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Integrated nitrogen management in fodder oats (*Avena sativa*) in hot arid ecosystem of Rajasthan

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ABSTRACT

A field experiment was conducted during *rabi* of 2006-07 and 2007-08 at Bikaner to find out the effect of different levels of nitrogen (0, 50, 100 and 150 kg/ha), biofertilizer (uninoculated and inoculated with *Azotobacter*) and sheep manure (0 and 10 t/ha) on performance of fodder oats (*Avena sativa* L). Results revealed that 150 kg N/ha significantly increased the growth attributes leading to higher dry matter (11.13 t/ha) and crude protein yields (988.7 kg/ha). Seed inoculation with *Azotobacter* increased the dry matter and crude protein yields by 5.93 and 7.00% over uninoculated control. Sheep manure @ 10 t/ha significantly increased the green fodder, dry matter, and crude protein yields to the extent of 21, 22.1 and 26.0% respectively over no sheep manure. Interaction effect of nitrogen and sheep manure was significant and dry matter yields recorded at 100 kg N/ha alongwith 10 t sheep manure/ha and 150 kg N/ha alone were at par. Highest values of net returns (Rs 23,285/ha), net B:C ratio (1.00), N, P and K uptake, energy responsiveness (8.32 MJ/Re) were recorded at 150 kg N/ha. However, maximum values of energy ratio (8.26) and energy productivity (458.9 g/MJ) were obtained with 100 kg N/ha, whereas, highest values of agronomic N-use efficiency (43.9 kg dm/kg-N applied) and physiological N-use efficiency (68.7 kg dm/kg N uptake) were recorded with 50 kg N/ha. Application of *Azotobacter* inoculation and sheep manure registered higher values of above traits than their respective control except agronomic and physiological N-use efficiencies, where control treatment recorded greater values. The residual soil organic carbon and available N contents were significantly influenced with application of nitrogen and sheep manure. The results show that nitrogen @ 100 kg/ha alongwith *Azotobacter* inoculation and sheep manure @ 10 t/ha may be applied for higher and quality fodder of oats.

Key words: *Azotobacter*, Economics, Energy conservation, Nitrogen, Nutrient uptake, Sheep manure

Oats (*Avena sativa* L.) is an important winter fodder and is a fast growing and high-yielding crop, thus requires a large quantity of fertilizer N for enhancing production of quality herbage (Singh and Dubey, 2007). High dose of chemical fertilizers to fodder can raise the possibilities of nitrate hazards to livestock as well as ground water pollution. At the same time, low priority to fodder crops, rise in fertilizer prices and their short supply at peak growing period limits the use of chemical fertilizers in forages. It is therefore felt necessary to look for the alternative and renewable sources of plant nutrition in order to achieve optimum and economic yield of fodder oats. *Azotobacter chroococcum* is a free living hetrotrophic nitrogen-fixing bacteria which produces a variety of growth promoting substances (Rao, 1975) may play a significant role in integrated N management in fodder oats. Use of organic manure and biofertilizers alongwith chemical fertilizers improves the soil physical, chemical and biological properties, fertilizer use efficiency, supplies of plant micronutrients, stimulates the proliferation of diverse group of soil micro-organism and plays an important role in the maintenance of soil fertility as well as ecological balance of rhizosphere. The information on integrated use of organic, inorganic and bio-fertilizers on fodder oats in hot arid region is lacking. Hence, an experiment was conducted to study the effect of integrated N supply through organic, inorganic and bio-fertilizer on fodder oats.

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MATERIALS AND METHODS

A field experiment was laid out during *rabi* of 2006-07 and 2007-08 at Research Farm, Central Sheep and Wool Research Institute, Arid Region Campus, Bikaner. The soil of experimental site was sandy with pH value 8.23, low in organic carbon (0.24%), available N (138.4 kg/ha), P (8.93 kg P/ha) and medium in available K (164.3 kg/ha). Treatments consisted of 4 N levels (0, 50, 100 and 150 kg/ha), 2 biofertilizer (uninoculated and inoculation with *Azotobacter chroococcum)* and 2 levels of sheep manure (0 and

10 t/ha) application. These treatments were replicated 3 times in factorial randomized block design. The experiment was taken in same field in both the years but place was changed to avoid residual effect of previous year treatments. Oats 'Kent' was sown at 25 cm row spacing using 100 kg seed/ha on 12 and 10 November and harvested first on 17 and 19 January and secondly on 8 and 4 March in respective years. Sheep manure which contained 0.89% N, 0.34% P and 0.98% K on dry weight basis was applied as per treatment before 30 days of sowing. One-third of N as per treatment through urea was drilled at sowing. Half of the remaining dose of N was top dressed after first irrigation (28 days after sowing) and rest after first cut. A common dose of P (17.6 kg/ha) and K (33.2 kg/ha) was applied to each plot at the sowing through single super phosphate and muriate of potash, respectively. Seed was treated with efficient strain of *Azotobacter chroococcum* (Mac 68) as per treatment and with standard procedure. The crop was raised under irrigated condition and received 6 irrigations (60 mm each) each year at 18 to 23 days interval as per need of the crop. Organic carbon, soil pH, available N, P and K of soil and N, P and K content in plant were estimated by standard methods. Nutrient uptake was estimated by multiplying the dry matter accumulation by content of nutrient in fodder. Economics was calculated on the basis of prevailing market prices of different inputs and output. Agronomic and physiological N-use efficiencies (ANUE and PNUE) were worked out by using the standard formulae. Energy inputs and outputs were calculated using the energy equivalents viz., man-power 1.96 MJ/hour, dry fodder 18 MJ/kg, sheep manure 0.3 MJ/kg, nitrogen 60.6 MJ/kg, P_2O_5 11.1 MJ/kg, K_2O 6.7 MJ/kg etc. as suggested by Panesar and Bhatnagar (1987).

RESULTS AND DISCUSSION

Growth attributes

The growth of oats measured as tillers height, tiller number/unit area and leaf area index (LAI) revealed that all the treatments except biofertilizers brought about marked increase in all the growth attributes (Table 1). Nitrogen levels at 150 kg/ha maintained significantly higher number of tillers (165.0 and 137.2), tiller height (68.4 and 94.7 cm) and LAI (7.93 and 10.08) at both the cut stages. Similar trend was also followed by 100 and 50 kg N/ha when compared with their respective lower doses. Increased growth attributes due to increasing N levels might be due to adequate availability of N to the crop that being a constituent of amino acids and chlorophyll enhanced the chlorophyll formation leading to increased photosynthetic activity with the eventual improvement in the growth attributes. Increase in growth attributes of fodder oats with increase in N levels was also reported by Singh and Dubey (2007). Seed treatment with *Azotobacter* did not cause any

Table 1. Growth attributes, fodder and crude protein yields and nutrient uptake as influenced by treatment variables (pooled data of 2 years)

Treatment	Number of tillers/ m row		Tiller height (cm)		Leaf area index		Fodder yield t/ha		Crude protein yield (kg/ha)	Nutrient uptake (kg/ha)		
	Ist cut	IInd cut	Ist cut	IInd cut	Ist cut	IInd cut	Green	Dry		N	P	K
N levels (kg/ha)												
0	121.0	111.5	57.0	72.5	4.12	6.74	26.6	6.23	517.7	82.8	19.5	42.4
50	142.1	117.7	61.3	80.2	4.87	8.07	35.8	8.43	717.0	114.7	28.8	60.3
100	150.3	129.8	65.5	89.8	6.02	9.06	44.0	10.34	906.7	145.1	39.2	71.3
150	165.0	137.2	68.4	94.7	7.93	10.08	47.3	11.13	988.7	158.2	42.6	79.0
SEm±	4.3	3.7	3.0	2.3	0.26	0.35	1.26	0.29	25.2	4.01	1.03	2.11
CD (P=0.05)	8.7	7.5	6.1	4.8	0.53	0.71	2.52	0.58	50.2	8.01	2.07	4.21
*Biofertilizer**												
Uninoculated	142.1	122.4	62.4	83.1	5.65	8.41	37.4	8.77	756.1	120.9	30.9	60.9
Inoculated	147.1	125.7	63.8	85.5	5.81	8.56	39.5	9.29	809.0	129.4	34.2	65.6
SEm±	3.0	2.6	2.1	1.7	0.18	0.24	0.89	0.21	17.8	2.84	0.73	1.49
CD (P=0.05)	NS	NS	NS	NS	NS	NS	1.78	0.41	35.5	5.66	1.46	2.97
Sheep manure (t/ha)												
0	138.4	119.3	60.6	78.3	5.29	8.00	34.8	8.13	692.5	110.8	28.6	57.2
10	150.8	128.8	65.6	90.3	6.17	8.97	42.1	9.93	872.4	139.5	36.5	69.3
SEm±	3.0	2.6	2.1	1.7	0.18	0.24	0.89	0.21	17.8	2.84	0.73	1.49
CD (P=0.05)	6.2	5.3	4.3	3.4	0.37	0.50	1.78	0.41	35.5	5.66	1.46	2.97

**Azotobacter chroococcum*

marked increase in the number of tillers, tiller height and LAI at both the cut stages when compared with uninoculated control. Application of sheep manure brought about significant increase in tiller number (150.8 and 128.8), tiller height (65.6 and 90.3) and LAI (6.17 and 8.97) at both the cut stages over control. This increase was to the tune of 8.96 and 7.96% in number of tillers, 8.25 and 15.3% in tiller height and 16.6 and 12.1% in LAI over control at first and second cuts, respectively. The favourable effect of sheep manure on growth attributes of crop might be attributed to increased supply of major and micro nutrients and increase in the activities of heterotrophic bacteria and fungi in soil, which in turn increased the activity of enzymes, responsible for conversion of unavailable form of nutrients to available form leading to higher nutrient uptake and improvement in crop growth attributes. Singh and Dubey (2008) also reported improvement in the growth of oat due to application of FYM and *Azotobacter* inoculation.

Forage yields and quality

Application of N, *Azotobacter* inoculation and sheep manure markedly influenced the green fodder, dry matter and crude protein yields in both the years (Table 1). Highest dose of nitrogen (150 kg/ha) recorded maximum green fodder, dry matter and crude protein yields, which proved significantly superior to the yields obtained with lower levels of nitrogen and control. The corresponding increase of 7.50, 32.1 and 77.8% in green fodder, 7.64, 32.0 and 78.6% in dry matter and 9.04, 37.9 and 91.0% in crude protein yields was observed with 150 kg N/ha over 100 kg, 50 kg N/ha and control respectively. Increased green fodder and dry matter yields may be attributed to the improvement in the growth attributes due to N application. While increase in crude protein yield may be because of N sufficiency under increased rates of N, which proved instrumental in activating the growth, regenerative growth and N uptake by the plants. Increase in green fodder, dry matter and crude protein yields with increased levels of nitrogen were also reported by Singh *et al.* (1997), Sharma and Verma (2005) and Bhilare and Joshi (2007).

Seed inoculation with *Azotobacter* significantly increased the green fodder, dry matter and crude protein yields and the extent of increase was to the tune of green fodder by 5.61%, dry matter by 5.93% and crude protein by 7.00% over uninoculated control. Increased fodder yield seems to be the function of improved growth attributes under *Azotobacter* inoculation, while improvement in sheep protein might be due to combined effect of higher dry matter yields and slight increase in N content of the plants due to increase in N mineralization in the soil and greater uptake by plants. The beneficial effect of *Azotobacter* inoculation was also reported by Das *et al.* (1995) for crude protein.

Application sheep manure @ 10 t/ha significantly increased the green fodder (42.1 tonnes/ha), dry matter (9.93 tonnes/ha) and crude protein (872.0 kg/ha) yields over control. The magnitude of increase was to the tune of 21.0, 22.1 and 26.0%, respectively over control. It showed that organic manure has stimulatory effect on efficiency of chemical fertilizers and mitigates micronutrient deficiency besides supplying major nutrients and improving the physico-chemical properties of soil. Singh and Dubey (2008) also reported enhanced fodder yield of oats due to *Azotobacter* inoculation and addition of FYM.

The interaction effect of nitrogen and sheep manure was also found significant for dry matter and crude protein yields (Table 2). N levels increased the dry matter and CP yields significantly at each levels of sheep manure. Dry matter yield recorded at 150 kg N/ha + 10 t sheep manure/ha being on par with 150 kg N/ha alone and 100 kg N/ha + 10 t sheep manure/ha was significantly higher over rest of the N levels with or without sheep manure. While in case of CP yield, the difference in yields at 100 or 150 kg N/ha along with 10 t sheep manure/ha were statistically at par but significantly greater than rest of the N levels with or without sheep manure application. Such results are obvious as application of fertilizers N in combination with organic manure is known to improve various physico-chemical properties of soil resulting in enhanced growth and nutrients uptake for higher and quality herbage pro-

Table 2. Interaction effect of nitrogen and sheep manure on dry matter, crude protein yield and net returns

Sheep manure (t/ha)	N levels (kg/ha)			
	0	50	100	150
Dry matter yield (t/ha)				
0	4.85	7.31	9.63	10.74
10	7.61	9.54	11.07	11.51
SEm±		0.41		
CD (P=0.05)		0.82		
Crude protein yield (kg/ha)				
0	395.4	615.2	829.1	930.6
10	640.0	818.7	984.2	1046.9
SEm±		35.6		
CD (P=0.05)		71.0		
Net returns ($x10^3$ Rs/ha)				
0	2.6	11.5	21.3	25.7
10	6.8	14.1	19.7	20.9
SEm±		1.2		
CD (P=0.05)		2.5		

Pooled data of 2 years

duction. Similar results were also reported by Singh and Dubey (2007) for fodder yields of oat.

Nutrient uptake

There was no significant improvement in N content due to nitrogen application and N, P and K contents of fodder due to sheep manure application. Each increase in nitrogen application significantly influenced the N, P and K uptake upto the highest level of 150 kg/ha (Table 1). The maximum nutrient uptake (N 158.2 kg/ha, P 42.6 kg/ha and K 79.0 kg/ha) recorded at 150 kg N/ha were higher to the tune of 9.03, 37.9 and 91.1% in N, 8.67, 47.9 and 118.5% in P and 10.8, 31.0 and 86.3% in K uptake over 100, 50 and 0 kg N/ha, respectively. Higher N uptake may be attributed to the beneficial effect of nitrogen sufficiency in the soil solution and higher dry matter yields leading to improved N uptake to a significance level. Similar results were also reported by Singh *et al.* (1996). *Azotobacter* inoculation increased the N (8.5 kg/ha), P (3.3 kg/ha) and K (4.7 kg/ha) uptake to a significant levels and increase was to the tune of 7.03, 10.7 and 7.72%, respectively over uninoculated control. Increased uptake of nutrients with *Azotobacter* inoculation may be a combined effect of higher dry matter production and creation of proper environment by bacteria for uptake of various plant nutrients. Application of sheep manure significantly increased the N (28.7 kg/ha), P (7.9 kg/ha) and K (12.1 kg/ha) uptake by 25.6, 27.6 and 21.1%, respectively over control. The uptake of nutrients was associated mainly with high crop yields and comparatively higher concentration of nutrients in above ground portion of biomass due to addition of sheep manure in soil.

N - use efficiency

On the basis of mean dry matter yields of 2 years, agronomic N-use efficiency (ANUE) and physiological N-use efficiency (PNUE) were worked out and it was observed that all the treatment variables recorded reverse trend (Table 3). The maximum values of ANUE (43.9 kg dm/kg N applied) and PNUE (68.7 kg dm/kg N uptake) were observed with lowest dose of nitrogen (50 kg/ha) and these were gradually decreased with each increase in N levels. The minimum values of ANUE (32.7 kg dm/kg N applied) and P-NUE (64.7 kg dm/kg N uptake) were recorded with 150 kg N/ha. Decreased trend in ANUE and PNUE might be due to proportionately lower increase in dry matter yields at higher rates than the increase in N applied and uptake. Similarly, seed inoculation with biofertilizer and application of sheep manure recorded comparatively lower values of ANUE (39.0 and 33.1 kg dm/kg N applied) and PNUE (66.0 and 69.3 kg dm/kg N uptake) than their respective control (ANUE 39.5 and 45.5 kg dm/kg N applied and PNUE 67.3 and 69.3 kg dm/kg N uptake). Decreased values of ANUE in treated plots with *Azotobacter* and sheep manure application was the function of higher dry matter yields of oats in control (no nitrogen) and treated plots than untreated (control i.e. nitrogen alone) plots, which reduced the differences in dry matter yields at different levels of N application, while divisor (N applied) was the same in both conditions. Similarly, higher N uptake and lower differences in dry matter yield under the treatment of *Azotobacter* inoculation and sheep manure application decreased the values of P NUE than their respective control.

Response function

The relationship between dry matter yield of fodder oats at different levels of N was studied from mean data of 2 years by fitting response equations. The response equations were:

$$Ys_0 = 4790.0 + 60.32\,x - 0.136x^2 \quad (r^2 = 0.9971)$$
$$Ys_{10} = 7567.5 + 48.85\,x - 0.149\,x^2 \quad (r^2 = 0.9977)$$

Where, Ys_0 and Ys_{10} are dry matter yields (kg/ha) with out sheep manure and with sheep manure, respectively and x is dose of nitrogen in kg.

The response of nitrogen with the application of sheep manure in relation to dry matter yield was quadratic and the optimum economic dose of N, maximum yield dose of N and maximum expected yields worked out were 149.3 kg/ha, 163.9 kg N/ha and 11.57 t/ha, respectively.

Energetics

Computation of energy input, energy ratio, energy productivity and energy responsiveness showed that although highest energy responsiveness (8.32 MJ/Re) was recorded at 150 kg N/ha, but 100 kg N/ha registered highest values of energy ratio (8.26) and energy productivity (458.9 g/MJ) (Table 3). It might be due to proportionately lower increase in dry matter yields at highest dose of nitrogen in comparison with input energy used. *Azotobacter* inoculation increased the values of energy ratio, energy productivity and energy responsiveness to the extent of 5.0 to 6.0% over uninoculated control. Sharma and Verma (2005) also reported higher values of energetics due to N application and *Azotobacter* inoculation. However, application of sheep manure increased the energy ratio by 6.90% and energy productivity by 6.92% but energy responsiveness was decreased by 10.32% over control due to comparatively higher cost involved on sheep manure than increase in dry matter yields.

Economics

Nitrogen application proved instrumental and every increase in rate of nitrogen brought about corresponding increase in net returns and net benefit: cost (B:C) ratio. Maximum values of net returns (Rs 23,285/ha) and net B:C ratio (1.00) were recorded with highest dose of nitrogen viz., 150 kg/ha followed by 100 kg/ha and minimum values of above traits were obtained with control. *Azotobacter* inoculation increased the value of net returns by Rs 1,849/ha (12.8%) and net B:C ratio by 0.09 (14.5%) over control. Higher net returns and return per rupee invested due to N application and *Azotobacter* inoculation were also reported by Sharma and Verma (2005). Although, application of sheep manure @10 t/ha increased the net returns by 0.65% (Rs 64/ha) but value of net B: C ratio was decreased by 25.0% (0.19) over control. Decrease in net B:C ratio was because of higher cost involvement on account of sheep manure application, whereas the increase in monetary returns was not in same proportion. Interaction effect of nitrogen and sheep manure for net returns was also significant (Table 2) and results showed that N application upto the level of 50 kg/ha along with sheep manure @ 10 t/ha was beneficial and recorded significantly higher net returns over 50 kg N/ha alone. But, thereafter sheep manure applied with 100 kg N/ha was statistically at par as recorded with 100 kg N/ha alone. However, 150 kg N/ha + sheep manure recorded statistically lower net returns than 150 kg N/ha without sheep manure. It was mainly because of comparatively lower increase in fodder yields when compared with cost involved on sheep manure application.

Residual soil fertility

Different treatments, particularly nitrogen and sheep manure have brought about substantial changes in post-harvest residual organic carbon, available N, P and K contents from their initial soil test values (Table 3). Highest dose of nitrogen (150 kg/ha) recorded significantly higher organic carbon (0.27%) and available N (144.3 kg/ha) over lower levels of nitrogen except 100 kg N/ha, where differences were not significant. The improvement in organic carbon and available N due to application of 150 kg N/ha was to the tune of 14.8 and 12.4% respectively over control. It might be due to combined effect of increased mineralization of organic matter at higher doses of N in the soil, which increased the available N and partial absorption by plant due to early harvest for fodder purpose at lush green stage resulted higher OC and N content in

Table 3. Economics (× 10^3 Rs/ha), energy relationships, nitrogen use efficiency and residual soil fertility as influenced by treatment variables (mean data of 2 years)

Treatment	Economics*			Energy relationships				N-use efficiency		Residual soil fertility			
	Cost of cultivation	Net returns	Net B:C ratio	Energy input (x103 MJ/ha)	Energy ratio	Energy productivity (g/MJ)	Energy responsiveness (MJ/Re)	ANUE (kg dm/ kg N applied	PNUE (kg dm/ kg N uptake)	OC (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Nitrogen level (kg/ha)													
0	22.1	4.7	0.20	16.6	6.77	376.3	5.07	-	-	0.237	128.4	8.80	164.4
50	23.0	12.8	0.56	19.6	7.76	431.1	6.60	43.9	68.7	0.245	134.9	8.98	163.8
100	23.5	20.5	0.90	22.6	8.26	458.9	7.92	41.2	66.0	0.264	141.4	9.06	164.9
150	24.1	23.3	1.00	25.6	7.84	435.5	8.32	32.7	64.7	0.272	144.3	8.91	165.6
SEm±		0.88	0.04							0.007	1.32	0.18	1.44
CD (P=0.05)		1.80	0.08							0.014	2.69	NS	NS
Biofertilizer													
B0	23.1	14.4	0.62	21.1	7.50	416.5	6.83	39.5	67.3	0.254	137.5	8.82	164.9
B1	23.3	16.3	0.71	21.1	7.93	440.3	7.18	39.0	66.0	0.256	137.0	9.05	163.3
SEm±		0.62	0.03							0.005	0.93	0.13	1.02
CD (P=0.05)		1.27	0.06							NS	NS	NS	NS
Sheep manure (t/ha)													
0	19.6	15.3	0.76	21.1	6.95	386.1	7.46	45.5	69.3	0.235	133.3	8.36	157.8
10	26.7	15.4	0.57	24.1	7.43	412.8	6.69	33.1	63.3	0.275	141.3	9.52	170.4
SEm±		0.62	0.03							0.005	0.93	0.13	1.02
CD (P=0.05)		NS	0.06							0.010	1.93	0.26	2.08

* Price of green fodder, Rs 1,000/t; Sheep manure, Rs 600/t; Nitrogen, Rs 10.87/kg; labour wages – Rs. 107/manday

soil. Available P and K content did not vary significantly due to N application. *Azotobacter* inoculation did not exert any pronounced effect on soil fertility. There was a significant improvement due to sheep manure application in soil organic carbon (0.04%), and available N (8.0 kg/ha), P (1.16 kg/ha) and K (12.6 kg/ha) status to the extent of 17.8, 6.0, 13.9 and 7.98% respectively over control. The improvement in fertility status due to sheep manure application could be attributed to addition of organic matter and increased activity of micro-organisms leading to higher mineralization of applied and inherent plant nutrients in soil.

Thus, considering the fodder yield, quality, economic evaluation and soil physico-chemical properties of soil, fodder crop of oats may be fertilized with 100 kg N/ha along with *Azotobacter chroococcum* inoculation and application sheep manure @ 10 t/ha for realizing higher and economical fodder productivity of multi-cut oats in hot arid region of Rajasthan.

REFERENCES

Bhilare, R.L. and Joshi, Y.P. 2007. Productivity and quality of oat (*Avena sativa*) in relation to cutting management and nitrogen levels. *Indian Journal of Agronomy* **52**: 247–250.

Das, Bhagwan., Sheoran, R.S. and Das, B. 1995. Effect of nitrogen and biofertilizer application on the quality of oats fodder. *Crop Research* **9**: 93–95.

Panesar, S.B. and Bhatnagar, A.P. 1987. Energy norms for input and output of agricultural sector. In: *Proceedings of National Conference on Energy in Production Agriculture and Feed Processing*, 30-31 October held at Punjab Agricultural University, Ludhiana. pp. 8-26.

Rao, D.L.N. 1975. Soil Micro-organism and Plant Growth (Subbarao, N.S. Ed.). Oxford and IBH Pub.Co. New Delhi.

Sharma, K.C. and Verma, R.S. 2004. Effect of chemical and biofertilizers on growth behaviour of multicut fodder oats (*Avena sativa* L.). *Range Management and Agroforestry* **25**: 57–60.

Sharma, K.C. and Verma, R.S. 2005. Effect of N and P fertilizers and bio fertilizers on the yield, marginal rate of return, energy relationship, economics and residual effect on soil in fodder oats (*Avena sativa* L.). *Forage Research* **31**: 118–122.

Singh, G.S., Behra, B.D., Prasad, G. and Dash, B. 1996. Effect of nitrogen and biofertilizers on yield, economics and forage quality in oats (*Avena sativa*). *Environmental Ecology* **14**: 238–239.

Singh, K.N., Bali, Amarjeet Singh., Hasan, B., Shah, M.H., Bali, A.S. and Khan, A.U. 1997. Effect of seed rate and nitrogen on biomass production and quality of oats (*Avena sativa*). *Indian Journal of Agronomy* **42**: 310–312.

Singh, S.D. and Dubey, S.N. 2007. Soil properties and yield of fodder oat (*Avena sativa* L.) as influenced by sources of plant nutrient and cutting management. *Forage Research* **33**: 101–103.

Singh, S.D. and Dubey, S.N. 2008. Efficiency of *Azotobacter* to enhance the growth and yield of fodder oats (*Avena sativa* L.) under different levels of nitrogen and FYM. *Forage Research* **34**: 116–118.