Available online at
http://currentagriculturetrends.vitalbiotech.org/

ISSN (E): 2583 – 1933

Curr. Agri.Tren.:e- Newsletter, (2025) *4*(4), 18-20

Current Agriculture Trends: *e-Newsletter*

Article ID: 381

Nitrogen Use Efficiency in Cereal Crops

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Article History
Received: 06. 04.2025
Revised: 10. 04.2025
Accepted: 15. 04.2025

INTRODUCTION

Cereal crops like wheat, rice, and maize are food staples for most of the world's population. Among the nutrients essential for plants, nitrogen (N) is essential for vegetative growth, chlorophyll synthesis, and grain filling. Although it is critical, NUE in cereals is generally less than 50%, i.e., greater than half of the nitrogen applied is lost via leaching, volatilization, and denitrification. With increasing fertilizer costs and environmental awareness, enhancing NUE is a key in sustainable agriculture. Increasing NUE lowers input costs, reduces greenhouse gas emissions, and conserves water quality.

2. Factors Influencing Nitrogen Use Efficiency

a) Soil and Climatic Factors

- Sandy soils and heavy rainfall regions enhance nitrogen leaching.
- Soil pH influences nitrogen availability and microbial activity.
- Temperature controls the rate of nitrogen mineralization and uptake.

b) Crop Type and Variety

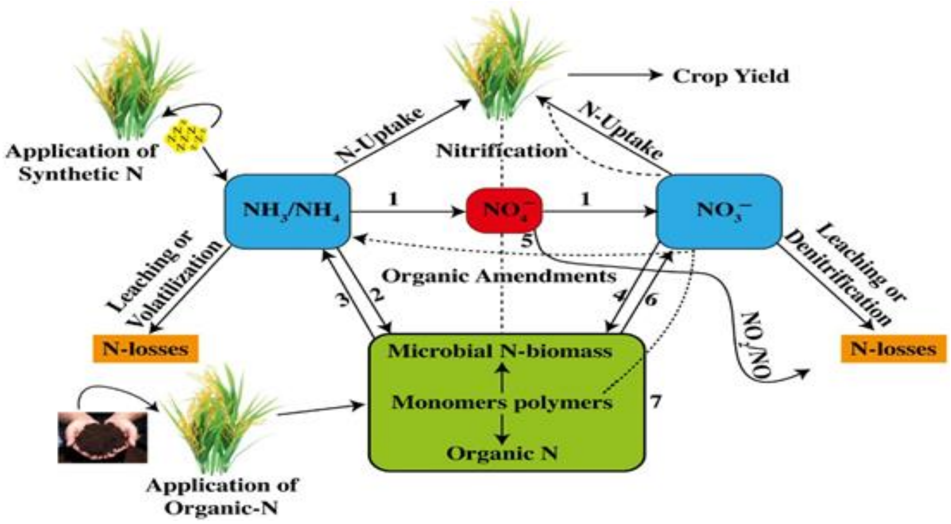
- Various cereals possess different nitrogen needs and uptake.
- New high-yielding varieties tend to react more favorably to well-balanced nitrogen application.

c) Fertilizer Type and Method of Application

- Urea, ammonium nitrate, and slow-release fertilizers vary in efficiency.
- Broadcasting vs. banding and split application influences uptake rates.

d) Water Management

- Flooded conditions (such as in rice) enhance nitrogen loss by denitrification.
- Effective irrigation scheduling maximizes nitrogen availability and root uptake.



Source: Frontiers

3. Strategies to enhance nitrogen use efficiency

a) 4Rs of Nutrient Stewardship

- Right Source: Application of slow-release, coated, or stabilized fertilizers.
- Right Rate: Crop demand- and soil test-based nitrogen application.
- Right Time: Synchronization of nitrogen supply with crop growth phases (tillering, flowering).
- Right Place: Banding and deep placement minimize nitrogen loss and increase uptake.

b) Application of N-efficient Varieties

Employment of nitrogen-efficient (N-efficient) crop varieties is a sustainable approach to improve nitrogen use efficiency (NUE) in cereal crops. These varieties are bred to absorb and utilise nitrogen more efficiently, even under conditions of low fertiliser availability. Breeding programmes now involve selecting and encouraging genotypes having superior NUE characters like superior root architecture, increased nitrogen uptake, and increased assimilation. State-of-the-art biotechnological and molecular breeding techniques facilitate the detection and incorporation of nitrogen-responsive genes into high-yielding genotypes. Adoption of these varieties minimizes the requirement of excessive nitrogen applications, decreases costs of production, and reduces negative environmental effects and thus leads towards more efficient and sustainable agriculture.

c) Integrated Nutrient Management (INM)

Integrated Nutrient Management (INM) is an integrative strategy maximizing nitrogen use efficiency by integrating chemical fertilizers with organic inputs such as farmyard manure (FYM), compost, and green manure. This incorporation enhances soil health, structure, and microbial activity, which results in enhanced availability and uptake of nutrients. The use of biofertilizers such as Azotobacter, Azospirillum, and Blue-Green Algae (BGA) also promotes biological nitrogen fixation, particularly in cereals such as rice and wheat. INM not only saves dependency on synthetic fertilizers but also enhances sustainable cycling of nutrients, improves crop yield, and conserves long-term soil health and thus becomes one of the prominent strategies in sustainable agriculture.

d) Precision Agriculture

Precision nitrogen management entails site-specific application of nutrients using new technologies such as remote sensing, GPS, and GIS technologies for optimizing the efficiency of nitrogen application in cereal crops. These technologies facilitate the detection of spatial variability of soil fertility and crop nitrogen requirements, enabling the application of tailor-made fertilizers. Real-time nitrogen status meters like SPAD meters, GreenSeeker, and drones supply precise measurements of chlorophyll content and health of plants and enable timely, effective, and efficient nitrogen applications. This method reduces losses of nitrogen, lowers environmental effects, and increases crop yield and quality, hence a pillar of contemporary, data-driven, and sustainable nutrient management practices.

e) Crop Rotation and Intercropping

Legume-based crop and intercropping systems optimize the use of nitrogen through the natural fixation of atmospheric nitrogen by symbiotic bacteria. This minimizes the application of synthetic nitrogen fertilizer and optimizes soil fertility and structure. Intercropping legumes and cereals provides effective nitrogen use and encourages sustainable and low-input farming practices.

4. Case Studies: NUE in Major Cereals

a) Wheat

split nitrogen application—50% at planting, 25% at crown root formation, and 25% at heading—improves nitrogen use efficiency (NUE) by synchronizing crop demand with supply. Also, controlled-release fertilizers such as neem-coated urea reduce losses of nitrogen by leaching and volatilization, enhance crop yield, and encourage sustainable nutrient management.

b) Rice

Deep placement of USG in rice farming minimizes losses of nitrogen during submerged conditions by providing for slow and effective release of nutrients. When applied with Alternate Wetting and Drying (AWD) irrigation, this method increases nitrogen use efficiency (NUE), maximizes use of water, and increases crop yield with efficient use of water resources.

c) Maize

For corn, foliar application of nitrogen at tasseling and silking enhances grain filling and efficiency of nitrogen use (NUE). In addition, application of nitrification inhibitors in maize-wheat cropping systems minimizes nitrogen loss by inhibiting the transformation of ammonium into nitrate, improving nitrogen availability to crops and productivity.

5. Environmental and Economic Benefits

- Environmental: Mitigation of nitrous oxide emissions and leaching of nitrate.
- Economic: Reduced cost of fertilizer inputs and increased net returns.
- Sustainability: Improves soil health and climate variability resilience.

6. Future Directions

Genome editing (CRISPR) advances, artificial intelligence, and remote sensing are likely to transform nitrogen management in cereals. Balanced fertilization policies and subsidies for precision equipment can drive adoption at the farm level Joint research among agronomists, breeders, and environmental scientists is essential to create comprehensive nitrogen management models appropriate for various agro-ecological zones.

CONCLUSION

Enhancing Nitrogen Use Efficiency of cereal crops lies at the core of attaining sustainable agricultural intensification. Mixing better varieties, agronomic, and advanced technology can considerably amplify NUE. This not just enhances global food security but helps in environmental sustainability as well.

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