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Managing neem (*Azadirachta indica*)-coated urea and ordinary urea in wheat (*Triticum aestivum*) for improving nitrogen-use efficiency and high yields

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ABSTRACT

Modifications in fertilizer source and/or management can lead to reduced losses of N, high wheat yields and increased fertilizer N-use efficiency. Relative performance of neem (*Azadirachta indica* A Juss)-coated urea vis-à-vis ordinary urea applied to wheat (*Triticum aestivum* C. emend Fiori & Paol.) was studied when applied at different levels (48, 96 and 120 kg N/ha), drilled in between rows as a single dose of 96 kg N/ha and when applied in 3 split doses (48, 48 and 24 kg N/ha). The field experiments were carried out at 2 locations, i e Ludhiana–sandy loam soil and Gurdaspur – clay loam soil during 2005–08. When nitrogen was applied in 2 equal split doses at the time of sowing and first irrigation, the neem coated urea did not out perform urea in increasing grain yield at any level of N application at both the locations. Performance of neem coated urea @96 kg N/ha drilled during sowing of wheat was better than neem-coated urea applied @ 120 kg N/ha in 2 split doses at Ludhiana. Better performance of urea and neem-coated urea applied in 3 rather than 2 split doses only in coarse-textured soil at Ludhiana suggests that losses of applied N via leaching can be substantial as compared to in the fine textured soil at Gurdaspur. This study suggests that neem-coated urea can lead to improved N-use efficiency when applied either in 3 split doses or drilled between rows as a single dose in coarse-textured soils rather than in fine-textured ones.

Key words: Drilling of urea, Neem (*Azadirachta indica*), Neem-coated urea, Nitrogen-use efficiency, Split application of urea, Urea, Wheat

On- farm measurement of recovery efficiency of fertilizer N by wheat in India rerely exceeds of 50% (Cassman *et al*. 2002). Improving efficiency of fertilizer N use is vital to achieve and sustain high crop yields and reduce losses of N that can potentially deteriorate environmental quality. Appropriate modification in fertilizer source or management practices can lead to reduced losses of N and increased fertilizer N-use efficiency. Oil derived from neem seeds (*Azadirachta indica* L Juss.) contains melicians (generally known as neem bitters) of which Epinimbin, Deacetyl, Salanin and Azadirachtin show dose-dependent nitrification inhibition action (Devakumar and Goswami 1992). Although it has been established that neem products when applied along with urea are capable of enhancing nitrogen-use efficiency in crops (Singh and Singh 1986), large-scale use of neem products along with urea could not become possible as process for large-scale coating of urea with neem products was not available. Recently, Indian Agricultural Research Institute, perfected a urea coating technology employing neem oil emulsion at 0.5 to 1.0 kg/tonne of urea (Suri *et al.* 2004). Coating of urea prills with neem oil in this way is very economical as it costs only about ₹ 100/tonne of urea. The National Fertilizer Ltd adopted this technology at their plant in Panipat (India) and has already started commercial production of neem coated urea.

Besides efficient N fertilizer source, another approach to increase N fertilizer-use efficiency is to achieve synchrony between N needs to the crop and N supply. In order to match the time of high N demand with N availability, application of N in split doses and as side banding can prove useful. The present investigations were undertaken to evaluate the relative performance of neem-coated urea vis-à-vis ordinary urea applied to wheat at different rates and following different schedules of application and when drilled in between rows in both coarse- and fine-textured soils.

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MATERIALS AND METHODS

Field experiments were conducted at 2 sites during 2005–08 at Ludhiana on a Typic Ustipsamment (Fatehpur sandy loam) at the experimental farm of the Punjab Agricultural University and at Gurdaspur on clay loam soil at experimental area of Regional Research Station of Punjab Agricultural University. The climate of Ludhiana (30°56′ E longitude and altitude 247 m above mean sea level) is sub-tropical, semi-arid with an annual rainfall of 733 mm, of which about 80% is received during June to September. The climate of Gurdaspur (32° 02′ N, 75° 24′ E) is sub-humid and semi-arid. Annual rainfall is 887 mm, about 80% of which occurs from June–September. The soil organic carbon, *p*H, available P and available K were 0.41 and 0.68%, 7.40 and 7.11, 2.88 and 4.71 mg/kg and 78 and 83 mg/kg, respectively, at Ludhiana and Gurdaspur before initiation of the experiments in November 2005.

The two sources of N (neem-coated urea and ordinary urea) were compared at 3 levels of N (48, 96 and 120 kg N/ha) applied in 2 equal split doses, i e broadcasted before sowing and before first irrigation. In addition to these treatments, 96 kg N/ha from both the sources was drilled in between the rows as single dose at sowing for comparison. The recommended rate of 120 kg N/ha from both the sources was also tried in 3 split doses as 48+48+24 kg N/ha before sowing, first irrigation and second irrigation, respectively. The experiment consisted of 11 treatments; (1) no-N control (2) urea @ 48 kg N/ha (3) urea @ 96 kg N/ha (4) urea @ 120 kg N/ha (5) neem-coated urea @ 48 kg N/ha (6) neem-coated urea @ 96 kg N/ha (7) neem-coated urea @ 120 kg N/ha (8) urea @ 120 kg N/ha applied in 3 doses of 48, 48 and 24 kg N/ha (9) neem-coated urea @ 120 kg N/ha applied in 3 doses of 48, 48 and 24 kg N/ha (10) urea @ 96 kg N/ha drilled at sowing and (11) neem-coated urea @ 96 kg N/ha drilled at sowing. The 11 treatments were laid out in a randomized block design with 3 replications.

Land was prepared by 2 ploughings and 1 planking, followed by pre-sowing irrigation. Seed bed was prepared by 2 ploughings, followed by planking. A basal dose consisting of 26 kg P/ha and 50 kg K/ha was applied to all the plots at sowing. Phosphorus and potash was applied as single superphosphate and muriate of potash, respectively, through seed-cum-fertilizer drill. Wheat (*Triticum aestivum* L. emend. Fiori & Paol.) was sown during first fortnight of November and harvested in between 10 and 20 April during all the 3 years at both the location. 'PBW 343' wheat was sown at both the locations during all the years. The row-to-row spacing was 22.5 cm in 30 m^2 treatment plots at both the locations. Recommended package of practices were followed to control weeds and insect-pests. At maturity, grain and straw yields were recorded. Grain and straw samples were analyzed for N content to calculate total N uptake by above ground portion of the crops at maturity. Apparent recovery efficiency (RE) and agronomic efficiency (AE) of added fertilizer N were calculated as:

$$\text{RE (\%)} = \frac{\text{(total N uptake in N fertilized plot – total N in control plot)} \times 100}{\text{(quantity of fertilizer N applied)}}$$

$$\text{AE (kg grain/kg N applied)} = \frac{\text{(grain yield in N fertilized plot– grain yield in control plot}}{\text{(quantity of fertilizer N applied)}}$$

Analysis of variance (ANOVA) was carried out using IRRISTAT version 5.0. Least significance difference (LSD) at a 0.5 level of probability was used to test the significance of differences among treatment means.

RESULTS AND DISCUSSION

Application of N through neem-coated urea or ordinary urea up to 120 kg N/ha significantly increased grain yield of wheat at Gurdaspur but the increase was significant only up to 96 kg N/ha at Ludhiana for both the sources of N (Table 1). When nitrogen was applied in 2 equal split doses at sowing and at first irrigation, the neem-coated urea did not out perform urea in increasing grain yield of wheat at any level of N application at Ludhiana or at Gurdaspur. Similar trend was also observed for straw yield at both Ludhiana and Gurdaspur locations (Table 1). However, it was interesting to note that neem-coated urea gave 9.4, 5.6 and 2.5% higher grain yield over urea with application of 48, 96 and 120 kg N/ha, respectively, at Ludhiana. The corresponding increase was 3.2 , 4.5 and 1.6% at Gurdaspur. These results suggest that positive impact of nitrification inhibition properties of neem-coated urea is more visible in the coarse-textured soil at Ludhiana than in the relatively fine-textured soil at Gurdaspur. Data pertaining to total N uptake by wheat, however, revealed that at 48 and 96 kg N/ha application level, neem-coated urea could supply significantly higher amount of N than urea. It was true at both Ludhiana and Gurdaspur, although higher N uptake could not be translated into significant yield effects (Table 1). Substantially higher recovery and agronomic efficiencies recorded for neem-coated urea as compared to urea, particularly at 48 and 96 kg N/ha further prove the superiority of neem-coated urea over urea (Table 2).

Ammonia volatilization constitutes major N loss mechanism when urea is the fertilizer (Katyal *et al.* 1987). In coarse-textured soil, substantial losses may also occur via nitrate leaching, particularly when water management in irrigated wheat does not coordinate well with fertilizer N management (Bijay Singh and Sekhon 1976). Losses via ammonia volatilization in soils amended with urea can be effectively controlled either by drilling urea at a depth or by applying urea- just before an irrigation (Katyal *et al.* 1987). In the present investigation, applying neem-coated urea rather than urea should encourage losses via ammonia volatilization

Table 1 Grain and straw yield, and nitrogen uptake by wheat at Ludhiana and Gurdaspur under different sources and rates of nitrogen (pooled data over 3 yars)

Treatment	Ludhiana			Gurdaspur		
	Grain yield (tonnes/ha)	Straw yield (tonnes/ha)	Total N uptake (kg/ha)	Grain uptake (tonnes/ha)	Straw yield (tonnes/ha)	Total N uptake (kg/ha)
Control	1.67	2.56	36	2.34	3.35	41
Urea (48 kg N/ha)	2.66	4.60	59	3.78	5.50	76
Urea (96 kg N/ha)	3.78	5.50	86	4.49	6.43	114
Urea (120 kg N/ha)	3.97	6.20	100	4.88	6.98	138
NCU (48 kg N/ha)	2.91	5.04	70	3.90	5.72	85
NCU (96 kg N/ha)	3.99	5.95	100	4.69	6.81	125
NCU (120 kg N/ha)	4.07	6.70	108	4.96	7.06	141
Urea (120 kg N/ha applied in 3 doses; 48, 48 and 24 kg N/ha)	4.54	6.40	116	4.66	6.38	119
NCU (120 kg N/ha applied in 3 does; 48, 48 and 24 kg N/ha)	4.57	6.72	127	4.72	6.67	121
Urea (96 kg N/ha drilled at sowing)	4.23	6.38	110	4.41	7.89	109
NCU (96 kg N/ha drilled at sowing)	4.49	6.94	112	4.45	6.23	106
LSD (*P*=0.05)	0.349	0.582	10.7	0.255	0.434	8.8

N, Neem-coated urea

Table 2 Fertilizer N-use effciencies of wheat as influenced by sources and rates of N at Ludhiana and Gurdaspur (data pooled over 3 years)

Treatment	Ludhiana		Gurdaspur	
	Agronomic efficiency (kg grain/kg N)	Recovery efficiency (%)	Agronomic efficiency (kg grain/kg N)	Recovery efficiency (%)
Control				
Urea (48 kg N/ha)	20.6	47.9	30.0	72.9
Urea (96 kg N/ha)	22.0	52.0	22.4	76.0
Urea (120 kg N/ha)	19.2	53.3	21.2	80.8
NCU (48 kg N/ha)	25.8	70.8	32.5	91.7
NCU (96 kg N/ha)	24.2	66.7	24.5	87.5
NCU (120 kg N/ha)	20.0	60.0	21.8	83.3
Urea (120 kg N/ha applied in three doses; 48, 48 and 24 kg N/ha)	23.9	66.7	19.3	65.0
NCU (120 kg N/ha applied in three does; 48, 48 and 24 kg N/ha)	24.2	75.8	19.8	66.7
Urea (96 kg N/ha drilled at sowing)	26.7	77.1	21.6	70.8
NCU (96 kg N/ha drilled at sowing)	29.4	79.2	22.0	67.7

because it retards nitrification of NH_4^+-N. However, due to the fact that both urea and neem-coated urea were either incorporated into soil (basal dose at planting) or applied before first irrigation event, losses due to ammonia volatilization were effectively controlled and it resulted in similar performance of neem-coated urea and urea in increasing the yield of wheat.

Performance of neem-coated urea @ 96 kg N/ha drilled during sowing of wheat was better than neem-coated urea applied @120 kg N/ha in 2 split doses at Ludhiana. Urea drilled @ 96 kg N/ha performed better than similar amount of urea-N applied in 2 split doses (Table 1). These results revealed that ammonia volatilization losses were very effectively controlled due to drilling of both neem-coated urea and urea (Katyal *et al.* 1987) and in sharp contrast to urea losses due to nitrate leaching in neem-coated urea treated plots were also reduced due to its nitrification inhibition properties. These effects were visible at Ludhiana where soils are relatively coarse in texture and leaching losses of N can also be significant (Aulakh and Bijay Singh 1997). Drilling of half N at sowing of wheat has been shown to perform better than broadcasting (Khanna and Chaudhary 1979). Application of the first half N dose with pre-sowing irrigation resulted in significantly higher wheat grain yield than its application at sowing (Sidhu *et al.* 1994). Possibly N applied along with pre-sowing irrigation was transported to depth and thus was not prone to losses of N via ammonia volatilization. Mengel *et al.* (1982) observed that incorporation of N fertilizers results in reduced N losses as compared with broadcasting Sharma and Chaudhary (1984) reported that deep placement of fertilizer N to wheat in a coarse-textured soil resulted in its more uniform distribution in the root zone, more extensive root proliferation and enhanced subsoil N utilization. These observations clearly support the results pertaining to yield and N uptake in the present investigation.

Effect of drilling urea and neem-coated urea at sowing of wheat rather than applying in 2 split doses was not visible on grain yield of wheat at Gurdaspur (Table 1) where the soil is relatively fine-textured and losses due to ammonia volatilization and nitrate leaching should not be significant. Better performance of urea and neem-coated urea applied in 3 split doses rather than 2 split doses suggest that losses of applied N via leaching at Ludhiana can be substantial as compared to at Gurdaspur (Table 1). The superiority of split application of N in 3 doses in increasing grain yield in different varieties and soil conditions, particularly in light-textured soils have been reported (Singh *et al.* 1999; Krishnakumari *et al.* 2000). It seems that at Ludhiana even losses due to ammonia volatilization were also reduced by increasing number of split doses from 2 to 3. Possibly, the portion of fertilizer N applied after crown root-initiation stage was rapidly taken up by plants thus making it less susceptible to losses via ammonia volatilization.

The beneficial effects of various neem products, when used in combination with ordinary urea, are well established in decreasing N losses and increasing yield of crops like rice and wheat. Singh and Singh (1986) observed at significant reduction in NO_3-N leaching when urea was blended with neem cake. Neem seed cake blending with urea reduced ammonia volatilization by 31.4% (Reddy and Mishra 1983). An increase of 22.3% in rice grain yield was observed with the application of neem seed extract treated urea (Bains *et al.* 1971), 8.2% grain yield increase with neem cake blended urea (Ketkar 1974), 12.8% with Nimin-coated urea (Vyas *et al.* 1991), 1.3 to 11.1% (Mangat 2004) and 5.6% (Thind *et al.* 2010) with neem-coated urea. An increase of 4–12% in grain yield of wheat has been observed by using neem cake-coated urea (Agarwal *et al.* 1980). Small beneficial effects of neem-coated urea over ordinary urea in wheat might be attributed to deep root system of wheat as compared with rice which might have taken up nitrate-N from deeper layers.

It can be concluded that neem-coated urea can help to improve N-use efficiency as compared to urea when applied wither in 3 split doses (48+48+24 kg N/ha) or dribbled between rows as a single dose (96 kg N/ha) in coarse-textured soils rather than in fine-textured soils. When applied in 2 equal split doses (at sowing and at first irrigation) performance of neem-coated urea is at par with urea in both coarse- and fine-textured soils.

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