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Research Communication

Effect of different sources of nitrogen on productivity, profitability and N use efficiency of fodder oat (*Avena sativa*)

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ABSTRACT

A field experiment was conducted during the *rabi* season of 2020-21, to assess the effect of different source of nitrogen on fodder yield, economics and N use efficiency of oat (*Avena sativa* L.). The experiment consisted of seven treatments viz. control (no N); recommended dose of N (RDN); 50% N through fertilizer + 50% N through FYM; 50% N through fertilizer + 50% N through vermicompost; 50% N through fertilizer + two sprays of nano-urea; two spray of nano-urea and site-specific nitrogen management (SSNM). Results showed that application of 50% RDN through fertilizer + two sprays of nano-urea produced 58.3 t/ha green fodder which was at par with all other treatments except two sprays of nano urea and control. However, green fodder yield reduced under two foliar sprays of nano-urea by 20.7% as compared to 100% RDN (59.2 t/ha). The SSNM treatment recorded the highest net returns (₹ 49947/ha) and benefit to cost ratio (1.45) which were significantly higher than all other treatments except 100% RDN and 50% RDN through fertilizer + two sprays of nano-urea. The nano-urea treatments exhibited the highest nitrogen use efficiency. The study suggested that 50% recommended dose of nitrogen through conventional fertilizer along with two sprays of nano-urea could be applied in oat to get higher nitrogen use efficiency without any yield reduction.

Key words: Fodder yield, Nano-urea, Organic manure, N use efficiency

Nitrogen (N) is the most important nutrient for forage crops. It has great significance due to its role in enhancing luxuriant vegetative growth, higher biomass and quick regeneration following cutting or defoliation (Choudhary *et al*., 2018). Most N management studies have shown a linear increase in biomass yield with incremental increases in N applications (Choudhary and Prabhu, 2016; Finch *et al*., 2023). Further, optimum N nutrition improves leaf to stem ratio, succulence and palatability of forage crops. Nitrogen fertilization also influences nutritional value in forages. The majority of farmers apply N through urea. Since it is easy to use, cost effective and quick nutrient suppliers. Conventional fertilizers offer nutrients in chemical forms that are not often fully accessible to plants. Despite the excessive use of mineral N fertilizer, a huge amount is lost and/or unavailable to plants. Moreover, sole mineral fertilization enhances the decomposition of soil organic matter, which leads to degraded soil structure and declined soil aggregation and loss of nutrients through leaching, fixation, and greenhouse gases emission (Iqbal *et al*., 2019). Additionally, the use of inorganic fertilizers on soil over long periods of time may affect its capability to maintain healthy crop growth and productivity. In contrast to inorganic fertilizer, organic manure has multiple benefits like improving soil physical and chemical properties, enhanced soil microbial activity (Choudhary *et al*., 2023). This can improve soil nutrients availability for crop growth and development. However, organic fertilizer is quite low in nutrient content and its nutrient releasing ability is also low to meet crop requirements in a short time, hence the sole application of manure could not meet the usual intensity of agriculture production. Organic manure coupled with synthetic fertilizers has been confirmed to be a better approach to improve and sustain soil fertility and crop production than the sole application of mineral or organic manure (Paramesh *et al*., 2023).

Several innovations have been done in the area of plant nutrition in order to improve nutrient use efficiency by reducing nutrient loss. Development of nano-fertilizers is one

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of the important innovations among them. Some beneficial effects include increase in nutrient use efficiency, better yield and reduced soil pollution. Applying nano-fertilizers can also reduce environmental pollution than traditional chemical fertilizers applied with high rates. Nano-fertilizers possess unique features which enhance plants' performance in terms of ultrahigh absorption, increase in production, rise in photosynthesis, and significant expansion in the leaves' surface area (Kumar *et al.,* 2023). The IFFCO invented and released nano-urea as an alternative to commercial urea. Nano Urea (Liquid) contains 4% (40000 ppm) nanoscale nitrogen particles which have more surface area (10,000 times over 1 mm Urea prill) and number of particles (55,000 nitrogen particles over 1 mm Urea prill) which makes it more impactful. Despite of having numerous advantages of using nano materials in agriculture, the application and popularity of such inputs is very less. Thus, keeping these facts in view, an experiment was carried out to assess the effect of different sources of nitrogen on fodder yield, economics and N use efficiency in oat.

A field experiment was carried out at The Central Research Farm of Indian Grassland and Fodder Research Institute Jhansi, India (25°27′N latitude, 78°33′E longitude and 270 m above mean sea level) during *Rabi* 2020-21. The soil of experimental site was clay loam in texture, neutral in reaction (pH 7.2), medium in organic carbon (6.3 g/kg soil), low in available nitrogen (206 kg/ha) and medium in available P (11.4 kg/ha) and K (230 kg/ha). The experiment was laid out in randomized block design with three replications. The experiment comprised of seven treatments T_1, control (No N); T_2, 100% recommended dose of N (100 kg/ha through fertilizer in 2 splits, half of the dose at the time of sowing and remaining dose at first irrigation (25 DAS) as top dressing); T_3, 50% RDN through fertilizer + 50% N through FYM; T_4, 50% RDN through fertilizer + 50% N through vermicompost; T_5, 50% RDN through fertilizer + two spray of nano-urea; T_6, two spray of nano-urea (2 ml/l at 30 and 50 DAS); T_7, site specific nitrogen management (SSNM). In T7, 30 kg N was applied at the time of sowing; 30 kg at first irrigation; and 30 kg N was applied at second irrigation (50 DAS) when SPAD meter reading reached < 37. In T3 to T5, fertilizer (50 kg N/ha) was applied as basal at the time of sowing. However, organic manure was applied at the time of field preparation. A uniform dose of 60 kg P_2O_5 and 40 kg K_2O per hectare was applied at the time of sowing. Oat variety 'JHO-822' was sown at 25 cm row spacing at about 3-4 cm depth through seed drill using seed rate of 100 kg/ha. Oat crop was harvested at 50% flowering stage and weighed for green fodder yield. In general, four terms are used in relation to nitrogen use efficiency: Partial Factor Productivity (PFP), Agronomic Efficiency (AE), Recovery Efficiency (RE) and Physiological Efficiency (PE). The following expressions were used to determine these efficiencies as suggested by Congreves *et al.* (2021):

PFP (kg DM yield per kg N applied) = Yf / Na

AE (kg DM yield increased per kg N applied) = (Yf – Yc) / Na

RE (% of N taken up by a crop) = [(NUf – NUc)/Na] × 100

PE (kg DM yield increased per kg N uptake) = [(Yf – Yc) / (NUf – NUc)] × 100

Where, Yf and Yc are the DM yields (t/ha) in fertilized and control (no N) plots, respectively. NUf and NUc are the amounts of N taken up by oat crop in fertilized and control plots, respectively and Na refers to the amount of N applied (kg/ha).

Benefit to cost ratio was calculated by dividing the net returns value to the production cost in order to determine the economic efficiency. Data were subjected to analysis of variance (ANOVA) using SAS 9.3 (SAS Institute, Cary, NC, USA). Fischer's protected least significant difference (LSD) test was used to test the differences between treatment means at $P < 0.05$.

Green fodder yield of oat was significantly influenced by different sources of N fertilization (Table 1). Application of 50% RDN through fertilizer + 50% N through vermicompost produced significantly the highest green fodder yield (61.1 t/ha) followed by SSNM which was doubled than control. Furthermore, green fodder yield reduced by 20.7% under two foliar spray of nano-urea compared to 100% RDN (59.2 t/ha). However, 50% RDN–fertilizer + two sprays of nano-urea recorded statistically at par but numerically different fodder yield as of 100% RDN. This is possibly due to the synchronous release of N from the nano-urea following the demand of the crop. Upadhyay *et al*. (2023) reported that application of two sprays of nano-urea in combination of fertilizer may curtail 25% of the recommended dose of N in maize-wheat and pearl millet-mustard cropping systems. However, Sarkar *et al*. (2023) found reduction in the yield of wheat by 28.6% under 50% RDF + two spray of nano-urea.

Integrated use of fertilizer (50% N) and organic manures (50% N) recorded the statistically at par yield with 100% RDN through fertilizer alone. Organic manure (FYM and vermicompost) acts as a substrate for microorganisms which brings about the transformation of unavailable form of nutrients present in soil and applied as fertilizer in available form which are readily utilized by growing plants and also improve soil condition, favourable for availability of nutrients to crop (Ma *et al*., 2020). Therefore, synergistic effect of organic manure with fertilizer resulted in higher fodder yield.

The production cost of oat varied from minimum with

control (₹ 32760/ha) to maximum under 50% RDN through fertilizer + 50% N through VC (₹ 49110/ha) (Table 1). The cost of cultivation with 50% RDN through fertilizer + two sprays of nano-urea was comparatively higher than 100% RDN through fertilizer due to spraying cost of nano-urea. The maximum gross returns were calculated in 50% RDN through fertilizer + 50% N through VC (₹ 85493/ha) and minimum in control (₹ 10267/ha). The higher green fodder yields in fertilizer treatments also believed to be reason for the higher gross returns. However, the maximum net returns were computed in SSNM (₹ 49947/ha). Like net returns, highest benefit to cost ratio was calculated in SSNM (1.45) followed by RDN (1.41) and lowest in control (0.31). Integration of organic manure (FYM and vermicompost) with fertilizer also increased the cost of treatment, therefore, reduced the economic returns as compared to chemical fertilizers. Lower benefit to cost ratio under organic manure treatments mainly because of proportionate returns from manure was less in comparison to cost involved.

Data on nitrogen-use indices like partial factor productivity (PFP), agronomic efficiency (AE), recovery efficiency (RE) and physiological efficiency (PE) of oat are presented in Table 1. The highest partial factor productivity (188 kg DM/kg N applied), agronomic efficiency (83 kg DM increased/kg N applied) and recovery efficiency (175%) were computed with application 50% RDN through fertilizer + two spray of nano-urea followed by SSNM. However, maximum physiological efficiency (54.3 kg DM increased/kg N uptake increased) was computed under nano-urea spray treatment. Synchronizing crop N demand with fertilizer N supply using SPAD meter-based N management (SSNM) strategy led to higher AE and RE of applied N. In this study, higher PFP and AE under nano-urea treatments was mainly due to lower N application without much compromising fodder yield. Foliar application of nano-fertilizers can enter plants through the epidermis or stomata and then translocate through the apoplast or symplast pathways, which enhances nitrogen use efficiency. Kottegoda *et al*. (2017) in field conditions the nitrogen agronomic efficiency was 48% for nano-urea while in the case of urea it was 18% demonstrating that the expected slower N release by nano-urea resulted in a better N-efficiency compared to traditional fertilizer. Higher efficiency of nano fertilizer was also reported by Upadhyay *et al*. (2023).

Total uptake of nutrients (N, P and K) by oat crop was significantly ($P<0.05$) influenced with diverse nitrogen fertilization (Fig 1). The uptake of nutrients is in the order of N > K > P. In general, N uptake is 6 to 7 times of P uptake. Significantly maximum uptake of N (194 kg/ha) and K (150 kg/ha) was recorded in SSNM while 50% N-fertilizer

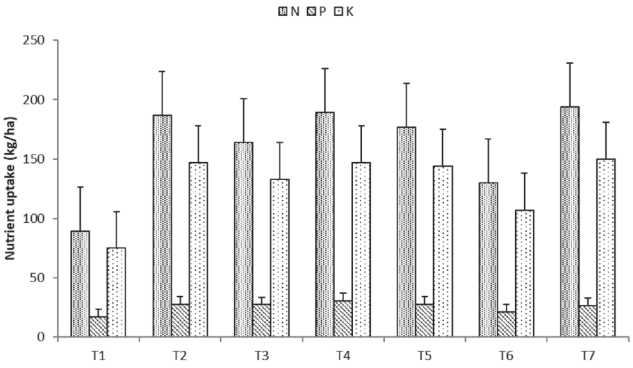

Fig. 1. Effect of different source of nitrogen on nutrient uptake in oat. Error bar represents LSD at 5% level of significance.

Table 1. Effect of different source of nitrogen on fodder yield and economics of oat

Treatments	Green fodder yield (t/ha)	Total cost (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	BCR	N Use Efficiency			
						PFP	AE	RE	PE
Control (No N)	30.7	32,760	43,027	10,267	0.31	-	-	-	-
100% RDN	59.2	34,410	82,833	48,423	1.41	99	46	97	47.2
50% N-fertilizer + 50% N-FYM	56.4	42,793	78,913	36,120	0.84	90	38	75	50.4
50% N-fertilizer + 50% N-vermicompost	61.1	49,110	85,493	36,383	0.74	102	49	100	49.6
50% N-fertilizer + nano-urea spray	58.3	34,940	81,573	46,633	1.33	188	83	175	47.5
Nano-urea spray*	47.0	34,240	65,753	31,513	0.92	-	-	-	54.3
SSNM	60.3	34,520	84,467	49,947	1.45	112	53	116	45.7
SEm±	2.66		3,722	3,722	0.10				
LSD (P=0.05)	8.19		11,468	11,468	0.30				

SSNM– site specific nutrient management; PFP–partial factor productivity (kg DM/kg N applied); AE–agronomic efficiency (kg DM increased/kg N applied); RE–recovery efficiency (%); PE–physiological efficiency (kg DM increased/kg N uptake increased)

*In this treatment, very minute quantity of N was applied through Nano-urea resulting very high values of PFP, AE and RE. Hence, data was not provided.

+ 50% N-vermicompost recorded maximum uptake of P (30.8 kg/ha). Furthermore, control recorded least uptake of N (89 kg/ha), P (17 kg/ha) and K (75 kg/ha) followed by two spray of nano-urea. The nutrient uptake in crop is largely dependent on dry matter accumulation and nutrient concentration in plant and available nutrient status in the soil. The uptake increased in aforesaid treatments because of higher availability of theses nutrient and biomass yield. Similar results were reported by Kumar *et al*. (2021).

It can be concluded that oat crop should be fertilized with 50% recommended dose of N through fertilizer + two sprays of nano-urea at 30 and 50 days after sowing for achieving higher productivity, profitability and nitrogen-use efficiency. However, the findings of the nano-urea need to be further validated in long term experiments.

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