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Neem Coated Urea (NCU), An Efficient Nitrogen Source for Paddy Cultivation: A Review

Ashvin Kumar Meena, R.N. Meena, Kartikeya Choudhary,
Anoop Kumar Devedee, Kamlesh Meena[1]

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ABSTRACT

Green revolution dramatically change the nitrogen application in paddy cultivation and day by day its demand increased but excessive and imbalanced use of nitrogen fertilizer has raised certain global concerns, also its low nitrogen use efficiency. Nitrogen is required in huge amounts for rice and supply of N in the right amount, at the right rate and at right time throughout the growing season is most important to increase the yield. Approximately 90% of the N-fertilizer applied worldwide is in the NH_4^+ form, which is rapidly oxidized to NO_3^- by soil nitrifier bacteria. Whereas, NCU temporarily delays the bacterial oxidation of the ammonium-nitrogen by depressing over a certain period of time the activity of Nitrosomonas bacteria in the soil. So far more than 75 studies have been conducted to study the performance of NCU in increasing the yield of rice and several other crops. In rice more than 30% of the urea consumed in India is applied, the mean increase in grain yield by replacing urea with NCU is 5 to 6%. NCU has been observed to improve nitrogen use efficiency and subsequently grain yield of rice. Possibly, applying NCU following the site-specific nutrient management principles will lead to paddy production of higher levels as observed with ordinary urea but with lower fertilizer application rates.

Key words: Denitrification, Leaching, Neem coated urea, Nitrogen use efficiency, Rice.

Rice is the most important and widely cultivated crop in the world. It is the staple food for more than 60% of world population. Approximately, 750 million of the world's poorest people depend on rice to survive (Zeigler, 2006). It is also the staple food of millions of poor people in Asia, where 90% of world's rice grown and eaten in this continent and more than two billion people are getting 60-70% of their energy requirement from rice and its derived products (IRRI, 2010).

Nitrogen (N) is an important element in the soil and the biosphere (O'Hara *et al*., 2002). It is a very crucial and important nutrient required for rice growth, yield and in its absence, the yield is reduced drastically (Hirzel *et al.,* 2011). Nitrogen play an important role in increasing demand for rice production but excessive and imbalanced use of N fertilizers has raised certain global concerns, owing to its low efficiency. In the soil, Nitrogen is lost through nitrate-nitrogen (NO_3^- N) leaching, ammonia (NH_4^+) volatilization, surface runoff and denitrification resulting in 20-50 % nitrogen use efficiency (NUE) only (Shivay *et al.,* 2005). In lowland rice ecosystem, nitrogen use efficiency can be increased by adding a nitrification inhibitor (NI) with the N fertilizers. Split application of N fertilizers is one of the strategies for efficient use of N throughout the growing period by synchronizing with plant demand, reducing denitrification losses and improved N uptake.

Invariably, effect of neem coated urea (NCU) has been found superior to prilled urea at the same dose and splits in *kharif* rice. Application of 120 kg N ha^{-1} through neem coated urea in three equal splits *i.e.* one third each at basal (during land preparation), active tillering (25 days after transplanting) and panicle initiation (48 DAT) produced 5.6% higher grain yield than prilled urea (Thind *et al.,* 2009). Meena *et al.* (2019) reported that application of neem coated urea @ 150 kg N ha^{-1} in three equal *i.e.* one third each at basal (during land preparation), active tillering (25 DAT) and panicle initiation (45 DAT) resulted in significantly higher total N (113.1 kg ha^{-1}), P (28.9 kg ha^{-1}) and K (113.5 kg ha^{-1}) uptake over prilled urea with the same dose and splits. Pusa neem micro-emulsion urea (PNME) @ 40 kg N ha^{-1} recorded significantly higher N uptake efficiency, agronomic efficiency (26.5 kg grain increased kg^{-1} N applied) and N apparent recovery (49.3%) over prilled urea with the same dose and splits (Jat and Pal, 2002). In March 2015, the government of India made it mandatory for fertilizer producers to produce NCU up to 70% of capacity and finally in May 2015 directed to manufacture full capacity. This decision was motivated not only by the better performance of NCU vis-à-vis prilled urea in terms of paddy production, but also by an expectation

Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221 005, Uttar Pradesh, India.
[1]Krishi Vigyan Kendra, Indian Institute of Vegetable Research-ICAR, Deoria-274 506, Uttar Pradesh, India.

Corresponding Author: Ashvin Kumar Meena, Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221 005, Uttar Pradesh, India.
Email: ashvin.agro@gmail.com

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that it will cut down the consumption of urea for paddy cultivation. With NCU already being supplied to farmers as fertilizer N in India, it is not yet clear as to what extent it will lead to increased paddy production and/or reduced demand for urea. Therefore, research investigations based on scientifically-sound experiments and published in peer-reviewed journals have been critically analyzed to better understand the agronomic benefits of neem coated urea vis-à-vis prilled urea.

Role of Nitrogen in Rice

Nitrogen is the essential constituent of compounds such as amino acids, proteins, RNA, DNA and several phytohormone thereby an essential macro element for plants (Wang and Schjoerring, 2012). It is also involved in many biological processes including carbon metabolism, amino acid metabolism nucleic acid metabolism and protein synthesis as a regulator (Cai *et al.,* 2012). It is the most abundant mineral element in plant tissues which is derived from the soil. However excess N may cause significant biochemical changes in plants and may lead to nutritional imbalances (Salim, 2002).

Nitrogen is a most limiting nutrient for optimum rice grain yields under irrigated lowland ecosystems. Increasing rice yield per unit area through the use of appropriate nitrogen management practice has become an essential component of modern rice production technology (Metwally *et al.,* 2011). Nitrogen is taken up by rice during early growth stages, accumulated in the vegetative parts of the plant and is utilized for grain formation. A large portion of the nitrogen is absorbed during differentiation stage. Nitrogen fertilization increased the number of tillers and panicles m^{-2} and the total number of spikelets, reflecting on grain yield. Excessive tillering caused by inadequate nitrogen fertilization reduced the percentage of the fertile tiller, filled spikelet percentage and grain weight $panicle^{-1}$ (Dastan *et al.*, 2011). Rice needs 1 kg of nitrogen to produce 15-20 kg of grain. Lowland rice in the tropics can use enough naturally available nitrogen to produce 2-3 t ha^{-1} while for higher yield, additional nitrogen must be applied (Ladha and Reddy, 2000).

Need for NCU

Farmers generally applied nitrogen through urea. When urea is applied to the soil, a cascade of chemical and biological reactions transforms urea nitrogen into several other nitrogen forms, of which some are susceptible to loss and therefore lead to reduced availability of nitrogen to crop plants. Most notable two broad categories of transformations are hydrolysis of urea by urease enzyme which rapidly converts urea-nitrogen to ammonium-nitrogen and nitrification brought about by a group of nitrifying bacteria that leads to conversion of ammonium-nitrogen to nitrate-nitrogen. Nitrate-nitrogen can escape soil-plant system through leaching below the rooting zone and in gaseous forms via denitrification leading to reduced fertilizer nitrogen use efficiency (Prasad *et al.,* 1999). Neem coated urea temporarily delay the bacterial oxidation of the ammonium-nitrogen by depressing over a certain period of time the activity of Nitrosomonas bacteria in the soil. Thus neem coated urea control the loss of nitrate by leaching and/or denitrification from the topsoil by keeping nitrogen in the ammonium form longer and thereby increasing the fertilizer nitrogen use efficiency and yield of crops (Singh, 2016).

Impact of NCU on Rice

Growth

Shivay *et al.* (2001) reported that successive increase in nitrogen level from 0 to 120 kg N ha^{-1} to rice crop resulted in significant increase in plant height and the highest plant height (90.9 cm) was recorded with 120 kg N ha^{-1} and the shortest plant stature (77.1 cm) was obtained from in control (0 kg N ha^{-1}). Among the sources, NCU registered the highest plant height (89.2 cm), which was statistically at par to prilled urea. The dry matter production (DMP) increased progressively up to 120 kg N ha^{-1}, which was significantly superior to all the other nitrogen levels tested. Overall NCU resulted in 6.6% increase in straw yield of rice over prilled urea. Application of neem coated urea @ 120 kg ha^{-1} resulted in significant increase in plant height over prilled urea (Singh and Shivay, 2003). Consistent supply of available N to plants under NCU promoted the initiation of more number of tillers and higher leaf production and resulted in higher dry matter accumulation under NCU than PU which was subjected to various nitrogen losses and reduced the nitrogen availability to the plants and hence accumulated lower dry matter (Meena *et al.,* 2019).

Suresh and Swarna (2008) reported that the application of 120 kg N ha^{-1} as neem coated urea in three splits to rice crop resulted in the highest plant height which was significantly higher than prilled urea. The number of tillers $plant^{-1}$ at 30 DAT was the highest with the application of neem coated urea at 120 kg N ha^{-1} applied in three recommended splits. Kumar and Shivay (2009) reported that application of pusa neem golden urea proved better than prilled urea in respect to tiller $hill^{-1}$, plant height and dry matter accumultion. Kumar *et al.* (2011) concluded that plant height in transplanted rice at harvest was affected signiûcantly by different neem oil components and their varying doses. The highest plant height was observed in meliacins-coated urea @ 100 kg ha^{-1} in three equal splits at basal, tillering and panicle initiation stages of rice growth, which was significantly higher than prilled urea.

Yield and yield attributes

Tomar and Gupta (1992) reported that application of Nimin coated urea resulted in higher grain yield of rice compared to prilled urea. Nimin coated urea resulted in significantly higher grain yield than that of prilled urea. Significantly higher productive tiller $hill^{-1}$, panicle length, panicle weight and grain yield were recorded with neem oil coated urea (Prasad *et al.*, 1999). Shivay *et al.* (2001) reported that application of neem oil emulsion-coated urea had beneficial effects on all

the yield attributing characters over prilled urea. There was around 7.7 to 10.9% increase in grain yield of rice owing to application of neem oil coated urea over prilled urea. Jat and Pal (2002) were also observed 3.78% increase in the rice grain yield with PNME coated urea over prilled urea. As regards sources PNME @ 120 kg N ha^{-1} gave 24% higher grain yield over prilled urea at same dose (Bharde *et al.*, 2003).

Kumar *et al*. (2007) that reported application of NCU produced significantly higher panicles m^{-2} and grain yield over prilled urea. Application of NCU resulted in significantly higher grain and straw yield over the existing practice. The increase in grain and straw yield with NCU over prilled urea with the same dose and splitting was higher by 4.1 and 1.64%, respectively, which further increased to 4.5 and 2.87% under three equal splits schedule (Meena *et al.,* 2018). Kumar and Shivay (2009) reported that pusa neem golden urea (PNGU) resulted significantly higher panicle m^{-2}, panicle weight, panicle length, filled grain $panicle^{-1}$ and grain yield over prilled urea. Thind *et al.* (2009) reported that NCU significantly increased rice grain and straw yields. Application of 120 kg N ha^{-1} through NCU in three equal splits produced significantly higher grain yield, increase being 5.6% than prilled urea. Bhatt (2012) reported that application of a lower dose of nitrogen grain yield was 14.8% higher in plots supplied with neem coated urea than in those supplied with prilled urea.

Nutrient uptake and nitrogen use efficiencies

Nitrogen is a highly mobile element inside the plant and when nitrogen is deficient in plant body it is readily translocated from stems and older leaves to younger leaves or developing panicles. Critical nitrogen concentration in the rice plant generally increases quadratically with increasing N application rate and decreases with an increase in plant age due to the dilution effect whereas total nitrogen uptake increases with increased dry matter (Fageria and Baligar, 2001). When the supply of nitrogen to rice is optimum, 50 percent of the total nitrogen is absorbed before half of the total dry matter is produced. Remaining 30-50 percent of the total nitrogen uptake occurs after the start of panicle initiation. About 60-70 percent of the above ground nitrogen is translocated in rice panicle at maturity. Most of the nitrogen in rice grain at harvest is absorbed between rice panicle emergence and heading. It is initially stored in plant tissue and eventually translocated to the panicle (Buresh *et al.,* 2008). The nitrogen content of rice straw and grain at maturity usually contains 20-40 per cent more nitrogen than that supplied by fertilizer and this extra nitrogen is supplied by native soil nitrogen (Moore *et al.,* 1981). In the case of rice, nitrogen fertilizer use efficiency varies widely depending upon the source, application time or both. The recovery efficiency of nitrogen fertilizer by rice generally ranges from 20-80 per cent (Fageria *et al.,* 2003) with an average of about 30-40 per cent (Cassman *et al.,* 1993). The rate, source and application time of nitrogen fertilizer determine nitrogen recovery efficiency in the above ground biomass of rice. The time and dose of application of nitrogen should be according to critical growth stages of rice (Fageria *et al.,* 2003).

Chauhan and Mishra (1989) reported that the nitrogen uptake by the rice crop increased progressively after transplanting. During early growth stage N uptake in the treatment receiving, neem cake coated urea and prilled urea was similar but later the neem cake coated urea supplied plants had more N than prilled urea. Neem coated urea showed higher apparent recovery (52.5%) of applied N than prilled urea (35%). Arafat *et al.* (1999) reported that percent increase in total N uptake with NCU over prilled urea was 31 per cent. Application of NCU gave the highest value of N recovery and utilization efficiency (85.5%) over prilled urea (47.5%). Chauhan (1999) reported maximum recovery of applied N as neem cake coated urea was 32.1% by rice crop as against 22.75% with prilled urea.

Shivay *et al.* (2001) reported that neem cake- coated urea and neem oil emulsion-coated urea irrespective of concentrations had a significant effect on N uptake by rice grain and straw. Based on the total nitrogen uptake in grain and straw, there was 10.30% increase was due to application neem emulsion-coated urea over prilled urea. Apparent recovery of N was also influenced significantly due to the application of neem oil emulsion-coated urea materials irrespective of concentrations. The highest apparent N recovery (45.5%) was recorded with neem cake coated urea, followed by neem oil emulsion-coated urea (39.1%).

Improved nitrogen use efficiency in rice due to the application of NCU over prilled urea might be attributed to reduced leaching losses as a result of nitrification retardation (Thind *et al.,* 2010). Thind *et al.* (2010) found that application of 120 kg N ha^{-1} through NCU in three equal split schedules at almost similar growth stages to the present study increased the agronomic efficiency to 24.0 from 21.0 kg grain/kg N applied through PU with the same split schedule. Meena *et al.,* (2018) reported that partial factor productivity (PFP) and agronomic efficiency (AE) of applied fertilizer nitrogen decreased with increasing dose of nitrogen. Application of 120 kg N ha^{-1} through NCU improved the PFP (45.62 kg grain kg^{-1} N applied) and AE (22.57 kg grain increase kg^{-1} N) over prilled urea.

Economics

India has often been called the “Subsidy Raj”. About 61% of India’s expenditure goes toward direct and indirect subsidies, one of the highest in its income bracket. Of these, fertilizer has the second largest subsidy bill at USD $11.2 billion a year (IMF 2015). The provision for urea subsidy has increased significantly from Rs 37,760 crore in 2011-12 to Rs 54,400 crore in 2014-15, which is a growth of 44.06 %. Subsidy payments for Urea fertilizer are made in two installments. A majority of the funds (95%) are released with certification by the company itself through the statutory auditor or the chartered account. The last 5% is released

after state government certification for quantity and quality which has to be done within 30 days and 6 months respectively. Despite the large amount of subsidy which is paid to manufacturers and importers of Urea, it still cannot be guaranteed that the end beneficiaries are farmers because of the leakages that exist. Farmers on average buy fertilizer at prices 60% higher than the government mandated price of Rs. 5390/MT. Urea subsidy is provided for agricultural purposes only. However, subsidized urea is diverted towards other industries like chemical industry, automobile systems and laboratories. This often leads to a shortage of urea for the intended beneficiary of the subsidy *i.e.* the farmer. Government of India has taken measures to control the black marketing of Urea, through a new policy of promoting neem coated urea. Indigenous manufacturers of urea have to mandatorily produce 75% of the subsidized urea as neem coated urea. Further, they are free to produce the whole amount of subsidized urea as NCU. NCU is not only environment friendly but it also prevents the usage of urea for non agricultural purposes.

Suresh and Swarna (2008) reported that the application of neem coated urea @ 120 kg N ha^{-1} in three splits (½ as basal and each ¼th at tillering and PI stage) recorded highest benefit-cost ratio of 1.21 rupees per rupee invested. It was followed by Nimin coated urea (1.16 rupees per rupee invested) with same dose and splits. Meena *et al.,* (2018) reported that corresponding increments in gross and net return with NCU over existing practice were 11.07 and 18.10%, respectively, highest B: C ratio (1.61) was also recorded with NCU. Sarangi *et al.* (2016) found that application 100% RDN as 50% at basal, 25% at tillering and 25% at PI through NCU gave significantly higher gross and net return than PU with improved B: C ratio and reduced cost of cultivation.

CONCLUSION

Neem coated urea temporarily delay the bacterial oxidation of the ammonium-nitrogen by depressing over a period of time the activity of Nitrosomonas bacteria in the soil. Thus, neem coated urea can control the loss of nitrate by leaching and/or denitrification from the topsoil by keeping nitrogen in the ammonium form longer and thereby increasing the fertilizer nitrogen use efficiency and yield of rice. Zest of review presented above clearly shows that there is substantial advantage with neem coated urea over prilled urea. Beside the growth and yield of rice, the nitrogen use efficiency and economic benefit are also higher when urea coated with nitrification inhibitors.

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