Agronomic evaluation of enhanced efficiency N fertilizers in lowland rice

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Abstract
Nitrogen use efficiency (NUE), expressed as agronomic efficiency, of prilled urea is quite low under lowland rice in India. Among the different strategies used for enhancing agronomic efficiency of fertilizer N, use of enhanced efficiency fertilizers holds a great promise. Therefore a field experiment was conducted at the Research Farm of ICAR-Indian Agricultural Research Institute, New Delhi for two consecutive years. Main objective of the study was to find out the effect of essential and vegetable oils coated prilled urea on grain yield and agronomic efficiency of rice. The treatments (22) comprised of combinations of 3 N rates (50, 100 and 150 kg N/ha) and 7 N sources (citronella oil, meliacins, karanj oil, lemongrass oil, cottonseed oil, palmarosa oil and no oil coated prilled urea) at a thickness of 1000 mg oil/kg urea, and an absolute control. The experiment was laid out in a Randomized Block Design with three replications. Rice grain yield increased significantly up to highest N rate (150 kg/ha). All the oil coated ureas, except palmarosa oil, produced significantly higher rice grain yield over uncoated urea. Citronella oil coated urea produced highest grain yield of rice, being at par to karanj oil and cottonseed oil coated urea, but significantly higher than other coated ureas. The highest agronomic efficiency of nitrogen was recorded with citronella oil coated prilled urea.

Keywords
Economic returns, essential oil, neem, nitrogen fertilizer, nitrogen losses, vegetable oils

Introduction
Rice is the most important cereal crop of India occupying largest area. The high yield of rice is associated with the high demand of plant nutrients, especially of nitrogen. The consumption of nitrogenous fertilizer has shown a gradual increase over the years. In the next 3 years, that is, by 2018 the demand for fertilizer N is predicted to increase by 29.1% in East Asia and by 24.5 % in Southeast Asia (FAO 2015). However, it is worth mentioning that the nitrogen use efficiency (NUE) of applied fertilizer N, either expressed as crop N recovery or agronomic efficiency, in rice is very low. The general recovery efficiency of nitrogen for cereals is 44% (Ladha et al. 2005), while it could be 21-33 % in rice (Prasad et al 2014). The low N recovery in rice and other crops is due to four nitrogen loss mechanisms, namely, surface run-off on sloping lands, ammonia volatilization, leaching and denitrification (Prasad et al. 1998; Prasad and Shivay 2015). This low recovery of fertilizer N reduces farm profits, water quality, air quality and the agronomic efficiency (AE). Dobermann (2007) defined AE as gain in productivity improvement by use of nutrient input. AE of fertilizer N in rice was reported to be 13 kg grain / kg N in India (Prasad et al. 2000) and 12 kg grain / kg N in China (Jin 2012).

Several strategies have been tried to enhance nitrogen use efficiency (NUE) in rice including split N application, the use of slow release N fertilizers and nitrification inhibitors (NIs). Although, most of the NIs such as nitrapyrin, dicyandiamide and ammonium thiosulphate remain still unpopular with most of the Asian farmers due to their high cost and limited availability (Kumar et al. 2010). Hence, need is being increasingly felt to develop some enhanced efficiency fertilizers for increased NUE and reduced inputs of N fertilizers. The ICAR-Indian Agricultural Research Institute pioneered the discovery and development of neem products as fertilizer urea adjuvants. In this direction, use of neem oil coated urea (NOCU) holds a great promise in India. Kumar et al. (2010) reported that neem (*Azadirachta indica*) coated urea increased NUE (N recovery and AE) in rice substantially. It is possible that the coated oil assists the plant in capturing N or may provide additional growth benefits.

Besides neem, there are several natural (plant) products (essential oils) that could also be employed for coating of prilled urea (Kiran and Patra 2003a; Kiran and Patra 2003b; Patra et al. 2006, 2009) for increased N recovery and agronomic efficiency. A recent study (Kashiri and Kumar 2016) concluded that citronella oil has nitrification inhibiting properties, and has a potential to substitute the neem oil, if coated onto prilled urea. The key scope of the present investigation was to study the effects of essential oils (citronella, lemon grass and palmarosa) and vegetable oils (meliacins, karanj and cottonseed) coated prilled urea on grain yield and agronomic efficiency of lowland rice.

Materials and methods

The field experiment was conducted at the Research Farm of ICAR-Indian Agricultural Research Institute, New Delhi (28^0 38' N; 77^0 11' E; elevation 228.6 m above m.s.l.) for two consecutive years (2009 and 2010). The experimental soil was sandy clay loam, initially testing low in available N (275 kg / ha), medium in available P (11.3 kg / ha), and available K (276 kg / ha) with pH of 7.9 and organic carbon 0.52%. Chemical analysis of soil (0-15 cm) at the start of the experiment was done by using Subbiah and Asija (1956) procedure for determination of available N, Olsen's method for available P (Olsen et al. 1954), 1 *N* ammonium acetate method for available K determination (Hanway and Heidel 1952) and the chromic acid oxidation method for organic carbon (Walkley and Black 1934).

The treatments (22) in rice comprised of 21 combinations of 3 N rates (50, 100 and 150 kg N/ha) and 7 nitrogen sources (citronella oil, meliacins, karanj oil, lemongrass oil, cottonseed oil, palmarosa oil and no oil coated prilled urea) at a thickness of 1000 mg oil/kg urea, and an absolute control. In a previous study (Kumar et al. 2010), coating of prilled urea with 1000 mg neem-oil/kg prilled urea was proved better over uncoated prilled urea or prilled urea coated with lower or higher concentration of neem oil. Hence, coating thickness of 1000 mg oil/kg urea was used in the present study. The individual plot size was 5 m x 3 m. The experiment was laid out in a Randomized Block Design with three replications.

A tractor drawn disc harrow was used to plough the experimental field and it was puddled twice using plough in standing water. Afterwards the field was leveled properly using a plank. ‘PRH 10’, a superfine, medium duration (115-120 days’ duration) rice hybrid with basmati quality developed at ICAR-IARI, New Delhi, was used as the test cultivar. Rice was transplanted in the first week of July at a spacing of 20 cm x 10 cm under puddled condition. Basal dose of 26 kg P and 33 kg K/ha, through single super phosphate and muriate of potash, respectively, was applied just before puddling in all plots. Nitrogen, as per source and rate, was used in three splits at basal, tillering and panicle initiation stages.

The rice crop was harvested in the first week of October each year. The harvested produce was tied into bundles, numbered and left out in the field to dry for few days. After threshing, proper cleaning and winnowing the grain weight of each plot was recorded at 14% moisture. Various observations recorded in the present study were subject to analysis of variance and the significance of treatment effects was tested by ‘F’ test. Least significant difference (LSD) values of different groups of treatments at 5% probability level of significance were computed to judge the significance of results. The absolute control (no nitrogen) treatment was excluded in statistical analysis and the grain yield data of this treatment was used to estimate the agronomic efficiency of applied N. The statistical analysis was carried out using SAS 9.2 (SAS Institute, Cary, NC, USA). The agronomic efficiency (AE) was computed using the following formula, as suggested by Dobermann (2007).

$$\text{Agronomic efficiency (AE)} = \frac{\text{Grain yield in treatment (kg/ha) - Grain yield in control (kg/ha)}}{\text{Amount of nitrogen applied (kg/ha)}}$$

Results and discussion

Statistical analysis of the data showed that the interactive effect of N sources and rates on rice grain yield was non-significant during both the years. Hence, instead of two-way table, the main effects of these two factors are summarized in Table 1. The results show that citronella oil, karanj oil and meliacins coated prilled ureas produced significantly higher grain yield of rice over uncoated prilled urea (no any oil coating onto prilled urea). The values of highest agronomic efficiency and economic returns (Rupees/Rupee invested in N) were recorded with citronella oil coated prilled urea. Averaged across two years, the citronella oil coated prilled urea produced 36% more rice grain over uncoated prilled urea. The next best N sources were karanj oil and meliacins coated prilled urea. On an average, the karanj and cottonseed oil coated prilled ureas produced 30% and 28.7% higher grain yield over uncoated prilled urea, respectively. It may be possible that the coated oil allowed the plant to incorporate N more efficiently or it provided a growth benefit for the plant, but need to be confirmed. Further, coating of different oils onto prilled urea may have made it partially hydrophobic and it therefore took longer to hydrolyse and thus improving the timing of N supply to the rice. However, citronella oil coated prilled urea may have increased the N recovery by slowing down the process of nitrification. This could have helped the rice crop to get N for longer periods. Kashiri and Kumar (2016) have confirmed from a soil incubation study that citronella oil has nitrification inhibiting properties if coated onto prilled urea.

The grain yield of rice was influenced significantly due to N application rates. In year 1 the grain yield increased substantially and significantly due to the successive N rates. However, in year 2 the grain yield increased significantly only up to 100 kg N/ha. Furthermore, the nitrogen use efficiency (NUE) and economic returns were highest at the lowest N rate and then decreased with the increase in N rates successively.

Table 1. Effect of N sources and rates on grain yield, agronomic efficiency and economic return of hybrid rice (grain yields for the N sources is the mean yield across N rates and vice-versa)

Treatment	Grain yield (t/ha)		AE (kg grain increase/ kg N)		Economic return (Rs/Re invested in N)***	
	*Year 1	**Year 2	Year 1	Year 2	†Year 1	††Year 2
Source of N						
Citronella oil coated prilled urea	6.59	6.23	36.2	32.4	31.0	31.8
Meliacins coated prilled urea	5.92	5.81	29.5	28.1	25.3	27.5
Karanj oil coated prilled urea	6.56	5.68	35.9	26.8	30.7	26.3
Lemon grass oil coated prilled urea	5.80	4.87	28.3	18.7	24.2	18.3
Cottonseed oil coated prilled urea	6.38	5.75	34.1	27.5	29.2	26.9
Palmarosa oil coated prilled urea	5.39	4.51	24.2	15.1	20.7	14.8
Uncoated prilled urea	5.10	4.32	21.3	13.2	18.2	12.9
LSD (P=0.05)	0.44	0.74	-	-	-	-
N rate (kg/ha)						
50	4.93	4.41	39.2	26.0	33.6	25.5
100	6.29	5.57	33.2	24.6	28.4	24.1
150	6.66	5.95	24.6	18.9	21.1	18.5
LSD (P=0.05)	0.29	0.49	-	-	-	-
Interaction (Source of N x N rate)	NS†††	NS†††	-	-	-	-

*Grain yield of control plot (0 kg N/ha) = 2.97 t/ha; **Grain yield of control plot (0 kg N/ha) = 3.11 t/ha; ***Rs. - Indian rupees (INR) per rupee (Re.) invested in N; †Taking GOI procurement price of fine paddy at Rs.9.0 per kg, and cost of N at Rs.10.5/kg.; ††Taking GOI procurement price of fine paddy at Rs.10.3/kg, and cost of N at Rs.10.5/kg.; †††Not significant.

Conclusion

Coating of prilled urea with different essential/ vegetable oils, except palmarosa oil, gave significantly and substantially higher grain yield of rice over uncoated prilled urea during both the years. Among the coated prilled ureas, citronella oil coated urea produced highest grain yield of rice, being at par to karanj oil and cottonseed oil coated urea, but significantly higher than other coated ureas. The highest agronomic efficiency and economic returns were also obtained with citronella oil coated prilled urea. The increased rates of N application decreased the profit per unit N applied.

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