin, as the main capsaicinoid compound, is the primary source of pungency in chili and has a wide range of biological activities, including antioxidant, anti-inflammatory, analgesic, anti-obesity, antimicrobial, and anticancer effects. It also has positive effects on cardiovascular and metabolic health (Hernández-Pérez et al., 2020; Faisal and Mustafa, 2025).

In chili production, nitrogen supply level and its form affect leaf chlorophyll content, photosynthetic capacity, biomass accumulation, and fruit yield. However, excessive nitrogen may delay maturity, reduce pungency, lower quality, and increase the risk of environmental pollution. Optimizing nitrogen application has been shown to improve nitrogen use efficiency while maintaining or increasing yield and reducing resource waste (Zamljen et al., 2023). In addition to its effects on primary growth, nitrogen also regulates secondary metabolism. Nitrogen application rate and nitrogen form (ratio of ammonium to nitrate) can influence the content of capsaicin and dihydrocapsaicin, the activity of related enzymes (such as PAL and capsaicin synthase), and the expression of genes involved in capsaicinoid biosynthesis.

This study evaluates nitrogen management strategies for achieving both high yield and high capsaicin content in chili production. It focuses on the effects of nitrogen rate and nitrogen form on plant growth, yield, and capsaicinoid accumulation. The study explores how different nitrogen supply levels and nitrogen sources affect