



Growth and yield performance of fodder oats (*Avena sativa*) grown under different nutrient management practices

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ABSTRACT

The present experiment was conducted to study residual effect of three maize (*Zea mays* L.) varieties on oats (*Avena sativa* L.) (V₁: African Tall, V₂: J-1006; V₃: P-3396) and four nutrient management practices (N₀: Control; N₁: 100% RDF; N₂: 75% RDF + PGPR + Panchagavya spray; N₃: 50% RDF + 25% FYM + PGPR + Panchagavya spray) using split plot design. Results showed that residual effect of maize varieties on oats were found to be non-significant for different growth attributes and green fodder yield. Nutrient management practices caused significant variations on growth as well as green fodder yield. Significantly better growth in terms of plant height, number of leaves, leaf length, leaf width, stem girth, number of tillers, CGR as well as RGR at both cuts were recorded with application of 75% RDF + PGPR + Panchagavya spray (N₂) compared with control (N₀) and 100% RDF (N₁). The use of 75% RDF + PGPR + Panchagavya spray recorded significantly highest green fodder yield and production efficiency among all nutrient management practices. Our results indicate that integrated use of organic and inorganic nutrient sources (N₂) enhances the productivity of fodder oats, besides reducing 25% dose of chemical fertilizers which can sustain the crop productivity.

Keywords: CGR, Green fodder yield, Oats, Panchagavya, PGPR

Cereal crops are well known for higher productivity in terms of green biomass. Oats (*Avena sativa* L.) among cereals is an important nutritious fodder crop grown during *rabi* season in India (Kumar *et al.* 2018). It is grown in North, Central and Western zone of the country. The total area covered under oats cultivation in the country is about 0.5 Mha (Pandey and Roy 2011). The green forage of oats is a good source of protein, fibre and minerals. It is used as fresh fodder, feed and straw, but can also be used as silage/ hay during fodder deficit periods. Its green fodder is relished by all animals owing to its higher palatability and softness than wheat and barley (Hameed *et al.* 2014). Being a cereal, adequate nutrient management is essential for oats because it plays a key role in improving productivity. Oats are grown after *kharif* maize (cereal–cereal cropping sequence) which necessitates the judicious use of organic and inorganic sources of nutrients for sustainable crop production (Kumar *et al.* 2021). Indiscriminate and continual use of

higher dose of chemical fertilizers for cereal fodder creates harmful effect, viz. inadequacy in one/more micronutrients which leads to drop in productivity. The use of only organic sources may not be sufficient to meet nutrient requirements of cereal–cereal cropping sequence. Integrated nutrient management helps in increasing crop productivity (Kumar *et al.* 2022). Inclusion of organic manures has resulted in significant increase in crop productivity (Bandyopadhyay *et al.* 2010). FYM is one of the most preferred components of organic manures to which farmers have access in mixed farming system. Plant growth promoting rhizobacteria (PGPR) is a good alternative for nutrient management in modern agriculture. Apart from it, panchagavya which contains essential nutrients (Kumar *et al.* 2021, 2022), growth regulatory substances and beneficial microbes, has capacity to promote the plant growth and provide immunity within plant systems. Hence, the combined use of organic, viz. FYM, PGPR, panchagavya and inorganic inputs (chemical fertilizer) may be a better nutrient management approach for sustainable fodder production under Indian condition. Keeping this in view, the present study was done to study the effect of maize varieties and nutrient management practices on oats.

MATERIALS AND METHODS

Site: The experiment was laid out during *rabi* season of 2018–19 and 2019–20 at Research Farm of Agronomy

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Section, ICAR-National Dairy Research Institute, Karnal (India). Karnal is located at 29°43' N latitude, 76°58' E longitude and 245 m above mean sea level. The soil of experimental field had pH 7.61, 0.312 dS/m electrical conductivity, 0.63% organic carbon, 192.4 kg/ha available N, 29.71 kg/ha available P and 195.7 kg/ha available K.

Experimental design, treatments and crop management:

The experiment was conducted in split plot design with three replications. In main plot, the residual effect of three maize cultivars on oats cv. Kent (V_1 : African Tall; V_2 : J-1006; V_3 : P-3396) and in sub-plot, four nutrient management practices (N_0 : Control; N_1 : 100% RDF; N_2 : 75% RDF + PGPR + Panchagavya spray; N_3 : 50% RDF + 25% FYM + PGPR + Panchagavya spray) were studied. Recommended dose of FYM was applied @10.0 t/ha at the time of sowing (as per respective treatments). Recommended dose of N, P_2O_5 and K_2O were applied @120, 40 and 40 kg/ha through urea, single super phosphate and muriate of potash, respectively. One third of N and full dose of P_2O_5 and K_2O was applied as basal and remaining two third of N was applied in two equal amounts at 32 DAS and three days after first cut. Panchagavya was prepared and applied at 25, 40 and 85 DAS through foliar spray. Seed rate of 80 kg/ha was taken and treated with Bavistin 50% WP @2 g a.i./kg seeds followed by PGPR (as per treatment) @120 ml/ha seeds. After shade drying around half an hour, the seeds were sown using *Pora* method.

Measurement of crop growth attributes and yield:

The growth attributes, viz. plant height, number of leaves, leaf length, leaf width, stem girth and number of tillers

per running metre row length were measured at 30 DAS, at first and second cut. Leaf to stem ratio was measured only at first cut. Green fodder yield (GFY) was recorded plot wise and converted into hectare basis. The increase in plant biomass per unit area and time or cumulative crop growth rate (CGR) and relative increment in growth rate of crop (RGR) were calculated as per equation given by Radford (1967).

$$CGR \left(\frac{g}{m^2/day} \right) = \frac{1}{P} \times \frac{(W_2 - W_1)}{(t_2 - t_1)}$$

$$RGR \left(\frac{mg}{g/day} \right) = \frac{(\log_e W_2 - \log_e W_1)}{(t_2 - t_1)}$$

Where, P = Unit land area (m^2); W_1 = Total dry matter of crop plant (g) at the time interval t_1 (days); W_2 = Total dry matter of crop plant (g) at the time interval t_2 (days)

The production efficiency was calculated by dividing GFY to number of crop duration in days which is as follow:

$$\text{Production efficiency (q/ha/day)} = \frac{\text{GFY (}\text{₹q/ha})}{\text{Crop duration (days)}}$$

Statistical data analysis: Experimental data were analyzed with the help of analysis of variance technique for split plot design using statistical analysis system software at ICAR-Indian Agricultural Statistics Research Institute server. Significance among treatments mean differences for various parameters were analyzed by least significant differences at $P=0.05$.

Table 1 Characteristics of FYM and Panchagavya used for experimentation during 2018–19 and 2019–20

Parameter	FYM		Panchagavya	
	2018–19	2019–20	2018–19	2019–20
pH _{1:5}	8.25 ± 0.01	8.31 ± 0.01	4.35 ± 0.04	4.28 ± 0.05
EC _{1:5} (dS/m)	3.40 ± 0.08	3.36 ± 0.12	6.14 ± 0.06	6.21 ± 0.05
Oxidizable OC (%)	11.25 ± 0.09	11.72 ± 0.07	—	—
Total carbon (%)	20.78 ± 0.28	20.85 ± 0.19	—	—
Total N (%)	0.62 ± 0.07	0.69 ± 0.08	0.64 ± 0.01	0.65 ± 0.02
Total P (%)	0.45 ± 0.01	0.46 ± 0.02	0.10 ± 0.01	0.10 ± 0.01
Total K (%)	0.82 ± 0.02	0.85 ± 0.03	0.47 ± 0.03	0.46 ± 0.02
Ca (g/kg)	27.35 ± 0.15	27.57 ± 0.13	121 ± 4.85	127 ± 5.95
Mg (g/kg)	11.79 ± 0.34	12.02 ± 0.42	42 ± 2.54	45 ± 2.35
Fe (g/kg)	3.21 ± 0.02	3.28 ± 0.03	8.75 ± 0.12	8.83 ± 0.10
Zn (mg/kg)	205.3 ± 8.34	221.4 ± 10.24	1.05 ± 0.02	1.04 ± 0.01
Mn (mg/kg)	323.0 ± 6.05	332.7 ± 6.38	1.48 ± 0.02	1.52 ± 0.04
Cu (mg/kg)	52.6 ± 1.35	57.3 ± 1.51	0.62 ± 0.01	0.59 ± 0.01
Total Bacteria ($\times 10^5$ CFU/ml)	—	—	38.2 ± 1.45	40.6 ± 2.18
Total Fungi ($\times 10^3$ CFU/ml)	—	—	25.6 ± 1.52	26.8 ± 1.05
Total Actinomycetes ($\times 10^2$ CFU/ml)	—	—	18.8 ± 1.12	19.0 ± 1.39
Azotobacter ($\times 10^2$ CFU/ml)	—	—	7.0 ± 0.65	7.4 ± 0.42
P solubilizers ($\times 10^2$ CFU/ml)	—	—	8.2 ± 0.38	8.0 ± 0.56

RESULTS AND DISCUSSION

Plant height: Results (Table 1) revealed that plant height of oats was not influenced significantly by residual effect of maize varieties. Though, nutrient management practices significantly influenced the plant height. The use of N_1 , N_2 and N_3 practices significantly enhanced the plant height at 30 DAS, first and second cut over control. At 30 DAS, N_2 , N_1 and N_3 practices performed statistically similar. At first cut, N_2 practice showed significantly higher plant height as compared to N_1 and N_3 . While at second cut, N_2 was statistically at par with N_3 practice and found superior over N_1 .

Number of leaves/plants: Data (Table 1) revealed that residual effect of maize varieties had non-significant effect on number of leaves of oats. Whereas, nutrient management practices caused significant effect on this attribute. Application of N_1 and N_2 showed statistically higher number of leaves at 30 DAS over N_0 , but remained at par with N_3 . At first cut, N_2 treatment was at par with N_1 and resulted in significantly higher number of leaves compared to N_3 and N_0 . While at second cut, application of N_2 practice remained at par with N_3 and showed higher number of leaves than N_1 and N_0 .

Leaf length: Residual effect of maize varieties on oats was found to be non-significant for leaf length (Table 1). Though, application of 100% RDF (N_1) as well as N_2 and N_3 caused significant improvement in leaf length at all studied stages of fodder oats over control. At 30 DAS, the use of N_1 , N_2 and N_3 practices remained statistically similar and higher over N_0 . At first cut, N_2 practice was observed with significantly increased leaf length than remaining treatments. However, at second cut, application of N_2 practice was statistically at par with N_3 and observed

higher values over N_1 and N_0 .

Leaf width: Results indicated that residual effect of maize varieties did not show any significant effect on leaf width of oats at all studied stages (Table 2). However, nutrient management practices brought significant variations on leaf width at first and second cut. Nutrient applied treatments (N_1 , N_2 and N_3) caused significant improvement in leaf width over control. At first cut, N_2 practice resulted into significantly highest leaf width among all. Whereas at second cut, N_2 and N_3 practices were at par with each other and recorded significantly higher leaf width over N_1 and N_0 .

Stem girth: Results showed that stem girth of fodder oats did not varied significantly by residual effect of maize varieties at 30 DAS, first and second cut (Table 2). Nevertheless, nutrient management practices caused significant differences on this growth attribute, at all sequential periodical observations. At 30 DAS and first cut, the application of N_1 , N_2 and N_3 practices were noted statistically similar and higher over N_0 . While at second cut, the imposition of N_1 , N_2 and N_3 practices also brought significant enhancement in stem girth compared to N_0 . At this stage, N_2 practice was at par with N_3 and observed higher values over N_1 and N_0 .

Leaf: stem ratio: Data presented in Table 2 indicates that leaf: stem ratio of fodder oats at first cut is not influenced significantly by residual effect of maize varieties. However, nutrient management practices have succeeded to cause significant effect on leaf: stem ratio at first cut. Application of N_1 , N_2 and N_3 practices were found statistically similar to each other and higher over N_0 . Imposition of N_1 , N_2 and N_3 practices produced 5.2, 5.7 and 4.8% higher leaf: stem ratio over control.

Number of tillers: Results indicated that number of

Table 1 Plant height, number of leaves and leaf length of fodder oats as influenced by residual effect of maize varieties and nutrient management practices

Treatments	Plant height (cm)			Number of leaves per plant			Leaf length (cm)		
	30 DAS	I Cut	II Cut	30 DAS	I Cut	II Cut	30 DAS	I Cut	II Cut
<i>Residual effect of maize varieties on oats cv. Kent</i>									
African Tall	48.39	132.0	101.9	16.12	94.51	61.74	32.04	57.18	49.87
J-1006	46.61	125.9	96.2	15.63	91.42	59.25	31.14	54.76	47.05
P-3396	47.13	129.2	97.5	15.84	93.68	60.32	31.65	56.06	47.65
SEd ($\pm$)	1.55	3.7	3.6	0.39	2.01	1.95	0.95	1.23	1.58
LSD ($P=0.05$)	NS	NS	NS	NS	NS	NS	NS	NS	NS
<i>Nutrient management practices</i>									
N_0	40.18 ^B	90.2 ^C	73.5 ^C	15.05 ^B	71.98 ^C	49.19 ^C	28.13 ^B	41.52 ^C	36.27 ^C
N_1	49.39 ^A	139.9 ^B	102.6 ^B	16.34 ^A	99.58 ^{AB}	61.19 ^B	33.32 ^A	59.97 ^B	50.34 ^B
N_2	50.99 ^A	147.4 ^A	111.1 ^A	16.27 ^A	103.17 ^A	66.94 ^A	33.13 ^A	62.55 ^A	54.10 ^A
N_3	48.94 ^A	138.7 ^B	107.0 ^{AB}	15.79 ^{AB}	98.10 ^B	64.41 ^{AB}	31.86 ^A	59.96 ^B	52.04 ^{AB}
SEd ($\pm$)	1.01	2.1	3.1	0.43	1.74	1.58	0.80	0.86	1.09
LSD ($P=0.05$)	2.12	4.4	6.4	0.90	3.65	3.32	1.67	1.82	2.28

Note: N_0 , Control; N_1 , 100% RDF; N_2 , 75% RDF + PGPR + Panchagavya spray; N_3 , 50% RDF + 25% FYM + PGPR + Panchagavya spray; Same letter within each column indicates non-significant difference among treatments using LSD test ($P<0.05$).

Means of two years.

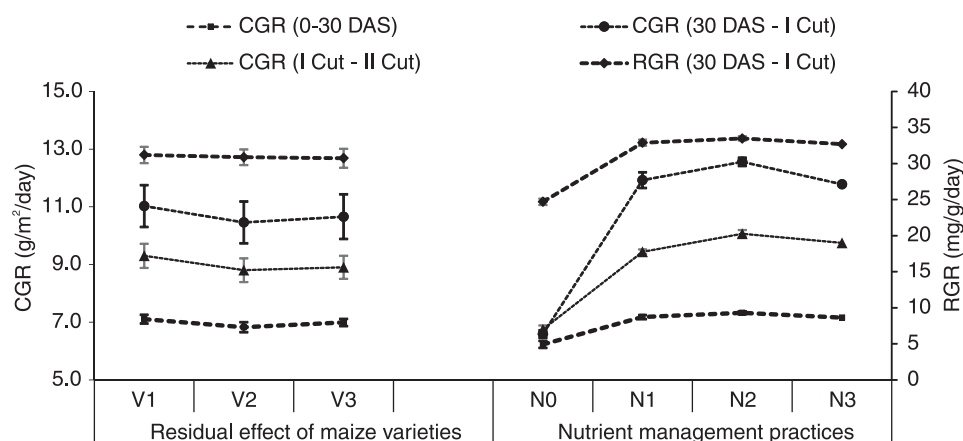


Fig 1 Crop growth rate and relative growth rate of fodder oats as influenced by residual effect of maize varieties and nutrient management practices (mean of two years).

Note, V₁, African Tall; V₂, J-1006; V₃, P-3396; N₀, Control; N₁, 100% RDF; N₂, 75% RDF + PGPR + Panchagavya spray; N₃, 50% RDF + 25% FYM + PGPR + Panchagavya spray; CGR, Crop growth rate; RGR, Relative growth rate; Capped lines indicate the standard error of mean.

tillers per meter row length of oats counted at 30 DAS, first and second cut remained unaffected statistically due to residual effect of maize varieties (Table 3). Though, nutrient management practices produced significant influence on number of tillers at all the studied stages. At 30 DAS, the use of N₂, N₁ and N₃ practices with respective values of 32.7, 31.5 and 31.4 for number of tillers were observed at par with each other and noticed significantly higher compared to control. At first cut, N₂ practice was considerably higher among all. At second cut, N₂ practice was noticed at par with N₃ and proved remarkably better over N₁ and N₀.

second cut, N₂ practice was at par with N₃ and showed significantly higher CGR over N₁ and N₀. Likewise, the application of N₁, N₂ and N₃ practices significantly increased the RGR recorded during 30 DAS-first cut over N₀.

Green fodder yield and production efficiency: Data (Fig 2) indicates that green fodder yield (GFY) and production efficiency (PE) of oats are not affected significantly by residual effect of maize varieties. Though, different nutrient management practices cause significant variations on both these parameters. At first cut, significantly higher GFY were attained by using N₂ practice compared

Crop and relative growth rate: Results showed that crop growth rate (CGR) and relative growth rate (RGR) of fodder oats did not differ remarkably by residual effect of maize varieties (Fig 1). However, CGR significantly differed due to application of nutrient management practices. During 0-30 DAS growth span, N₁, N₂ and N₃ practices were observed statistically at par with each other and higher over N₀ with respect to CGR. During 30 DAS-first cut, N₂ practice was substantially higher amongst nutrient management practices. During first cut and

Table 2 Leaf width, stem girth, leaf to stem ratio and number of tillers of fodder oats as influenced by residual effect of maize varieties and nutrient management practices

Treatments	Leaf width (cm)			Stem girth (cm)			Leaf: stem ratio	Number of tillers per r.m.l.		
	30 DAS	I Cut	II Cut	30 DAS	I Cut	II Cut	I Cut	30 DAS	I Cut	II Cut
<i>Residual effect of maize varieties on oats cv. Kent</i>										
African Tall	0.94	1.84	1.78	0.75	1.50	1.65	0.713	30.5	105.2	75.7
J-1006	0.92	1.78	1.71	0.71	1.46	1.58	0.710	29.5	100.4	71.6
P-3396	0.94	1.80	1.75	0.72	1.47	1.60	0.720	29.7	102.2	72.7
SEd (±)	0.04	0.06	0.04	0.02	0.03	0.04	0.008	1.1	3.4	2.5
LSD (<i>P</i> =0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
<i>Nutrient management practices</i>										
N ₀	0.89	1.43 ^C	1.39 ^C	0.65 ^B	1.33 ^B	1.42 ^C	0.687 ^B	23.8 ^B	73.3 ^C	55.3 ^C
N ₁	0.95	1.92 ^B	1.79 ^B	0.76 ^A	1.49 ^A	1.63 ^B	0.723 ^A	31.5 ^A	109.0 ^B	76.0 ^B
N ₂	0.95	1.96 ^A	1.93 ^A	0.76 ^A	1.55 ^A	1.71 ^A	0.727 ^A	32.7 ^A	116.8 ^A	82.9 ^A
N ₃	0.94	1.91 ^B	1.88 ^A	0.74 ^A	1.53 ^A	1.67 ^{AB}	0.720 ^A	31.4 ^A	111.2 ^B	79.1 ^{AB}
SEd(±)	0.03	0.02	0.03	0.02	0.04	0.02	0.008	0.8	2.2	2.1
LSD (<i>P</i> =0.05)	NS	0.04	0.07	0.05	0.07	0.05	0.023	1.7	4.5	4.4

Note: N₀, Control; N₁, 100% RDF; N₂, 75% RDF + PGPR + Panchagavya spray; N₃, 50% RDF + 25% FYM + PGPR + Panchagavya spray; r.m.l., running meter row length; Same letter within each column indicate non-significant difference among treatments using LSD test (P<0.05).

Mean of two years.

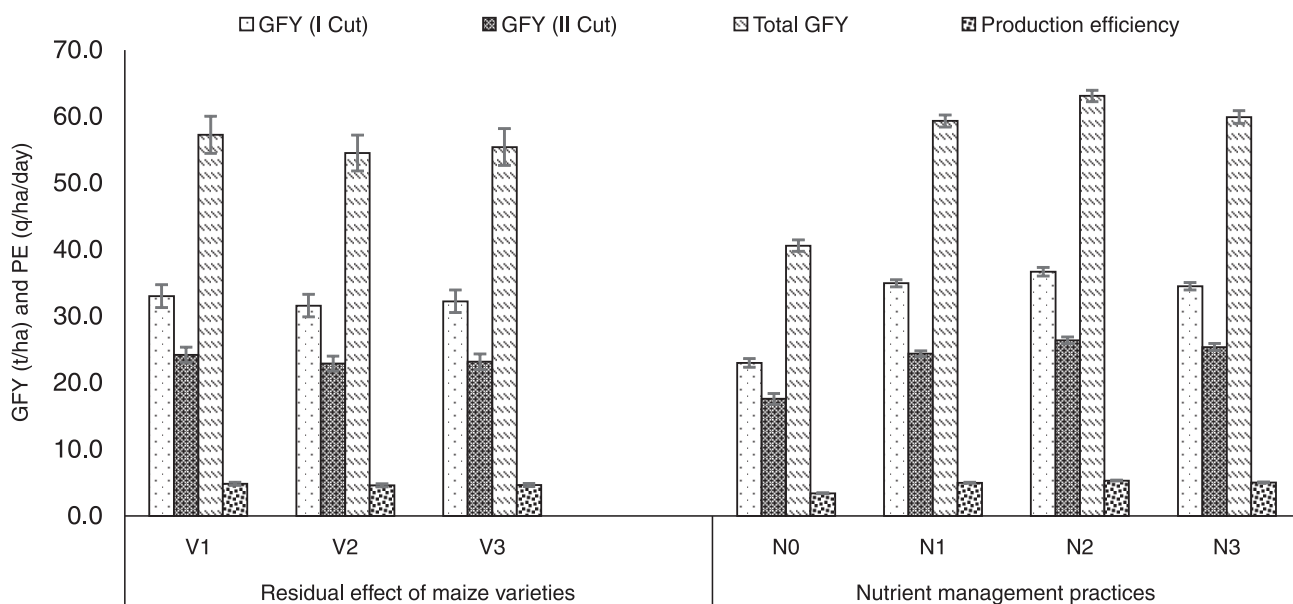


Fig 2 Green fodder yield and production efficiency of fodder oats as influenced by residual effect of maize varieties and nutrient management practices (mean of two years).

Note, V₁, African Tall; V₂, J-1006; V₃, P-3396; N₀, Control; N₁, 100% RDF; N₂, 75% RDF + PGPR + Panchagavya spray; N₃, 50% RDF + 25% FYM + PGPR + Panchagavya spray; GFY, Green fodder yield; PE, Production efficiency; Capped lines indicate the standard error of mean.

to other treatments. However, N₁ and N₃ practices are noticeably similar with respect to GFY at first cut. At second cut, application of N₂ practice produced significantly higher GFY over N₀ and N₁. Alike GFY at first cut, the total GFY of oats was considerably higher under N₂ practice than remaining treatments and N₁ and N₃ were statistically at par with each other. With respect to PE, application of N₂ practice showed significantly highest PE over N₃, N₁ and N₀. Though, N₁ and N₃ practices had statistically similar and higher PE over control.

The growth attributes as well as green fodder yield of oats were not influenced significantly due to residual effect of maize varieties which may be similar to the behavior of these varieties in rhizosphere conditions. Integrated use of organic and inorganic nutrient sources (N₂ and N₃) significantly increased all the growth attributes, except leaf width at 30 DAS. It might be due to better crop nutrition as well as production of phytohormones which makes favorable condition for crop growth by atmospheric nitrogen fixation as well as making P, K and Zn available to the crops. IAA is believed to be associated with cell division, expansion and root initiation. In addition to this, foliar application of panchagavya enhanced the crop growth directly through supplying the nutrients. Our results are in close conformity with earlier findings of Devi *et al.* (2014) who reported that application of FYM and PGPR considerably enhanced the plant height, shoots per unit area as well as leaf to stem ratio of fodder oats. Kumawat *et al.* (2013) also reported that the increased chlorophyll content, nitrate reductase activity as well as plant nutrients due to foliar spray of panchagavya leads to higher crop growth and development of groundnut.

Significantly higher GFY at first, second cut and their total were obtained by applying the N₂ practice compared to rest of treatments, except at second cut where it remained statistically at par with N₃ practice. The higher green fodder yield with 75% RDF + PGPR + Panchagavya might be associated with increased plant height, number of tillers and leaf stem ratio. Application of FYM does not only supply essential nutrients, but also reduces the loss of N by forming organic-mineral complexes, thus leading to continuous N supply resulting in higher yields (Deva 2015). PGPR activates certain growth promoting enzymes which might have played vital role in boosting green fodder yield. Further, the higher NPK fertilization either from chemical fertilizers or panchagavya enhances the chlorophyll content which leads to increased photosynthates, protoplasmic constituents and accelerated cell division and elongation which ultimately results into luxuriant vegetative growth and green fodder yield. Similar results in green forage yield of oats due to integrated use of organic and inorganic nutrients sources were also reported by Bilal *et al.* (2017). Bhakar *et al.* (2021) also recommended the partial replacement of RDF by organic nutrient sources (PGPR or seaweed extract) to get higher root and shoot growth as well as green fodder yield of sorghum and guar.

Based on the present investigation, it can be concluded that integrated use of organic and inorganic nutrient sources (75% RDF + PGPR + Panchagavya spray) enhances the productivity of fodder oats, besides reducing 25% dose of chemical fertilizers which can sustain the crop productivity.

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