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RELATIVE PERFORMANCE OF NEEM COATED UREA VIS-À-VIS ORDINARY UREA FOR PRODUCTIVITY, PROFITABILITY AND NITROGEN USE EFFICIENCY IN FODDER OATS UNDER SEMI ARID CONDITIONS OF PUNJAB, INDIA

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ABSTRACT

Neem coated urea fertilizer is a boon to the Indian agriculture as it helps to not only increase crop's yields but also lowers nitrogen losses to the environment. Relative performance of neem (*Azadirachta indica* A Juss)-coated urea *vis-à-vis* ordinary urea in oats (*Avena sativa* L.) was studied when applied at three levels of nitrogen (56.25, 75 and 93.75 kg N/ha). The field experiments were carried out at Punjab Agricultural University, Ludhiana during *rabi* seasons of 2019-20 and 2020-21. The experiment was laid out in a completely randomized block design with three replications. The performance of neem coated urea with regard to crop growth, fodder yield and fertilizer nitrogen use efficiency was superior to the ordinary urea at the three doses tested. Pooled over the two seasons, green fodder yield increased with increase in nitrogen dose and 75 kg N/ha through neem coated urea was comparable to the 93.75kg N/ha through either fertilizer source. On mean basis, highest green and dry fodder yields of 721 and 126q/ha, respectively was recorded with the application of 93.75 kg N/ha as neem-coated urea and it was statistically comparable to the application of 75 kg N/ha through the similar source. This increase in yield was attributed to significantly more plant height and tiller density with 75 and 93.75 kg N/ha applied through neem coated urea. On an average of two years, highest fertilizer N use efficiency was observed with 75 kg N/ha through neem coated urea, with agronomic efficiency of 339.1 (2019-20) and 355.6 kg yield/ kg N (2020-21) and recovery efficiency of 91% (2019-20) and 93% (2020-21). The benefit: cost ratio (3.16) of 75 kg N/ha obtained from the neem coated urea was significantly higher than ordinary urea. Hence, application of 75 kg N/ha through neem coated urea in fodder oats can be recommended for maximizing productivity, profitability and fertilizer N use efficiencies.

Keywords: Agronomic efficiency, Green fodder yield, N uptake, Neem coated urea, Oats

Oats (*Avena sativa* L.) is an important *rabi* cereal fodder crop grown mostly in north-western states of India. It provides highly digestible and palatable fodder rich in crude protein (10-12%) and can be fed to the animals both as green fodder as well as preserved silage (Dar *et al*., 2014). Its grains are also in great demand as feed ingredient particularly for horses, sheep and poultry. In Punjab, oats rank second in total area under the fodder crops grown during the *rabi* season (November to April). Being a non-leguminous crop and taking around 80-90 days to flowering or the harvest stage for green fodder, its nitrogen (N) demand is very high (Singh and Dubey, 2007). Besides, some multi-cut varieties have been developed which possess high regeneration ability, which require large quantity of fertilizers especially nitrogenous fertilizer for enhancing the production of quality rich herbage (Singh and Dubey, 2007). Urea is the most commonly used nitrogenous fertilizer across the globe, however, recovery efficiency of fertilizer N in India rarely exceeds 50% N particularly in wheat (Thind *et al*., 2010). Hence, improving fertilizer N use efficiency (NUE) of urea is very important to sustain crop yields as well as reduce N losses (Guo *et al*., 2019). The efforts to overcome the low NUE of urea through appropriate modifications in fertilizer source led to the development of neem-coated urea (Suri *et al*., 2004).

Neem coated urea (NCU) possesses excellent nitrification inhibition properties to increase crop yield and NUE (Khandey *et al*., 2017; Ghafoor *et al*., 2021). Several authors reported promising potential of nitrification inhibition in different plant parts and byproducts (oil) of neem to increase the crop yield and NUE under conventional sowing methods in different crops (Patra *et al*., 2006; Khandey *et al*., 2017; Ali *et al*., 2020; Ghafoor *et al*., 2021). The neem oil-based nitrification inhibitors are degradable and environmentally friendly and possess an appreciable potential to improve the NUE (Dimkpa *et al*., 2020). Based upon the results of extensive field trials, NCU

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was found to be agronomically superior to normal prilled urea (Mangat, 2004; Thind *et al*., 2010). Coating urea with neem oil prevents its misuse as well as puts the fertilizer in slow release mode thereby nourishing the plants for a longer period. Hence, it is being hypothesized that neem coated urea may improve fodder oats-wheat productivity and NUE through nitrification inhibition and slow N release. Therefore, the present study was formulated to assess the relative performance of NCU *vis-à-vis* ordinary urea for productivity, economics and NUE of oats as fodder crop in semi-arid region of northwestern India.

MATERIALS AND METHODS

The field experiment was carried out during the *rabi* seasons of 2019-20 and 2020-21 at Forage Research Farm, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana. The climate of Ludhiana (30°56′ E longitude and altitude 247 m above mean sea level) is subtropical, semi-arid with an annual rainfall of 733 mm, of which about 80% is received during June to September. The experimental soil was a well-drained sandy loam (Inceptisols) non-saline (EC: 0.11 dS/m) neutral in reaction (pH 7.8), low in organic carbon (0.35%), low in available N (218 kg/ha), high in available K (128.5 kg/ha) and medium in available P (39.8 kg/ha).

The two sources of N (neem-coated urea and ordinary urea) were compared at three levels of N (56.25, 75 and 93.75 kg N/ha) applied in two equal split doses, *i.e* broadcasted before sowing and at 30-35 days after sowing. The experiment consisted of seven treatment combinations; ordinary and NCU urea @ 56.25 kg, 75 kg (Recommended dose of N for oats) and 93.75 kg N/ha and no-N control. The treatments were laid out in a randomized block design with three replications. During both the years, the same field (under sorghum in *kharif* season) was prepared by two ploughings and one planking, followed by pre-sowing irrigation. A basal dose of 20 kg P_2O_5/ha as single superphosphate was applied to all the plots at sowing. Oats, 'OL 12' a single cut oats variety, was sown during first fortnight of November and harvested in first fortnight of March during both the years. The row-to-row spacing was 20 cm in a plot with 15 rows each 4 m long making a net plot of 4 x 3 m^2. At milk stage, the crop was harvested for green fodder. The data on growth parameters *viz*., plant height, number of tillers and yield (green fodder and dry matter) were recorded at the time of harvest. Plant samples collected after harvest were sun dried and then completely dried in hot air oven till a constant weight was obtained and their dry matter was recorded for further calculation of dry fodder yield. This dried plant material was then ground using Willy grinder to a uniform mesh size and the standard macro-Kjeldahl method (AOAC, 1970) by method no. 978.04 was used to determine the total nitrogen content and was converted into crude protein (CP) by multiplying percentage of N content by a factor 6.25. Also, the N content was used to calculate total N uptake by above ground portion of the crop at harvest. Nitrate-N was estimated with the procedure given by Cataldo *et al*. (1975) and 5% salicylic acid-H_2SO_4 with NaOH were added in water extracted Nitrate-N filtrate for its estimation at 410 nm. Amount of nitrate-N was calculated from standard curve prepared simultaneously with KNO_3 (0-50 μg) as standard. Economics of fodder oats under different treatments was computed by taking the prevailing local market price of inputs and the minimum support price of outputs and benefit cost ratio of different treatments was calculated by dividing the net returns from the total cost of cultivation.

Apparent recovery efficiency (RE) and agronomic efficiency (AE) of added fertilizer N were calculated as:

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

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

The data collected on various parameters were statistically analyzed by using Fisher's analysis of variance technique and the least significant difference test (LSD) at the 0.05 level of probability to compare the differences among the two treatment means.

RESULTS AND DISCUSSION

Data on plant height and tiller density of oats fodder at harvest as influenced by different treatments are presented in Table 1. All the fertilizer N treatments brought significant improvement in plant height and tillers production as compared to control. Further, higher doses of N (75 and 93.75 kg/ ha) applied through NCU had more plant height and

Table 1. Effect of different treatments on plant height, tillers and crude protein content of fodder oats

Treatments	Plant height (cm)		Number of tillers per meter row length		Crude protein (%)	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
Urea (56.25 kg N/ha)	131.7de	137.9c	64.5a	60.3a	6.9b	7.5c
Urea (75 kg N/ha)	136.5bcd	141.1bc	67.0a	61.0a	7.6a	7.8abc
Urea (93.75 kg N/ha)	140.9abc	144.7ab	68.3a	60.0a	7.6a	8.1ab
NCU (56.25 kg N/ha)	134.9cd	143.3ab	68.0a	61.3a	7.6a	7.7bc
NCU (75 kg N/ha)	142.1ab	146.5a	66.6a	62.2a	7.6a	7.9abc
NCU (93.75 kg N/ha)	147.2a	144.6ab	68.7a	62.3a	8.1a	8.2a
Control	126.5e	129.5d	51.5b	52.7a	6.6b	6.9d
SE(m)	2.1	1.5	2.8	1.2	0.2	0.1
CD (*p≤0.05*)	*6.8*	*4.8*	*8.5*	*3.5*	*0.6*	*0.4*

Within a column, means followed by different alphabets differ significantly at *p≤0.05* after DMRT

tillers' number as compared to other treatments. The plant growth in terms of tillers and plant height with application of ordinary urea remained comparatively lower as compared to the application of NCU. Increase in plant height in NCU suggested that there was increased availability of N for longer period of time for the growth of plants (Chand, 2002). It is, therefore, logical to speculate that increase in plant growth was influenced by consistent supply of N and stimulating effect of N as it is directly or indirectly involved in production of new cells and tissues and their enlargement which in turn increases plant biomass (Lawlor, 2002). All the fertilizer N treatments observed significant increase in crude protein content over the no N treatment *i.e.* control. However, the differences among the fertilizer N treatments could not reach statistical significance for crude protein content of green fodder.

The data in Table 2 revealed that different treatments have significant influence on fodder yields (both green and dry). All the treatments have brought improvements in fodder yields over no N control (Table 2). Fertilizer N application as ordinary urea and NCU increased both the green fodder and dry fodder yields significantly over no N control (Table

Table 2. Effect of different treatments on green fodder and dry matter yield of fodder oats

Treatments	Green fodder yield (q/ha)			Dry fodder yield (q/ha)		
	2019-20	2020-21	Mean	2019-20	2020-21	Mean
Urea (56.25 kg N/ha)	518c	535d	527d	93c	91d	92d
Urea (75 kg N/ha)	622ab	640bc	631bc	112ab	109bc	110bc
Urea (93.75 kg N/ha)	655ab	707ab	680ab	118ab	120ab	119ab
NCU (56.25 kg N/ha)	602b	627c	614c	108b	107c	107c
NCU (75 kg N/ha)	677ab	713ab	695a	122ab	121ab	122a
NCU (93.75 kg N/ha)	695a	747a	721a	125a	127a	126a
Control	422d	447e	435e	76d	76e	76e
SE(m)	26	24	19	5	4	3
CD (*p≤0.05*)	*80*	*75*	*60*	*15*	*13*	*11*

Within a column, means followed by different alphabets differ significantly at *p≤0.05* after DMRT

2). The mean green fodder and dry fodder yields increased significantly up to 75 kg N/ha, irrespective of N source. The increase in mean green fodder yield with 75 kg N/ha compared with no N control were 45.3% in case of ordinary urea and 60% for NCU, respectively. A further increase in the N dose (93.75 kg/ha) did not cause significant increase in fodder yields. At lower rates of N (56.75 and 75 kg N/ ha) fodder yields were higher for NCU compared to ordinary urea. On an average of two years, fodder yields increased with increase in N dose and 75 kg N/ha through NCU was comparable to the higher N doses through either fertilizer source. Increase in yield due to NCU application might be due to increased utilization of N by plants as a result of decreased losses of N (Beig *et al*., 2020). Comparing data of 50 field experiments, Singh (2019) estimated the average increase in rice grain yield to be 6.3 % with neem coated urea over urea and suggested application of neem coated urea on the basis of leaf greenness for further improvement in yield. Crude protein yield followed the trend of dry matter yield (Table 3). Almost similar mean crude protein yields were observed with 75 kg N/ha through NCU (9.42 q/ha) and 93.75 kg N/ha through ordinary urea (9.32 q/ha). Guggari (2018) showed that NCU recorded significantly higher grain yield, grain weight, and stover yield compared with other types of urea in pearl millet under rainfed condition.

Highest N contents (1.30-1.31%) were recorded with 93.75 kg N/ha through NCU followed by 93.75 kg N/ha through ordinary urea and 75 kg N/ha through NCU (Table 4). Significant differences with different fertilizer treatments were observed for N uptake and all treatments showed accelerated N uptake compared to control with no N application. Moreover, N uptake by the crop increased by about 101 and 80% with 93.75 kg and 75 kg N/ha, respectively, applied through NCU over the control treatment. The increased uptake of N might be attributed to the fact that coated fertilizers were effective in synchronizing the plant N demand and fertilizer release throughout growing season (Wang *et al*., 2015). Further, high N uptake in NCU treated plots was due to greater utilization of N as fertilizer losses

Table 3. Effect of different treatments on crude protein yield of fodder oats

Treatments	Crude protein yield (q/ha)		
	2019-20	2020-21	Mean
Urea (56.25 kg N/ha)	6.47c	6.85d	6.66d
Urea (75 kg N/ha)	8.52b	8.53bc	8.52bc
Urea (93.75 kg N/ha)	8.94ab	9.69a	9.32ab
NCU (56.25 kg N/ha)	8.20b	8.24c	8.22c
NCU (75 kg N/ha)	9.27ab	9.58ab	9.42ab
NCU (93.75 kg N/ha)	10.13a	10.36a	10.25a
Control	5.00c	5.23e	5.11e
SE(m)	0.5	0.3	0.3
CD (*p≤0.05*)	*1.42*	*1.08*	*0.9*

Within a column, means followed by different alphabets differ significantly at *p≤0.05* after DMRT

Table 4. Effect of different treatments on N content and N uptake of fodder oats

Treatments	N content (%)		Nitrogen uptake (kg/ha)		Mean
	2019-20	2020-21	2019-20	2020-21	
Urea (56.25 kg N/ha)	1.11b	1.21c	103.5c	109.7d	106.6d
Urea (75 kg N/ha)	1.22a	1.25abc	136.3b	136.4bc	136.4bc
Urea (93.75 kg N/ha)	1.22a	1.29ab	143.1ab	155.1a	149.1ab
NCU (56.25 kg N/ha)	1.21a	1.24bc	131.2b	131.8c	131.5c
NCU (75 kg N/ha)	1.22a	1.26abc	148.3ab	153.3ab	150.8ab
NCU (93.75 kg N/ha)	1.30a	1.31a	162.1a	165.8a	164.0a
Control	1.05b	1.10d	80.0c	83.7e	81.8e
SE(m)	0.3	0.02	7.4	5.6	4.7
CD (*p≤0.05*)	*0.10*	*0.06*	*22.6*	*17.2*	*14.4*

Within a column, means followed by different alphabets differ significantly at *p≤0.05* after DMRT through denitrification and leaching were decreased due to nitrification inhibiton. Singh and Shivay (2003) reported high N uptake by neem application is due to increased availability of N for longer period of time. The lower mean nitrate-N contents of 234 ppm in 2019-20 and 182 ppm in 2020-21 with 56.25 kg N/ha normal urea and 234 ppm in 2019-20 and 260 ppm in 2020-21 with the 56.25 kg N/ha neem coated urea were recorded compared to other N fertilizer treatments with lowest nitrate content was seen in control having no N application (Table 5). Nitrate-N is the anti-quality factor of fodder crops if it exceeds the permissible limit (2000 ppm). It is generally higher in oats as compared to other fodder crops. In our experiment (Table 5), nitrate-N concentration in fodder oats was however, below the toxic level in all the treatments and safe for animal feeding. The higher nitrate content with 93.75 kg N/ha normal and neem coated urea might be due to the fact that rate of nitrate conversion into protein was slower than its uptake rate which led to nitrate accumulation in foliage. The concern with nitrate consumption by livestock is the rapid conversion of nitrate to nitrite in the rumen. Once converted, excessive nitrites are then absorbed into the bloodstream and bind with hemoglobin to produce methemoglobin, which can result in a range of health issues in livestock, namely early-term abortions and/or reduced breeding efficiency (Kumar *et al.*, 2021).

Higher recovery and agronomic N use efficiencies recorded for NCU as compared to ordinary urea, particularly at 75 kg N/ha, further proved the superiority of NCU over ordinary urea (Table 6). Highest fertilizer N use efficiencies were observed with 75 kg N/ha through NCU during both the years with agronomic efficiency of 339 kg fresh or dry fodder/kg N (2019-20) and 355.6 kg fresh or dry fodder/kg N (2020-21) and recovery efficiency of 91% (2019-20) and 93% (2020-21). Neem coated urea is an enhanced efficiency N fertilizer with a coating of neem oil emulsion having active ingredients which inhibit nitrification activity. Neem coated urea thus slows down the oxidation of $NH4^+$-N to NO^{3-}-N (Suri *et al.*, 2004), which is highly mobile and prone to losses through leaching and denitrification. Hence, the fertilizer NUE increased with NCU due to the inhibition of nitrification and retaining of urea N in the form of NH_4^+-N that can be used by plants for a longer period and in turn improving the overall utilization efficiency of applied fertilizers (Jadon *et al.*, 2018).

Table 5. Effect of different treatments on nitrate content of fodder oats at harvest

Treatments	Nitrate-N (mg/kg) in fodder at harvest	
	2019-20	2020-21
Urea (56.25 kg N/ha)	234c	182d
Urea (75 kg N/ha)	611a	572b
Urea (93.75 kg N/ha)	676a	728a
NCU (56.25 kg N/ha)	234c	260cd
NCU (75 kg N/ha)	338bc	247cd
NCU (93.75 kg N/ha)	429b	351c
Control	13d	38e
SE(m)	34	36
CD (*p≤0.05*)	*105*	*112*

Within a column, means followed by different alphabets differ significantly at *p≤0.05* after DMRT

Table 6. Effect of different treatments on fertilizer N use efficiency of fodder oats

Treatments	Agronomic efficiency (kg yield/ kg N)		Recovery efficiency (%)	
	2019-20	2020-21	2019-20	2020-21
Urea (56.25 kg N/ha)	170.7	157.6	42	46
Urea (75 kg N/ha)	266.7	257.8	75	70
Urea (93.75 kg N/ha)	246.8	277.3	67	76
NCU (56.25 kg N/ha)	318.8	320.0	91	86
NCU (75 kg N/ha)	339.1	355.6	91	93
NCU (93.75 kg N/ha)	290.8	320.0	88	88
Control	-	-	-	-
SE(m)	-	-	-	-
CD (*p≤0.05*)	-	-	-	-

Benefit cost ratio of 93.75 kg N/ha through NCU was highest on mean basis (Table 7) and it was statistically similar to the benefit cost ratio with 75 kg N/ha through NCU which was again better than the similar dose through ordinary urea. Similar results have earlier been reported by Singh and Shivay (2003).

In a large number of studies, comparative performance of NCU and ordinary urea has been done for wheat and rice and in a few studies, other crops like potato, sugarcane, cotton, maize and finger millet were taken. In most of these comparative

Table 7. Effect of different treatments on economics of fodder oats (pooled data of two years)

Treatments	Cost of cultivation (× 10^3 ₹/ha)	Net returns (× 10^3 ₹/ha)	Benefit: cost ratio
Urea (56.25 kg N/ha)	24.9	54.1d	2.17c
Urea (75 kg N/ha)	25.0	69.6bc	2.78b
Urea (93.75 kg N/ha)	25.1	76.9ab	3.06ab
NCU (56.25 kg N/ha)	24.9	67.2c	2.69b
NCU (75 kg N/ha)	25.0	79.2a	3.16a
NCU (93.75 kg N/ha)	25.1	83.0a	3.30a
Control	24.7	40.5e	1.64d
SE(m)	-	2.9	0.1
CD ($p \leq 0.05$)	-	*8.9*	*0.4*

Within a column, means followed by different alphabets differ significantly at $p \leq 0.05$ after DMRT

studies, yield increase was observed by replacing urea with NCU (Singh, 2019). For wheat and paddy, recommendations have been formulated for different regions by different institutes and SAUs. However, in majority of the crops recommendations for using NCU needs to be formulated and hence research needs to be done so that guidelines regarding the use of NCU in different crops can be suggested to the farming community. In our study for fodder oats, application of NCU with lower fertilizer N application rates led to green fodder yield of similar level as observed with ordinary urea at recommended N rate. However, application of NCU at the recommended N rate gave significant increase in yield and net returns.

CONCLUSION

The application of neem coated urea at the recommended fertilizer nitrogen rate in fodder oats significantly improved growth, green fodder yield, N uptake, N-use efficiencies and benefit: cost ratio compared to ordinary urea at the similar rate through extended N availability and by reducing N losses. However, its application at lower rates was still practically at par with ordinary urea at the recommended rate but with slightly lower yields. Farmers are therefore suggested to not reduce the rate of N application in fodder oats while using neem coated urea to avoid any risk for obtaining lower yields.

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