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Research Communication

Performance of foliar applied urea and nano-urea in single cut fodder oat

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ABSTRACT

The field experiment was carried out during the *rabi* season of the year 2022–23 at Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar to study the effect of urea and nano-urea in single cut fodder oat. The experiment was laid out in a randomized block design with ten treatments replicated three times. The treatments included 100% recommended dose of nitrogen through urea (RDN), 75% RDN + 2 NU sprays @ 2 mL/L, 50% RDN + 2 NU sprays @ 2 mL/L, 75% RDN + 2 NU sprays @ 4 mL/L, 50% RDN + 2 NU sprays @ 4 mL/L, 75% RDN + 2 NU sprays @ 6 mL/L, 50% RDN + 2 NU sprays @6 mL/L, 75% RDN + 2 sprays of 2% urea, 50% RDN + 2 sprays of 2% urea and control. Application of 100% recommended dose of nitrogen through urea in fodder oat enhanced green and dry fodder yield by 13.6, 12.5 and 14.4% and 6.7, 4.3 and 8.9% compared to 75% recommended dose of nitrogen along with 2 sprays of nano-urea at 4 mL/L, 75% recommended dose of nitrogen along with 2 sprays of nano-urea at 6 mL/L and 75% recommended dose of nitrogen along with 2 sprays of 2% urea, respectively. Net return and B:C ratio also decreased significantly when 75% recommended dose of nitrogen along with 2 sprays of either nano-urea (at 4 or 6 mL/L) or urea (2%) was applied compared to RDN.

***Key words*:** Nano-urea, Foliar N fertilization, Fodder oat, Urea foliar spray

Agriculture sector is a major contributor to India's economy, and livestock plays a vital role within it. In India, agriculture and animal husbandry are deeply interconnected with the country's economic, cultural, and religious systems. Mixed farming and livestock rearing are fundamental aspects of rural life. These activities help enhance income and provide employment, making them effective tools to reduce rural poverty. This is especially important in arid and semi-arid regions of India, where crop cultivation is limited.

A steady supply of high-quality green fodder is essential to meet the nutritional needs of livestock and improve the overall performance of the sector. However, only 4% of India's cultivable land is dedicated to growing livestock feed. As a result, the country is currently facing a net shortage of green fodder by 35.6% (Singh *et al.*, 2022). To address this gap, it is important to increase the productivity of forage crops. This will help boost the supply of green fodder, reduce feeding costs, and ultimately improve profitability.

Oats (*Avena sativa* L.) also known as *Jai* in hindi have outstanding growth, quick regrowth and high nutritional value for milch and draught livestock and they can help to close the gap between supply and demand for green forage in the winter season. The cool climate of northern India makes oats an acceptable winter cereal fodder crop which is slowly spreading to the eastern zone of India also. Among nutrients, nitrogen has a prominent effect in increasing crop productivity. One of the main causes of the low yield and poor quality of fodder oats is the deficiency of nitrogen in the majority of Indian soils. Applying the right dose and using the appropriate source of nitrogen can significantly improve the yield and nutritional quality of fodder oat. However, using excessive or haphazard amounts of nitrogen can harm soil health. It can also lead to the buildup of nitrate nitrogen in the fodder, which is toxic to animals. After nitrogen fertilizers are applied to the soil, they undergo several transformation processes such as immobilization, nitrification, denitrification, and volatilization (Yadav *et al.*, 2023). These processes reduce nitrogen use efficiency. Additionally, nitrogen use efficiency further declines due to the leaching of nitrogen compounds into the soil. To overcome these problems, a new approach is

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introduced to supply nutrients through nano-particles to ensure the sustainability and safety of the production system (Dasgupta *et al.*, 2017). These, nano particles, have a high availability and absorption capability due to their increased surface area to volume size ratio and nano size. Furthermore, decreasing a material to the nanoscale alters its physicochemical properties in comparison to a similar substance at bigger sizes (Peters *et al.*, 2016). Hence, the nano-fertilizer application is gaining popularity due to its high efficiency and low bulkiness. Nano-urea contains 4% w/v nitrogen as encapsulated nitrogen analogues or forms embedded on an organic matrix (IFFCO). Nano-urea is small sized particle (20–50 nm) and has more surface area and number of particles per unit area than conventional urea. The advantages of nano fertilizer include a threefold enhancement in nutrient use efficiency, 55–60 times decrease in the need for chemical fertilizer, 10–12 times greater crop stress tolerance, 30–35% greater nutrient mobilization by plants and 18–54% increase in crop production (Rathore *et al.*, 2022). A meager work has been done on nano-urea particularly for forage cereal crops in general and fodder oat in particular. Therefore, keeping these things in mind, the current field experiment was carried out to study the relative performance of foliar applied prilled urea and nano-urea in single cut fodder oat.

The field experiment was carried out during the *Rabi* season of the year 2022–23 at the Forage Research Block of Cattle Farm, APRI, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar. The site is situated on the edge of the *Budhi Gandak* river and is located in the sub-tropical zone of the Indo-Gangetic plains (lati tude of 25°98′ N, longitude of 85°68′ E) at a height of 63.9 metre above mean sea level (MSL). The region experiences humid weather and receives an annual average of 1200 mm of precipitation. During winter season, temperatures are very chilly, but summer time temperatures are scorching, dry and humid. The experiment was laid out in a randomized block design with ten treatments replicated three times. The variety used for the experiment was RO 11-1. The treatments included 100% nitrogen through urea (RDN), 75% RDN + 2 NU sprays @ 2 mL/L, 50% RDN + 2 NU sprays @ 2 mL/L, 75% RDN + 2 NU sprays @ 4 mL/L, 50% RDN + 2 NU sprays @ 4 mL/L, 75% RDN + 2 NU sprays @ 6 mL/L, 50% RDN + 2 NU sprays @6 mL/L, 75% RDN + 2 sprays of 2% urea, 50% RDN + 2 sprays of 2% urea and control. Recommended fertilizer dose used in the experiment was 100: 60: 40 kg/ha of N: P: K was applied. Only full dose of phosphorus and potassium was applied in control plot. The full recommended dose of phosphorus and potassium was applied at the time of sowing while half dose of nitrogen was applied at the time of sowing as basal and remaining 50% RDN was equally applied at 25 and 45 days after sowing (DAS) as per treatment. Foliar application of nano-urea and urea applications were done at 25 and 45 DAS as per treatment. The crop was manually harvested at 50% flowering stage. The green fodder yield from each plot was measured in electronic weighing machine. Moreover, a500 g fresh plant sample was dried in hot-air oven until a constant weight was achieved in order to calculate the dry matter fraction for determining dry fodder yield. Production efficiency in terms of green and dry fodder yield was determined by dividing green and dry fodder yield with days taken to 50% flowering (days to harvest) (Prajapati *et al.*, 2023). The dried plant samples were also used to evaluate its N content. Crude protein (CP) content was calculated by multiplying N content with 6.25 (Nanda and Nilanjaya, 2022). Crude protein yield was calculated by multiplying CP content with dry fodder yield. P and K contents of fodder sample were determined and multiplied with dry fodder yield to get nutrient uptake. Production economics was calculated based on cost of inputs and price of output as per prevailed market price. The data were subjected Analysis of Variance (ANOVA) technique as given by Gomez and Gomez (1984) and for comparison of treatment means, least significant difference (LSD) was calculated at 5% level of significance.

Green fodder and dry fodder yield and their production efficiency were significantly affected by the different treatments (Table 1). Highest green and dry fodder yield (35.99 and 8.93 t/ha) was achieved with application of 100% recommended dose of nitrogen through urea (RDN) which was at par with 75% RDN + 2 NU sprays @ 6 mL/L (31.98 and 8.56 t/ha), 75% RDN + 2 NU spray @ 4 mL/L (31.67 and 8.37 t/ha), 75% RDN + 2 sprays of 2% urea (31.46 and 8.20 t/ha). On the other hand, lowest green and dry fodder yield was recorded in control plot (19.80 and 3.93 t/ha). Application of 100% recommended dose of nitrogen through urea in fodder oat enhanced green and dry fodder yield by 13.6, 12.5 and 14.4% and 6.7, 4.3 and 8.9% compared to 75% recommended dose of nitrogen along with 2 sprays of nano-urea at 4 mL/L, 75% recommended dose of nitrogen along with 2 sprays of nano-urea at 6 mL/L and 75% recommended dose of nitrogen along with 2 sprays of 2% urea, respectively. Higher nitrogen availability in soil with 100% RDN through urea might have increased the growth attributes like height of the plant, tiller count per meter row length and accumulated dry matter resulting in higher green and dry fodder yield. Comparable green and dry fodder yields with foliar application of nano-urea (4 and 6 ml/L) and urea (2%) in combination with 75% RDN was attributed to its quick absorption by the plants and its efficient movement within the plant's system which facilitated better rates of photosynthesis leading to a higher yield

Table 1. Effect of different treatments on fodder yield, production efficiency, crude protein content and its yield and production economics of fodder *oat*

Treatment	Green fodder yield (t/ha)	Dry fodder yield (t/ha)	Production efficiency (GFY) (t/ha/day)	Production efficiency (DFY) (t/ha/day)	Crude protein content (%)	Crude protein yield (t/ha)	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	Benefit: cost ratio
T_1, Control	19.80	3.93	0.18	0.04	5.22	0.20	32,574	39,591	7,017	1.22
T_2, 100% RDN	35.99	8.93	0.31	0.08	6.05	0.54	33,572	71,973	38,401	2.14
T_3, 75% RDN + NU sprays @ 2 mL/L	27.37	6.36	0.24	0.06	5.73	0.38	35,966	54,738	18,772	1.52
T_4, 50% RDN + NU sprays @ 2 mL/L	24.13	5.46	0.21	0.05	5.38	0.30	35,640	48,258	12,618	1.35
T_5, 75% RDN + NU sprays @ 4 mL/L	31.67	8.37	0.28	0.07	5.95	0.50	37,886	63,338	25,452	1.67
T_6, 50% RDN + NU sprays @ 4 mL/L	27.14	6.69	0.24	0.06	5.60	0.36	37,560	54,444	16,885	1.45
T_7, 75% RDN + NU sprays @ 6 mL/L	31.98	8.56	0.28	0.08	6.13	0.53	39,806	63,956	24,150	1.61
T_8, 50% RDN + NU sprays @ 6 mL/L	28.14	6.93	0.25	0.06	5.76	0.40	39,480	54,276	14,796	1.37
T_9, 75% RDN + 2% urea sprays	31.46	8.20	0.27	0.07	5.83	0.48	34,166	62,916	28,750	1.84
T_{10}, 50% RDN + 2% urea sprays	27.22	6.49	0.24	0.06	5.68	0.37	33,840	56,284	22,445	1.66
CD (P=0.05)	5.11	1.70	0.05	0.02	0.33	0.11	-	9,167	9,167	0.26

**(RDN- recommended dose of nitrogen through urea; NU- nano-urea)*

of green and dry fodder compared to control. Saklani *et al.* (2022) and Rajesh *et al.* (2022) also observed reduced green and dry fodder yield when 25% RDN was replaced by nano-urea. The production efficiency depends on the yield and days to maturity. The production efficiency of GFY and DFY was the highest in treatment with 100% RDN through urea which was at par with 75% RDF + 2 NU spray @ 6 mL/L, 75% RDF + 2 NU spray @ 4 mL/L and 75% RDF + 2 sprays of 2% urea. The least value was recorded in control plot. The increase in production efficiency by 100% RDN through urea was due to higher green and dry fodder yield recorded in this treatment.

Crude protein content in forages are important quality parameters. Different treatments caused significant variation in crude protein content and yield. The crude protein content was found to be the highest in T_7 (6.13%) followed by T_2 (6.05%) and lowest value was recorded in control treatment. The crude protein yield was found to be the highest in T_2 (0.57 t/ha) which was statistically at par with T_7 (0.53 t/ha), T_5 (0.50 t/ha) and T_9 (0.48 t/ha). The lowest value was recorded in control treatment. The higher yield of crude protein in T_2 is due to the fact that 100% RDN through urea had higher dry matter yield might be due to higher nitrogen absorption (Table 1). Similar findings were also reported by Saklani *et al.* (2023) and Sarkar *et al.* (2022).

Nitrogen management practices caused significant variation in production economics (Table 1). The cost of cultivation was the highest in 75% RDF + 2 NU spray @ 6 mL/L (T7) (₹39,806/ha) while the lowest cost of cultivation was observed in control treatment (T1) (₹32,574/ha). Two sprays of 2% urea (T_9) and nano-urea at 4 mL/L (T_5) and 6 mL/L (T_7) along with 75% RDN incurred 1.8, 12.8 and 18.6% higher cost compared to 100% RDN (T_2). Gross return reduced by 12.6, 12.0, 11.0% with two sprays of 2% urea (T_9) and nano-urea at 4 mL/L (T_5) and 6 mL/L (T_7) along with 75% RDN compared to 100% RDN (T_2). Similarly, the net return and B:C ratio reduced by 25.1 and 14.0%, 33.7 and 22.0% and 37.1 and 24.8%, respectively when two sprays of 2% urea (T_9) and nano-urea at 4 mL/L (T_5) and 6 mL/L (T_7) along with 75% RDN was applied compared to 100% RDN (T_2). Higher gross returns, net returns and B:C ratio with 100% RDN was attributed due to higher green fodder yield and lower cost of cultivation than through 75% RDN in combination with two sprays of nano-urea at 4 or 6 mL/L. Our findings confirm the findings of Saklani *et al.* (2022) who reported application of 75% RDN along with 2 sprays of nano-urea after first and second cut leads to 8.2, 12.3 and 9.5% reduction in gross, net return and B:C ratio compared to 100% RDN in case of fodder oat and Rajesh *et al.* (2022) found 75% RDN along with 25% RDN through nano-N resulted in 2.7, 3.8 and

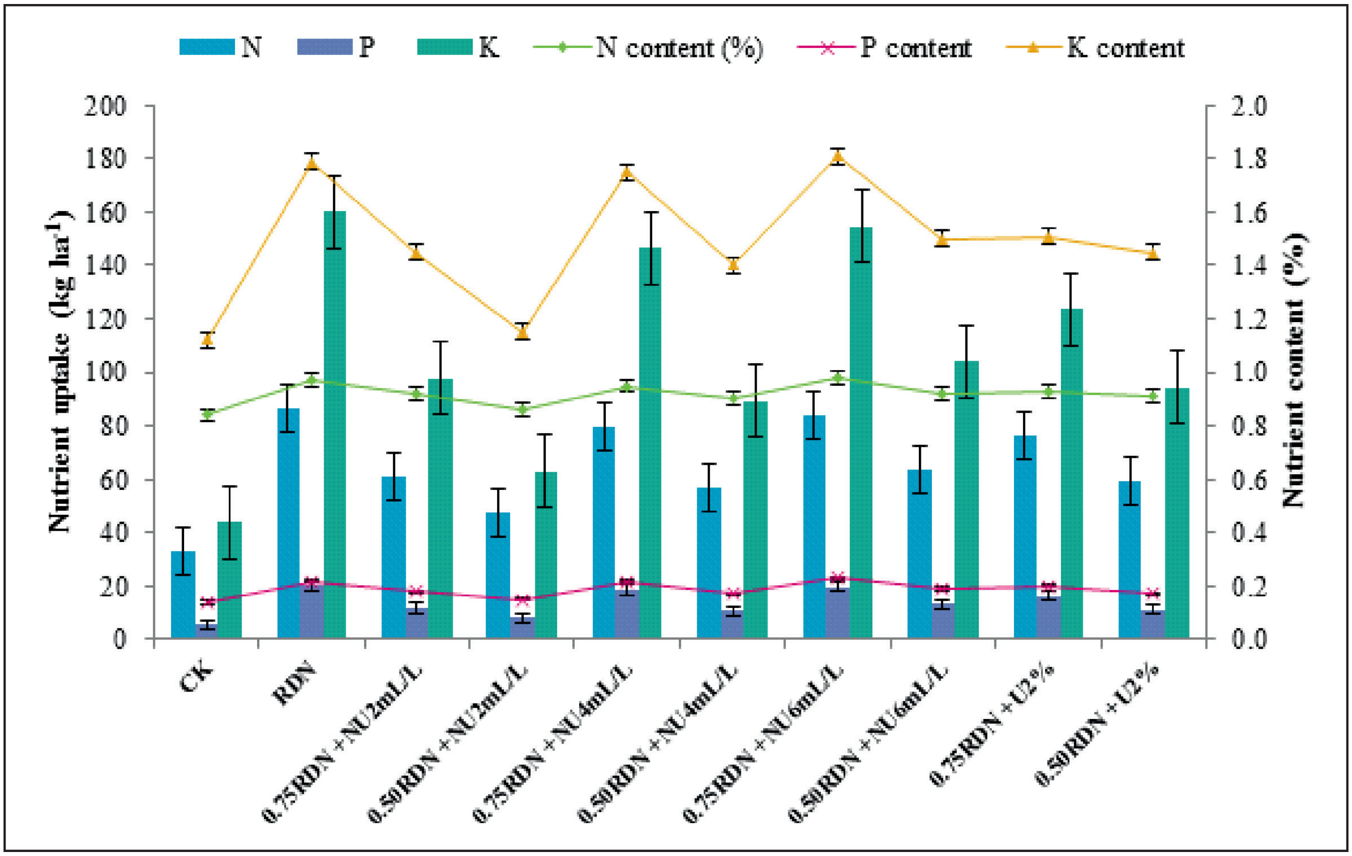

Fig. 1. Effect of different treatments on nutrient content and uptake by fodder oat. Error bars indicate LSD value ($p<0.05$). CK–control, RDN–100% recommended dose of nitrogen through urea (RDN), 0.75 RDN + NU 2 mL/L-75% RDN + 2 NU sprays @ 2 ml/L, 0.50 RDN + NU 2mL/L-50% RDN + 2 NU sprays @ 2 ml/L, 0.75 RDN + NU 4 mL/L-75% RDN + 2 NU sprays @ 4 ml/L, 0.50RDN+NU 4 mL/L–50% RDN + 2 NU sprays @ 4 ml/L, 0.75 RDN + NU6 mL/L–75% RDN + 2 NU sprays @ 6 ml/L, 0.50 RDN + NU 6 mL/L-50% RDN + 2 NU sprays @ 6 ml/L, 0.75 RDN + U2%–75% RDN + 2 sprays of 2% urea, 0.50 RDN + U 2%–50% RDN + 2 sprays of 2% urea

4.0% reduction in gross, net return and B:C ratio compared to 100% RDN in case of fodder oat.

Nitrogen management practices caused significant variation in N, P and K content and their uptake (Fig. 1). N, P and K contents were the highest in 75% RDN + 2 NU sprays @ 6 mL/L (T_7) which was at par with 100% RDN through urea and 75% RDN + 2 NU sprays @ 4 mL/L. However, for N content, 75% RDN along with 2 NU sprays @ 4 and 6mL/L and 2 sprays of 2% urea and 100% RDN through urea were comparable. The N, P and K uptake was found maximum with 100% RDN through urea (86.6 kg/ha, 20.0 kg/ha and 160.2 kg/ha, respectively) which was comparable to T_7 (84.0 kg/ha, 19.7 kg/ha and 154.8 kg/ha, respectively). The increase in nutrient uptake with 100% RDN through urea was due to higher dry fodder yield resulting in more uptake of nutrients. Nitrogen fertilization significantly increased the dry matter yield and nitrogen content that might be the main cause of enhanced nitrogen uptake for 100% RDN through urea. Increased N application leads to enhanced root length and root biomass (Fan *et al.*, 2010) and this enhanced root growth might have promoted substantial nutrient extraction from soil. Higher N, P and K uptake in 100% RDN through urea than 75% RDN through urea and 25% through nano-urea than 100% RDN through urea supports than findings of Rajesh *et al.* (2022).

Based on the results, it can be concluded that application of 100% recommended dose of nitrogen through urea in fodder oat achieved the maximum green and dry fodder yield which was at par with 75% recommended dose of nitrogen along with 2 sprays of nano-urea at 4 mL/L, 75% recommended dose of nitrogen along with 2 sprays of nano-urea at 6 mL/L and 75% recommended dose of nitrogen along with 2 sprays of 2% urea. However, net return and B:C ratio decreased significantly when 75% recommended dose of nitrogen along with 2 sprays of either nano-urea (at 4 or 6 mL/L) or urea (2%) was applied which is due to fertilizer subsidy. Hence, application of 100% RDN i.e. 100 kg N/ha through urea should be recommended to farmers for profitable fodder oat cultivation.

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