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# Application and Management of Nitrogenous Fertilizer in Rice Field: A Review

**Priyanka Yengkokpam [a++], Purnima Kumari [a#], Vyomendra Kumar Singh [b#], Keithellakpam Chanu Ningthi [a++], Sunidhi Dhiman [a++], Manthan Chaudhary [a#*] and Rakshita Sharma [a†]**

[a] *School of Agricultural Sciences and Technology, RIMT University, Mandi Gobindgarh, Punjab-147301, India.*
[b] *School of Agricultural Sciences and Engineering, IFTM University, Moradabad, Uttar Pradesh-244001, India.*

***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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***Review Article***

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## ABSTRACT

Rice (*Oryza sativa L.*) is one of the most significant cereal in the world. Globally, the top rice producing country is China, while India is the world's second largest producer and the largest exporter of rice in the world. It covers one-third of the total cultivated area in India as it is one of the major staple food crops. The application of nitrogenous fertilizer in crop production system is an

[++] *M.Sc. Agronomy;*
[#] *Assistant Professor;*
[†] *B.Sc. Agriculture;*
**Corresponding author: Email: chaudharyx007@gmail.com;*

important aspect of modern crop management practices and one of the determining factors to increase crop yield and thereby keeping pace with the expanding human population. Rice production can be increased by the application of nitrogenous fertilizer whether organic or inorganic at an appropriate time and place. The fertilizer should be applied in multiple split doses depending on the soil's nutritional status, crop demand and the sources of nutrients. However, most of the nitrogenous fertilizer applied to rice fields is not taken up by rice plants but instead lost to the environment as ammonia, nitrate and nitrous oxide. The 'reactive N' also known as fixed N has a negative impact on human health as well as causes serious environmental problems. Surface runoff, denitrification, ammonium volatilization and leaching should all be managed in order to reduce the nitrogen loss from rice fields. Sustainable and environmentally friendly fertilizer management techniques raise the crop yields and enhance the sustainable soil fertility status. So it is necessary to implement management practices in order to reduce nitrogen losses and increase the nitrogen use efficiency (NUE) in rice production.

*Keywords: Fertilizer; nitrogen use efficiency; organic; rice; nitrogen.*

## 1. INTRODUCTION

Rice (*Oryza sativa* L.) is a staple cereal crop, feeding the majority of the people [1], its production should be significantly increase to fulfill the demands of the ever-growing population. Globally, 98% of the rice grown is cultivated in Asia, Africa and Latin America [2]. "Asia accounts for 90% of Global rice production, with China being the largest producer" [3]. "The demand for rice consumption worldwide is predicted to rise from 439 million tons(mt) in 2010 to 496 mt by 2020, 553 mt by 2035 and 623 by 2050" [4,5]. "Through the use of improved varieties, judicious fertilizer and irrigation with good management practices, rice production can be increased" [6].

"Nitrogen is a crucial nutrient element for plants and is necessary for photosynthesis and biomass production in rice. Nitrogen encourages rapid plant growth and increases grain yield and quality by promoting tillering, leaf area development, grain formation, grain filling and protein synthesis. A certain range of nitrogen fertilizer increases net photosynthetic rate but excessive nitrogen fertilizer can also result in a decrease in a photosynthetic capacity" [7,8]. Rice's nutritional value and processing quality can both be enhanced by increasing nitrogen fertilization, however too much nitrogen fertilization can also degrade rice's overall quality.

Application of nitrogen fertilizer is important to increase the agricultural output thereby keeping pace with the increase population [9,10] however, rice had a 30% overall nitrogen use efficiency [11]. "Modern crop production system is low in efficiency in nitrogen retention since nitrogen is reactive and mobile. Typically, 50-70% of nitrogen applied as fertilizer is lost to the environment" [9]. "Most of the reactive nitrogen from the crop fields is lost as nitrate in soil and aquatic habitats and as nitrous oxide or ammonia in the atmosphere which is detrimental to environment and human resulting in eutrophication and contamination of water resources, poor ozone and air quality, greenhouse gas emissions, soil acidification and biodiversity losses [12]. "The adoption of appropriate nitrogen management practices has become a crucial part of modern rice production technology to reduce the loss of nitrogen in paddy fields and to increase rice yield per unit area" [13].

## 2. NITROGEN DEFICIENCY SYMPTOMS

"One of the most prevalent issues with rice in Asia is nitrogen deficiency which is common in all rice growing soils where modern varieties of rice are cultivated without sufficient mineral nitrogen fertilizer. It often occurs at important plant growth stages like tillering and panicle initiation when the demand for nitrogen is high but it may also occur when large amount of nitrogen fertilizer is applied incorrectly or at the wrong time. Deficiency of nitrogen in rice reduces photosynthesis and affects the formation of dry matter by impeding the synthesis of chlorophyll and protein" [14]. "When rice exhibits nutrition deficiency, the leaf sheath will also present specific symptoms. Alkaline and calcareous soils with low soil organic matter status and a high potential for ammonia volatilization losses are more prone to nitrogen deficiency. Old rice leaves and stems become light green under nitrogen stress and the base of the leaf sheath becomes white under severe nitrogen deficiency" [15]. "Nitrogen deficient crops are stunted and discolored, older leaves turn light green and chlorotic at the tip and young leaves are thin, short and rigid. It causes a decrease in plant height and the number of tillers and the roots also decreases in number and become slender and lengthy. Under high nitrogen stress, leaves can die; except for the younger leaves the leaves of nitrogen deficient plants are narrow, small, short, erect and lemon-yellowish green. Plants that are deficient in nitrogen reduce grain number and produced low yield" [16].

**Fig. 1. Symptoms of nitrogen deficiency**
*Source: www.agritech.tnau.ac.in/agriculture/plant_nutri/rice_nitrogen.html*

## 3. DISADVANTAGES OF EXCESSIVE NITROGEN FERTILIZER APPLICATION

"Application of excessive nitrogen fertilizer will not only increase production costs but also has a residual effect on the soil and environment. It causes serious environmental pollution, soil degradation and water eutrophication" [17,18,19]. "Excessive nitrogen application can lead to soil deterioration and acidification, which has an adverse effect on crop growth and yield" [20,21]. "Excess nitrogen fertilization increases chalkiness and poor appearance quality of rice" [22]. "Excess nitrogen causes "luxuriant growth", resulting in the plant being attractive to insect, diseases and pathogens. The excessive growth can also reduce stem strength resulting in lodging during flowering and grain filling and it also raises plant tissue susceptibility and rice canopy density, both of which are associated with a rise in disease incidence and severity on the leaf and panicle blast" [23]. Excess nitrogen during the reproductive stages of development led to the panicles with unfilled or partially filled grains [24,25] and it is also resulted in low nitrogen use efficiency (NUE) and environmental pollution [26,27].

## 4. APPLICATION OF NITROGENOUS FERTILIZERS

Application of nitrogenous fertilizer efficiently with approaches such as optimizing its application to paddy rice fields, timing and formulation of nitrogen fertilizer and improvement in the soil quality can increase the nutrient use efficiency [28,9,12]. "Hybrid rice absorbs mineral nitrogen more efficiently than inbred rice varieties so it is not recommended to apply an excessive amount of nitrogen to less responsive varieties. The fertilizer should be applied in multiple split doses, depending on the soil's nutritional status, crop demand and the sources of nutrients. Rice yields and nitrogen use efficiency can be improved with multiple split application while decreasing nitrogen losses" [29,30,31]. "Nitrogen fertilization in 3 splits at around 20-25, 40-45 and 60-65 days after germination for short duration varieties or 4 splits at around 20-25, 40-45, 60-65 and 80-85 days after germination for medium duration varieties is suitable for most crops" [32]. "The best strategy for increasing grain yield of rice is to apply nitrogen fertilizer preferably as a top dressing between active tillering and panicle initiation" [33]. "The addition of nitrogen fertilizer at the panicle initiation stage is also the most effective way to increase rice yield" [34].

Fertilizer formulations prevents ammonium from being exposed to nitrifiers or to volatilization and thus delays the release of nitrogen. Organic amendments improve the nitrogen use efficiency, delay nitrogen volatilization and improve the nitrogen conservation in the soil [35]. When it comes to preserving nitrogen in crop's rhizospheres, deep placement of fertilizer is a good alternative to the traditional broadcast fertilization [36]. "The deep placement of nitrogen fertilizer at 10-15cm is considered ideal for better nitrogen use efficiency and economic returns" [37,38]. "Controlled/slow releasing fertilizer often come in pelletized form and are coated to slow the process of dissolution. The use of controlled released urea (CRU) significantly increased rice grain production and nitrogen use efficiency when compared to traditionally nitrogen fertilizer" [39,40,41]. "In rice production, a single controlled release urea basal application is a promising alternative nitrogen management strategy for reducing time and labour intensive nitrogen application rates" [42]. Using 192kg of CRU per hectare of soil was an effective way to increase soil nitrogen content, conserving nitrogen fertilizer and improving nitrogen use efficiency.

## 5. IMPACT OF NITROGEN ON RICE GROWTH AND YIELD

"The impact of nitrogenous fertilizer on grain yield varies depending on the variety. The increased grain weight at higher nitrogen rates is primarily due to increase in chlorophyll content of leaves, which in turn led to a rise in photosynthetic rate and ultimately plenty of photosynthates available during grain development" [43]. "Nitrogen should be applied in split doses, 50% as basal, 25% at tillering and 25% at panicle initiation stage" [44]. "In consideration of nitrogen application rates, when nitrogen is supplied at rate of 205 kg/ha the maximum plant height was observed whereas as the lowest was observed when nitrogen was treated at the rate of 100 kg/ha" [45]. "The productivity of the rice plant is determined by the number of productive tillers rather than the overall number of tillers. The number of paddy tillers drastically rises with the use of NPK fertilizers and as the rate of nitrogenous fertilizer was raised, the number of rice tillers increases" [46]. "The length of panicles increases when NPKS fertilizer is used and with increasing nitrogen supply up to 90 kg N/ha, rice panicle length is also increased" [47,48].

The application of nitrogen fertilizer at the rate of 120kg N/ha produced a remarkably higher grain yield of scented rice [49]. The grain yield of aromatic rice greatly increased with each successive rise in nitrogen level [50]. The combination of chemical fertilizer with FYM or wheat straw increased the uptake of NPK by rice plants as well as grain weight and yield [51]. After conducting an experiment Cultivar response, dry matter partitioning and nitrogen use efficiency in dry direct- seeded rice, it has been reported that spikelet sterility increased by 22% when nitrogen levels were higher (180kh N/ha) as compared to lower level of nitrogen (120kg N/ha) [52].

## 6. NITROGEN LOSSES AND ITS MANAGEMENT STRATEGIES

### 6.1 Ammonium Volatilization

One of the most typical ways that nitrogen is lost from a rice field is through ammonium volatilization, which reduces nitrogen use efficiency and causes environmental pollution [53]. Total ammonia loss by ammonium volatilization ranged from 9.0-16.7% of the applied nitrogen throughout the entire rice growing stage [54], up to 60% of the urea-nitrogen fertilizer applied to waterlogged soils may be even lost due to ammonium volatilization [55]. A significant amount of ammonia is lost through volatilization in calcareous/alkali soils when ammonium sulphate and ammonium nitrate are applied directly or when the soil temperature is at its highest, however, acid soil has a lower rate of volatilization than alkali soils. Coated urea should be applied to a rice field at a depth of 3 to 5cm [56]. Phenyl phosphorodiamidate (PPD) can be used to delay urease activity in flooded soils and algaecides can be used to help stabilize pH variations in flood water in order to reduce ammonium volatilization losses from lowland rice [57].

### 6.2 Leaching

Leaching is the loss of soluble nitrate-nitrogen carried by excess soil water below the root zone. It accounts for 0.1-4.9% of the applied nitrogen, which is one of the main pathways through which nitrogen is lost in paddy soils [58]. More leaching is encouraged by soils with a coarse textured such as sandy, loamy sand and sandy loam, compared to soils with a light texture, such as loamy, clay and clay loam. In comparison to soils with high levels of organic matter, those with low organic matter levels loss more nitrogen through leaching. Split applications of nitrogenous simple fertilizer, granular application of complex and compound fertilizer as well as keeping the rice fields moist and dry alternately and using nitrification inhibitors such as N-serve and thiourea can reduce leaching losses.

### 6.3 Denitrification

"Denitrification is the reduction of nitrate to nitrite to gaseous forms of nitrogen, usually nitrous oxide ($N_2O$) and nitrogen ($N_2$). Through the denitrification process, around 10-40% of applied nitrogen is lost" [56]. "The presence of high levels of organic matter, moist environment, high temperatures, soil type and the presence of nitrate ions all favour denitrification loss. This loss can be avoided by using non nitrate fertilizer, deep placement of ammonium form fertilizer and proper water management techniques. Nitrogen supplied in the form of nitrate is also transformed to nitrogen gas in acidic upland soils and this type of gaseous loss can be controlled with a moderate lime application" [56].

### 6.4 Runoff Losses

In undulating areas, due to overflow of flood water nitrogen is lost through surface runoff. Excessive irrigation results in runoff through field bunds that are narrow and short in height and runoff through bund's minor cracks also results in nitrogen loss. Particularly frequent surface runoff loss occurs in undulating, muddy and steep soils. Nitrogen fertilizer loss due to surface runoff and subsurface leaching contribute about 7% of their nitrogen content to water bodies [59] and nitrogen runoff from rice fields is one of the most significant sources of water contamination [60,61]. Therefore, irrigation should be controlled according to the crop's water demands and raising wide and elevated bunds can also help in reducing runoff losses.

## 7. CONCLUSION

Nitrogen is essential to crops and its addition to rice production systems is crucial to increase crop yield and to keep up with the growing human population. The timing and techniques for applying nitrogenous fertilizer have a significant impact on the growth, development and yield of rice crops. The nitrogen added to the rice field may be lost due to surface runoff, denitrification, leaching and ammonium volatilization. Farmers should apply controlled released urea, deep placement of fertilizers and multiple split applications to maximize nitrogen use efficiency and increase the grain yield. To increase rice yield and maintain the health of the soil and ecosystem, farmers should employ nitrogenous fertilizer along with organic fertilizer. Nitrogen fertilization also improved the quality of the rice grain and its deficiency in soil may result in a considerable decrease in rice grain yield. As a result of the above discussion, it can be concluded that applying nitrogen as a basal dose at planting, followed by split doses as top dressing at internode elongation and between tillering and panicle initiation stages is an effective way to increase rice growth, yield and production.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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