Improving Nitrogen Use Efficiency in Lowland Rice: Practical Strategies for Addressing Reactive Nitrogen Loss

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The large-scale popularization and adoption of some of the emerging and promising N management practices is a great challenge. The major underlying reasons for this include lack of technical know-hows for using a leaf colour chart and chlorophyll meter, high-cost involvement with urease inhibitor and controlled release fertilizers, extra labour requirements for urea deep placement, and unavailability of biochar and nitrification inhibitors at farmers' level. This calls for the development of farmer-friendly fertilizer management approaches. Necessary steps should be taken by policymakers to ensure availability and adoption of such technologies at the farmers' level through greater extension efforts. This review identifies a set of available N management practices and some best tools for improving NUE in wetland rice in a sustainable and ecofriendly manner and at the same time not compromising with the yield. Deliberate application of recommended N management tools in rice cultivation might reduce the loss of N and thereby increase NUE, which will ultimately contribute towards climate change mitigation ensuring environmental sustainability.

Strategies to enhances NUE in lowland rice

Nitrogen management is the key for sustainable and profitable rice production in India. Nitrogen recovery can be improved through adoption of locally as well as scientifically available means of N management to ensure efficient use of agricultural inputs (chemical fertilizers, organic inputs, environmental input, and crops) that will enhance beneficial use of N in crops and minimize its losses (**Figure 1**). Various strategies (**Figure 2**) based on above discussed approach for improving NUE will be discussed below:

Soil test-based fertilization

Soil test- based fertilization is a vital component of the 4R strategy for nutrient management i.e., Right place, Right time, Right source, and Right rate. The 4R technique (**Figure 3**) minimizes nutrient losses, improve NUE, and reduces adverse effects on environmental.

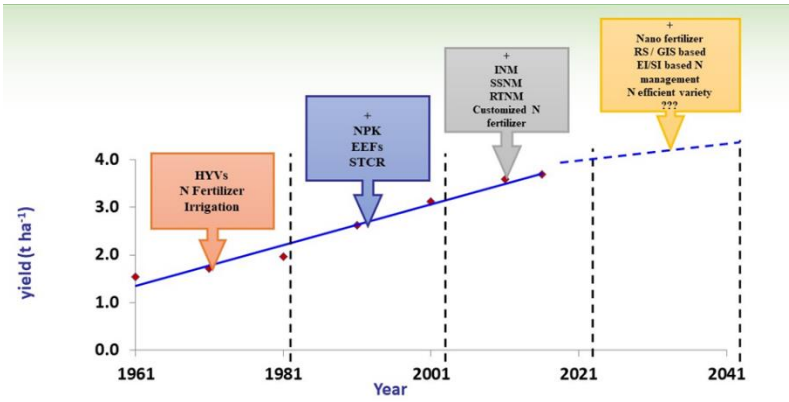

Figure 1: Scaling up of innovation of agronomic N management technologies for enhancing rice yield

Figure 2: Different nitrogen-smart technologies for lowland rice

Nutrient expert-based N management

A developing N management evaluation tool called Nutrient Expert applies fertilizers at the proper time, place, and amounts (a variable rate application) depending on the needs of the crop plants. It makes it easier to use inputs more effectively, saves money on fertilizer, and ensures that natural resources are used sustainably.

Site Specific Nutrient Management (SSNM)

The SSNM is a concept that encompasses field-specific N management strategies that include quantitative knowledge of field-specific variability in crop N demand and expected soil N supply capacity. The SSNM approach was introduced to improve NUE in wetland rice. In this approach, several factors are considered in calculating the appropriate N requirement for the crop. Factors include a crop's nutrient requirements, target yield, temperature, solar

radiation, soil N supply, irrigation, mineralization of crop residues, and other organic matter.

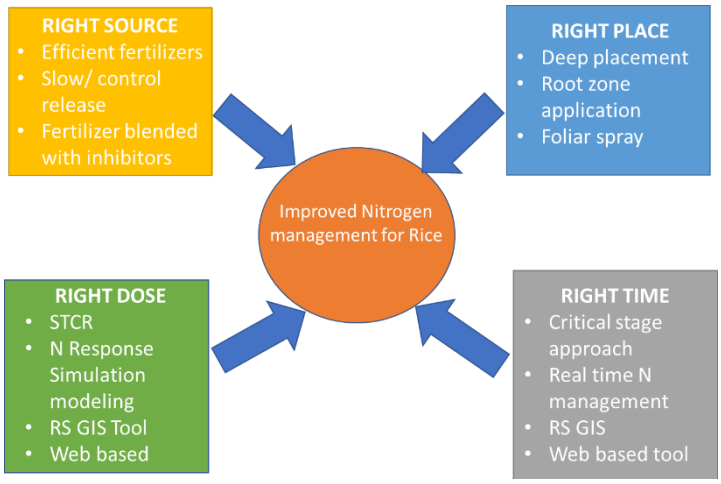

Figure 3: 4R stewardship for enhancing nitrogen use efficiency

Leaf Colour Chart (LCC)

Leaf colour chart is a diagnostic tool that helps farmers make decisions regarding the scheduling of N fertilizer applications in standing crops. Conventionally, growers rely on visual observations to assess crop nutrient status, particularly N levels. Leaf colour chart can serve as a diagnostic tool for plant health, especially for optimizing N supply to rice crops. Nitrogen is one of the main components of leaf chlorophyll. Its measurement at different phenological stages therefore serves as an indirect basis for N management. In China, a group of farmers were able to save 25% N fertilizer without affecting yield through LCC-guided N management in hybrid rice.

Chlorophyll meter (Soil Plant Analysis Development (SPAD))

The N status of crops can be assessed using a chlorophyll meter because most N is found in the chloroplasts of plants. Therefore, it is closely related to leaf chlorophyll content. SPAD meters, better known as chlorophyll meters, provide relative measurements of leaf chlorophyll content. Chlorophyll meters can self-calibrate with changing soils, seasons, and varieties. It is also recommended to evaluate the effectiveness of late-applied N in standing crops to increase grain yield and protein content. SPAD meter-based SSNM approach has been extensively demonstrated in Southwest Asian countries such as China, India, and Bangladesh.

Slow and controlled released fertilizer

Slow-release fertilizers (**Table 1**) appropriate modification in fertilizer source or management practices can lead to reduced losses of N and increased fertilizer NUE. Slow-release N fertilizer developed by coating urea granules with sulphur has been tested vis-a-vis ordinary urea in rice and this material out performed ordinary urea in almost all types of soils. A range of slow-release fertilizers is now marketed which have the potential to reduce various N losses and improve NUE. Controlled release N fertilizers offer a good option to reduce N losses from the system because their Slow and delayed N release strategy that balances crop demand and N requirements.

Table 1: Various slow and controlled release N fertilizers

Fertilizer Forms	Example
Coated with inert material	Urea coated with polymer, lac, gypsum, sulphur and rock phosphate
Enlargement of the granule	Urea super granule, granular urea
Limited solubility forms of urea	Urea form, oxamide, Urea -z
Coated with urease inhibitors	Hydroquinone, phenyl phosphor deamidate (PPD)
Coated with nitrification inhibitors	Nitra pyrin, DMPP, DCD, ATC (4-amino -1,2,4-triazole)

Nitrification inhibitors

Nitrification inhibitors, which slow the conversion of NH_4^+-N into NO_3^-- N, have been reported to increase NUE and crop yield. Application of nitrification inhibitors could also have considerable influence on emissions of N_2O and CH_4 from soil. Further research and development are needed to identify cheap locally available materials such as neem cake and neem oil, which can inhibit nitrification and increase NUE. Several nitrification inhibitors that are widely used in agriculture include: 2-chloro-6-(trichloromethyl) pyridine (nitrapyrin), dicyandiamide (DCD), and 3,4-dimethylepyrazole phosphate (DMPP).

Right method of N Application

Foliar Application

Foliar application helps to improve the NUE in farmers field by reducing surface runoff, microbial immobilization, leaching, volatilization and denitrification. Nano-urea, hydro nano-urea, nano-DAP these are applied through foliar methods to improve the NUE and help in quick recovery from N deficiency in rice land.

Deep placement

One of the most effective N management strategies created for rice is the deep-point placement of urea supper granule (USG) at a depth of 5-10 cm. However, it is labour-intensive. It is demonstrated that deep placement of urea reduced N loss by 65% and increased grain production of rice by 50% when compared to split application of granular urea.

Resource conservation technology (RCT)

Any technology that increases the effectiveness of the application or use of resources is called RCT. It helps to increase rice production and protect topsoil. Technology is being developed to regulate N in low-lying areas while conserving resources are conservation agriculture, crop residue retention, green manure, zero tillage, laser land levelling, direct seeding of rice and leaf colour chart.

Integrated nutrient management (INM)

Integrated N management requires the most use of locally available N components, such as crop wastes, organic manure, biological N fixation, and chemical fertiliser, as well as their complementing interactions to improve N recovery. The synergistic effects of integrated use of organic and inorganic N sources are due to either an optimal physicochemical soil environment or improved root growth and supply of secondary and micronutrients. Proper understanding and utilisation of these positive plant nutrient interactions is important to increase farmers' returns in terms of yields, improve soil quality, and increase NUE. The complementary interactions of N with other macro- and micronutrients could lead to significant improvements in yield and NUE. Therefore, balanced and prudent use of nitrogen by all available means will result in higher productivity.

Android App

RiceNxpert

This app captures photos of 10 fully developed healthy rice leaves with a white background. Nitrogen fertilisation recommendations for different rice ecologies when the green colour is less than the Pantone critical standard leaf colour.

RiceXpert

The app provides farmers with real-time information on rice varieties for different ecologies, pests, nutrients, weeds, nematodes, and disease-related problems, as well as farm equipment for different field and post-harvest practices. Farmers can use this app as a diagnostic tool in their rice fields and make customized requests to quickly solve their problems by sending a text, photo or voice recording. The app was developed for the Android platform and can be downloaded from the Google Play Store or from www.nrri.in.

Conclusion & future prospects

Addressing reactive N loss in lowland rice cultivation is essential to improve NUE, minimize environmental impacts, and ensure sustainable production. Nitrogenous fertilizers are quickly lost from the soil system through various mechanisms, for enhanced crop N uptake, N supply should be in synchrony with the N demand. Future prospects for addressing reactive N loss in lowland rice involve continued research and innovation. This includes developing improved varieties with enhanced NUE, exploring novel fertilizer formulations or delivery systems, and advancing precision agriculture technologies for more precise N management. Additionally, promoting awareness and providing training to farmers on best management practices for N utilization and environmental stewardship will be crucial for widespread adoption. By implementing the strategies and embracing future advancements, it is possible to mitigate N losses in lowland rice cultivation, enhance crop productivity, and contribute to sustainable agriculture and environmental conservation.

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