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Research Paper

Integrated use of organic and inorganic nutrient sources influences the nutrient content, uptake and nutrient use efficiencies of fodder oats (*Avena sativa*)

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ABSTRACT

A field experiment was carried out during the winter (*rabi*) seasons of 2018–19 and 2019–20 at Karnal, Haryana (India), to study the residual effect of maize (*Zea mays* L.) varieties and integrated nutrient-management practices on nutrient content, uptake and nutrient use efficiencies of fodder oats (*Avena sativa* L.). The experiment was laid out in split-plot design with 3 replications. In main plot, the residual effect of 3 maize varieties (V_1, 'African Tall'; V_2, 'J 1006'; V_3, 'P 3396') on oats and in subplot, 4 nutrient-management practices (N_0, Control; N_1, 100% RDF; N_2, 75% recommended dose of fertilizer (RDF) + plant growth-promoting bacteria (PGPR) + Panchagavya spray; N_3, 50% RDF + 25% FYM + PGPR + Panchagavya spray) were studied. Results showed that different maize varieties were found statistically ineffective in producing the residual effect on yield, nutrient content and uptake of fodder oats. Among the nutrient management practices, an application of 75% RDF + PGPR + Panchagavya spray resulted in significantly higher green fodder yield at I cut, II cut and total (36.7, 26.4 and 63.1 t/ha, respectively) as compared to the control and 100% RDF. Application of 75% RDF + PGPR + Panchagavya spray and 50% RDF + 25% FYM + PGPR + Panchagavya spray significantly enhanced the nutrient content and uptake of fodder oats over the control. The maximum nutrient-use efficiencies, viz. partial factor productivity (69.6 kg DM/kg NPK applied), agronomic efficiency (26.8 kg DM/kg NPK applied) and recovery efficiency (114.1%) were also found with the application of 75% RDF + PGPR + Panchagavya spray, while the least values of these efficiencies were noted under 100% RDF through chemical fertilizers. Overall, the application of 75% RDF + PGPR + Panchagavya spray may be recommended to enhance the yield, nutrient content, uptake and nutrient-use efficiencies of fodder oats, besides replacing 25% RDF through chemical fertilizers.

Key words: Agronomic efficiency, Green fodder yield, Nutrient uptake, Oats, Panchagavya

Oats has been cultivated from ancient times in many parts of the world, particularly in European countries. In India, oats is one of the most popular cereal fodders of winter season. It is grown in North, Central and Western zones of the country. It is widely grown for green fodder because of its luxuriant growth, good palatability, highly nutritious nature and rich in soluble carbohydrates and relished by all animals. At the present, India faces a net deficit of 35.6% green fodder (IGFRI, 2018). To meet the current deficit of fodder, it has to be met by improving productivity which may be possible through efficient nutrient-management practices.

Nutrient management is an important aspect of the Indian soil as it is deficient in several macro- and micronutrients. Intensive cereal – cereal cropping sequence necessitates the judicious use of organic and inorganic nutrient sources for sustainable crop production (Rathod *et al*., 2013). Indiscriminate and continual use of the higher dose of chemical fertilizers for cereal fodder creates harmful effect, viz. inadequacy in one or more micronutrients, which leads to drop in productivity and also adversely affects the soil health leading to various other problems (Kumar *et al*., 2021). It may also lead to drop in nutrient use efficiencies. Integrated use of organic and inorganic nutrient sources could be a better nutrient-management approach for sustainable agriculture. Inclusion of organic manures has resulted in significant increase in crop productivity (Bandyopadhyay *et al*., 2010). Farmyard manure (FYM) is one of the most preferred components of organic manures to which farmers have access in mixed farming

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system. For sustainable crop production, the soil organic matter and microbial activities which are crucial features in nutrient-management should be maintained (Johnston *et al*., 2009). Plant growth-promoting rhizobacteria (PGPR) boost the crop performance by colonizing plant roots (Kumar *et al*., 2021). The use of PGPR has been proven to be an environmentally sound approach for improving crop growth and yields by regulating hormonal and nutritional balance; and solubilizing nutrients (Vejan *et al*., 2016). Unlike other countries which rely on medium-to large-scale dairy farms, about 80% of the total livestock belong to small and marginal farmers with average herd size of 1–2 animals (Yes Bank, 2018). The dung produced by these cattle is insufficient for supplying plant nutrients and its urine also is not handled properly. If by-products of cow are converted to any valuable product, i.e. Panchagavya, which is rich in plant nutrients, could help in supplying adequate plant nutrients in crops. Panchagavya is a special preparation made up of 5 byproducts from cow, viz. dung, urine, milk, curd and *ghee*, along with certain other ingredients and contains many macro and micro nutrients (Kumar *et al*., 2021), growth- regulatory substances, viz. indole acetic acid (IAA), gibberellic acid (GA3), cytokinin, and beneficial microbes, viz. lactic acid bacteria yeast, photosynthetic bacteria etc. (Swaminathan *et al*., 2007). It has capacity to promote the plant growth and provide immunity in the plant systems. Integrated nutrient-management approach helps in increasing the productivity (Meena *et al*., 2019), nutrient-uptake (Nalini *et al*., 2020) and nutrient-use efficiencies (Singh *et al*., 2020) of various crops. Considering the above facts in view, the present study was carried out with the aim of improving the nutrient-use efficiencies (NUEs) of oats by adopting integrated nutrient-management practices.

MATERIALS AND METHODS

The present experiment was laid out during the winter (*rabi*) season of 2018–19 and 2019–20 at Research Farm of Agronomy Section, ICAR-National Dairy Research Institute, Karnal, Haryana (India). The experimental soil was neutral to slightly alkaline in reaction (*p*H 7.61). It contained 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. Climate of the experimental site was semi-arid and the average annual rainfall of the area varies from 690 to 720 mm. The experiment was conducted in split-plot design with 3 replications. In main plot, the residual effect of 3 maize varieties (V_1, 'African Tall'; V_2, 'J 1006'; V_3, 'P 3396') on oats cv. Kent and in sub-plot, four nutrient management practices [N_0, Control; N_1, 100% Recommended dose of fertilizer (RDF); N_2, 75% RDF + PGPR + Panchagavya spray; N_3, 50% RDF + 25% FYM + PGPR + Panchagavya spray] were studied. Recommended dose of FYM @ 10.0 t/ha was applied at the time of sowing (as per respective treatments), whereas N, P_2O_5 and K_2O were applied @ 120, 40 and 40 kg/ha through urea, single superphosphate and muriate of potash respectively. One-third of total N and full dose of P_2O_5 and K_2O were applied basal and the remaining two-thirds of N was applied in 2 equal splits at 32 days after sowing (DAS) and 3 days after the first cut. Panchagavya was prepared by mixing of 5 byproducts of cow, viz. urine (22.5 litres), dung (15 kg), milk (6 litres), curd (6 kg) and *ghee* (1.5 kg) along with coconut juice (6 litres), ripened banana (3 dozen), jaggery (3 kg) and turmeric powder (0.75 kg). This mixture was put in sealed container and shaked twice a day up to 25 days. It produced around 30 litre Panchagavya which is sufficient for 3 spray at 25, 40 and 85 DAS over 1 ha crops. 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 for around half an hour, the seeds were sown using *Pora* method. A pre-emergence herbicide, i.e. pendimethalin 30 EC @ 0.75 kg a.i./ha, was sprayed to control/ check the weed growth at initial stage. The first cut was taken at 68 and 70 DAS; and the second was taken at 51 and 48 days after the first cut during 2018–19 and 2019–20 respectively.

Green fodder samples (at both cuts) were collected and dried in hot-air oven at 65 ± 5°C till constant weight attained during both the years. These were ground for the estimation of nutrient content. The N, P and K contents were estimated using Modified Kjeldhal's method (Jackson, 1973), ammonium vanadomolybdo phosphoric acid yellow colour method (Richards, 1968) and flame photometer method (Jackson, 1973) respectively. Di-acid digestion (HNO_3-$HClO_4$) followed by atomic absorption spectrophotometer was used for Ca and Mg (Hanlon, 1998), S (Chesnin and Yien, 1950) and micronutrients estimation (Prasad *et al*., 2006). The accumulation of these nutrients was computed by multiplying the concentrations of respective nutrients with their dry-matter yield. Nutrient-use efficiencies, viz. partial factor productivity (PFP), agronomic (AE) and recovery efficiency (RE), were calculated using the total dose of N, P and K nutrients applied through chemical fertilizers, FYM and Panchagavya in their respective treatments. Although, addition of nutrients through PGPR was not considered in estimating the nutrient use efficiencies. Partial factor productivity is a simple production efficiency expression and was calculated in units of crop yield per unit of nutrient applied as per Fixen *et al*. (2014) where, DFY is dry fodder yield and DM is dry-matter.

Agronomic efficiency denotes the units of additional crop produced per unit of input (nutrient) added externally and was calculated as suggested by Fageria and Baligar (2005). Recovery efficiency (%) is the proportion of applied nutrient taken up by the crop, usually expressed as a percentage. It was calculated by using the equation suggested by Fageria and Baligar, (2003).

Experimental data were processed in Microsoft Excel – 2010 and analysed with the help of analysis of variance (ANOVA) technique for split-plot design using statistical analysis system (SAS) software at the ICAR-Indian Agricultural Statistics Research Institute (IASRI) server. Statistical significance among treatments means differences for various parameters were analysed by least significant differences (LSD) at 0.05 probability level.

RESULTS AND DISCUSSION

Fodder productivity

The green fodder yield of oats was not affected significantly due to residual effect of maize varieties (Fig. 1). This may be due to alike behaviour of maize varieties which left similar soil rhizospheric conditions (Kumar *et al*., 2021). However, various nutrient-management practices caused significant differences on green fodder yield. Application of 75% RDF + PGPR + Panchagavya spray significantly enhanced the green fodder yield at the first cut compared to the other treatments, while at the second cut, the use of 75% RDF + PGPR + Panchagavya spray resulted in significantly higher green fodder yield than the control and 100% RDF. Alike the first cut, the total green fodder yield was considerably higher under 75% RDF + PGPR + Panchagavya spray than the remaining treatments. Treatments of 100% RDF and 50% RDF + 25% FYM + PGPR + Panchagavya were statistically at par with each other. The enhancement in green fodder yield with 75% RDF + PGPR + Panchagavya might be owing to better growth and development. The PGPR helps in activating the certain growth-promoting enzymes which could have played vital role in boosting green fodder yield (Saleem *et al*., 2015). Further, the higher NPK fertilization either from chemical fertilizers or panchagavya enhanced the chlorophyll content which led to increased photosynthates, protoplasmic constituents and accelerated hyperplasia and hypertrophy which ultimately resulted into luxuriant vegetative growth and green fodder yield. Our results are in line with the earlier work of Singh *et al*. (2010), who reported the higher green fodder yield by applying 75% fertilizer + 25% RDN through FYM as compared to 50% fertilizer + 50% N as FYM.

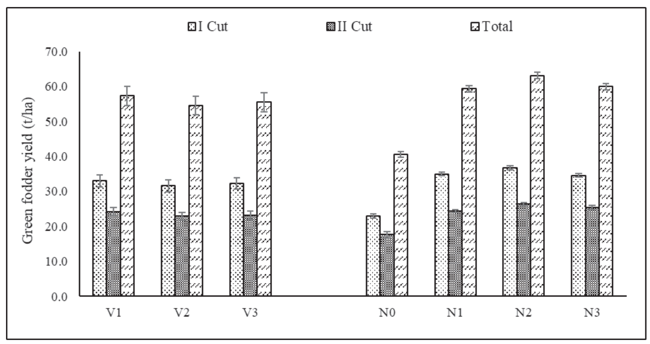

Fig. 1. Green fodder yield of oats as influenced by residual effect of fodder maize varieties and nutrient-management practices (mean of 2 years)

Nutrient content

The primary as well as secondary nutrient contents of fodder oats were not influenced significantly at both cuts by residual effect of maize varieties (Table 1). With respect

Table 1. Influence of residual effect of maize varieties and nutrient-management practices on primary and secondary nutrient contents of fodder oats (mean of 2 years)

Treatments	N (%)		P (%)		K (%)		Ca (%)		Mg (%)		S (%)	
	I Cut	II Cut	I Cut	II Cut	I Cut	II Cut	I Cut	II Cut	I Cut	II Cut	I Cut	II Cut
Residual effect of fodder maize varieties												
'African Tall'	1.90	1.71	0.32	0.26	1.40	1.27	0.40	0.37	0.26	0.25	0.17	0.16
'J 1006'	1.89	1.70	0.31	0.26	1.38	1.25	0.40	0.37	0.26	0.25	0.17	0.16
'P 3396'	1.83	1.64	0.31	0.26	1.37	1.25	0.39	0.36	0.25	0.25	0.17	0.16
SEm±	0.04	0.04	0.01	0.01	0.04	0.04	0.01	0.01	0.00	0.00	0.01	0.00
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient-management practices												
N_0	1.73^{C}	1.54^{C}	0.29^{B}	0.24^{C}	1.27^{B}	1.16^{B}	0.38	0.36	0.24	0.24	0.16^{B}	0.15^{B}
N_1	1.87^{B}	1.69^{B}	0.31^{A}	0.26^{B}	1.41^{A}	1.26^{A}	0.39	0.36	0.26	0.25	0.17^{B}	0.15^{B}
N_2	1.97^{A}	1.76^{A}	0.32^{A}	0.27^{A}	1.44^{A}	1.31^{A}	0.40	0.37	0.26	0.25	0.18^{A}	0.17^{A}
N_3	1.94^{AB}	1.73^{AB}	0.32^{A}	0.27^{A}	1.42^{A}	1.29^{A}	0.41	0.38	0.26	0.26	0.18^{A}	0.17^{A}
SEm±	0.04	0.02	0.01	0.00	0.03	0.03	0.01	0.01	0.01	0.01	0.00	0.00
LSD (P=0.05)	0.08	0.05	0.01	0.01	0.06	0.06	NS	NS	NS	NS	0.01	0.01

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

to nutrient-management practices, the application of nutrient treatments (N_1, N_2 and N_3) showed significantly higher N content at both cuts compared to the control. Further comparison indicated that, N_2 practice was statistically at par with N_3 at both cuts and noted significantly higher N content over N_1 and N_0. For phosphorus, the application of N_1, N_2 and N_3 treatments were statistically at par and showed 7.0, 11.5 and 10.6% respectively, higher P content at the first cut over the control. However, at the second cut, N_2 and N_3 practices were statistically at par with each other and both resulted in significantly higher P content than N_1 and N_0. Compared to the control, the application of N_1, N_2 and N_3 treatments performed statistically similar and showed significantly higher K content at both cuts than the control. The extent of enhancement in K content owing to application of N_1, N_2 and N_3 was 10.7, 12.6 and 11.4% respectively at the first cut and 8.3, 13.2 and 11.3%, respectively, at the second cut over the control. Among the secondary nutrient content, only S was significantly differed with nutrient management practices. Treatments N_3 and N_2 were statistically similar for S content at the first and second cut, respectively, and noted considerably higher values over N_1 and N_0.

The main plot treatments did not cause significant variations on micronutrient content (Table 2). However, an integration of organic and inorganic nutrient sources showed significant influence on micronutrient content at I and II cuts. As compared to the control, the application of N_1, N_2 and N_3 practices recorded significantly higher Fe content at both the cuts. Comparison among N_1, N_2 and N_3 treatments showed that, significantly higher Fe content was noted under N_3 and N_2 practices as compared to N_1 at first and second cut. In case of Zn, the application of N_3 and N_2 treatments significantly boosted the Zn content at the first cut over the control, while at the second cut, considerably higher Zn content was noted in N_3 practice than rest of all treatments, except N_2. With respect to Mn, treatments N_3 and N_2 were statistically similar and resulted significantly higher Mn content than N_1 and N_0 at the first and second cut respectively. Similarly, N_1, N_2 and N_3 practices were found statistically similar and enhanced the Cu content over the control (14.15 mg/kg) at the first cut, while at the second cut, N_2 and N_3 practices were statistically at par and recorded significantly higher values over N_1 and N_0.

Macro-as well as micro nutrient content of fodder oats at both cuts were not influenced significantly by residual effect of different maize varieties which may be due to similar behaviour of these varieties in soil system, thus remained statistically ineffective. However, application of 75% RDF + PGPR + Panchagavya spray and 50% RDF + 25% FYM + PGPR + Panchagavya spray practices considerably enhanced macro-and micro-nutrient content over the control. The addition of FYM to soil may have improved the soil structure, cation exchange capacity, water-holding capacity and microbial population which resulted in to higher nutrient solubilization and lower nutrient loss from soil by various process, henceforth supplied essential nutrients continuously. The greater root growth with PGPR inoculation could also be another probable reason for higher nutrient content. The release of phyto-hormones either from PGPR or by decomposition of FYM could lead to higher root-hair growth which enable crop to absorb more nutrients from soil. Furthermore, the higher micronutrient content in fodder oats might be owing to directly

Table 2. Micronutrient content of fodder oats as influenced by residual effect of maize varieties and nutrient-management practices (mean of 2 years)

Treatments	Fe (mg/kg)		Zn (mg/kg)		Mn (mg/kg)		Cu (mg/kg)	
	I Cut	II Cut	I Cut	II Cut	I Cut	II Cut	I Cut	II Cut
Residual effect of fodder maize varieties								
'African Tall'	225.4	206.0	26.15	21.98	76.56	67.99	15.25	11.96
'J 1006'	226.7	208.1	25.56	21.38	78.86	67.73	14.69	11.72
'P 3396'	221.1	202.9	25.96	21.44	75.22	66.34	15.04	11.79
SEm±	4.54	3.6	0.60	0.47	1.52	1.37	0.35	0.25
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient-management practices								
N_0	210.7^{C}	190.6^{C}	24.40^{C}	20.67^{C}	72.14^{C}	62.65^{C}	14.15^{B}	11.12^{C}
N_1	222.0^{B}	203.2^{B}	25.40^{B}	21.46^{BC}	74.88^{B}	64.96^{B}	14.99^{A}	11.66^{B}
N_2	231.1^{A}	213.8^{A}	26.60^{A}	21.88^{AB}	79.60^{A}	70.63^{A}	15.39^{A}	12.21^{A}
N_3	233.8^{A}	215.0^{A}	27.17^{A}	22.39^{A}	80.91^{A}	71.16^{A}	15.44^{A}	12.29^{A}
SEm±	3.28	1.6	0.44	0.41	1.20	0.92	0.22	0.17
LSD (P=0.05)	6.9	3.4	0.93	0.87	2.52	1.92	0.46	0.35

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

addition of micronutrients to soil through FYM or indirectly by solubilizing through PGPR. Besides above reasons, the addition of chemical fertilizers itself supply the essential plant nutrients. These confirm the findings of Pandey (2018).

Nutrient uptake

The uptake of primary (Table 3) as well as secondary (Table 4) nutrients in oats were not influenced significantly at both the cuts by residual effect of fodder maize varieties. With respect to nutrient-management practices, the application of 75% RDF + PGPR + Panchagavya spray significantly enhanced the N uptake at the first cut compared with rest of the treatments. While at the second cut, N_2 and N_3 options enhanced the N uptake significantly over N_1 and N_0 options. The integration of reduced dose of chemical fertilizers (75% RDF) with PGPR and Panchagavya spray (N_2) significantly increased the total N uptake as compared to that of N_3, N_1 and N_0. In case of P uptake, the INM practices (N_2 and N_3) significantly enhanced the P uptake over the control at the first, second cut and their total. For the first cut and total of both cuts, significantly higher P uptake was recorded under N_2 practice than rest of treatments. However, at the second cut, N_2 and N_3 practices were found statistically at par and recorded significantly higher P uptake than N_1 and N_0 practices. Likewise, significantly

Table 3. Influence of residual effect of maize varieties and nutrient-management practices primary on nutrient uptake of fodder oats (mean of 2 years)

Treatments	N (kg/ha)			P (kg/ha)			K (kg/ha)		
	I Cut	II Cut	Total	I Cut	II Cut	Total	I Cut	II Cut	Total
Residual effect of maize varieties									
'African Tall'	107.6	67.1	174.7	17.75	10.21	27.96	78.50	50.00	128.5
'J 1006'	101.6	63.3	164.9	16.66	9.56	26.22	74.14	46.14	120.3
'P 3396'	97.4	60.3	157.7	16.46	9.48	25.94	73.29	46.05	119.3
SEm±	5.6	3.5	8.1	0.51	0.33	0.72	2.29	2.67	4.2
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient-management practices									
N_0	64.5^C	42.2^C	106.8^D	10.83^C	6.55^C	17.38^D	47.64^C	31.71^C	79.4^C
N_1	108.3^B	65.7^B	174.0^C	18.06^B	9.98^B	28.05^C	81.77^B	48.93^B	130.7^B
N_2	123.0^A	75.3^A	198.4^A	20.17^A	11.52^A	31.69^A	89.13^A	56.05^A	145.2^A
N_3	112.9^B	71.0^A	183.9^B	18.76^B	10.95^A	29.71^B	82.69^B	52.90^A	135.6^B
SEm±	3.2	2.1	3.4	0.61	0.34	0.58	2.61	1.73	2.8
LSD (P=0.05)	6.6	4.4	7.1	1.29	0.71	1.22	5.48	3.64	5.9

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

Table 4. Influence of residual effect of maize varieties and nutrient-management practices on secondary nutrient uptake of fodder oats as (mean of 2 years)

Treatment	Ca (kg/ha)			Mg (kg/ha)			S (kg/ha)		
	I Cut	II Cut	Total	I Cut	II Cut	Total	I Cut	II Cut	Total
Residual effect of maize varieties									
'African Tall'	22.32	14.55	36.87	14.65	9.80	24.45	9.68	6.35	16.03
'J 1006'	21.53	13.59	35.12	13.70	9.17	22.88	9.12	5.89	15.01
'P 3396'	20.56	13.31	33.88	13.51	9.06	22.56	8.99	5.82	14.81
SEm±	1.18	0.99	1.97	0.50	0.55	0.99	0.58	0.29	0.76
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient-management practices									
N_0	14.26^C	9.71^C	23.97^C	9.12^C	6.49^C	15.61^C	6.03^C	4.10^C	10.13^C
N_1	22.66^B	14.08^B	36.74^B	14.99^B	9.70^B	24.69^B	9.61^B	6.02^B	15.63^B
N_2	25.19^A	15.96^A	41.15^A	16.36^A	10.70^A	27.05^A	10.99^A	7.08^A	18.06^A
N_3	23.78^{AB}	15.52^A	39.29^A	15.35^B	10.49^{AB}	25.84^{AB}	10.42^A	6.89^A	17.31^A
SEm±	0.74	0.57	0.98	0.46	0.43	0.60	0.37	0.24	0.47
LSD (P=0.05)	1.56	1.20	2.05	0.97	0.90	1.26	0.77	0.51	0.98

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

higher K uptake at the first cut and total of both cuts was obtained with N_2 practice as compared to N_3, N_1 and N_0, whereas at the second cut, N_2 and N_3 practices were observed statistically at par and resulted in significantly higher K uptake than N_1 and N_0.

In case of secondary nutrients (Table 4), significantly higher Ca uptake at the first cut was obtained with N_2 practice as compared to N_1 and N_0. However, it remained at par with N_3 practice. At the second cut and total of both cuts, N_2 and N_3 practices performed statistically similar and resulted in significantly higher Ca uptake than N_1 and N_0 practices. In the case of Mg, significantly higher uptake was obtained under N_2 practice than the remaining treatments. However, at the second cut and total of both cuts, N_2 practice significantly increased the Mg uptake over the control as well as N_1, but remained at par with N_3. In the case of S, the use of N_2 and N_3 practices showed statistically similar and higher S uptake over N_0 and N_1 at first, second cut and their total. Application of N_1 treatment also enhanced the S uptake significantly over control at first, second cut and their total.

The micronutrients uptake of fodder oats were not influenced significantly due to residual effect of maize varieties, except total Cu uptake (Table 5). Significantly higher total Cu uptake was noted when oats grown after maize cv. 'African Tall' compared to 'J 1006' and 'P 3396', though nutrient-management considerably influenced the micronutrients uptake. At the first cut, N_2 treatment was found statistically equal to N_3 and significantly higher Fe uptake than N_0 and N_1, while at the second cut, N_2 and N_3 practices were found to be statistically at par and both recorded considerably higher Fe uptake compared to N_1 and N_0 (Table 5). Further results revealed that, use of N_2 practice showed noticeably higher total Fe uptake amongst all nutrient-management practices. All the nutrient treatments significantly boosted the Zn uptake over the control at first, second cut and their total uptake. Use of N_2 and N_3 practices significantly enhanced the Zn uptake at first, second cut and their total as compared to N_0 and N_1. Considering the Mn uptake, the application of N_2 and N_3 practices significantly boosted the Mn uptake by 84.0 and 75.0% at first cut, 76.3 and 70.3% at second cut and 81.0 and 73.2% for total of both cuts, respectively, over the control. For Cu uptake, N_1, N_2 and N_3 treatments significantly increased its value at both cuts as well as their total over the control. At the first cut, N_2 was found statistically equal to N_3 practice and recorded significantly higher Cu uptake over the N_1 treatment. At the second cut, N_2 and N_3 practices were found statistically at par, and both the practices recorded considerably higher Cu uptake compared to 100% RDF. Further results revealed that, use of N_2 practice recorded noticeably higher total Cu uptake amongst all nutrient-management practices.

Integration of organic and inorganic nutrient sources (N_2 and N_3) recorded significantly higher nutrients uptake, especially S and micronutrients as compared to 100% RDF. Since nutrient uptake is a function of dry-matter yield and respective nutrient content. Henceforth, enhancement in both these factors resulted in higher uptake of nutrients. Pandey (2018) in oats and Vennila *et al*. (2019) in bajra napier hybrid grass also reported higher uptake of essential plant nutrient.

Nutrient-use efficiencies

In this study, various nutrient use efficiencies, viz. partial factor productivity (PFP_{npk}), agronomic efficiency

Table 5. Residual effect of maize varieties and nutrient-management practices on micronutrient uptake of fodder oats (mean of two years)

Treatment	Fe (g/ha)			Zn (g/ha)			Mn (g/ha)			Cu (g/ha)		
	I Cut	II Cut	Total	I Cut	II Cut	Total	I Cut	II Cut	Total	I Cut	II Cut	Total
Residual effect of maize varieties												
'African Tall'	1267	809	2077	147.1	85.9	232.9	430.1	266.6	696.7	85.6	46.8	132.4^{A}
'J 1006'	1212	770	1982	136.4	79.1	215.5	421.4	250.4	671.8	78.7	43.3	122.0^{B}
'P 3396'	1178	748	1926	138.1	78.7	216.8	402.1	245.4	647.5	80.0	43.3	123.3^{B}
SEm±	45	39	80	6.4	3.5	9.2	18.7	13.8	29.3	2.5	1.7	2.8
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	7.9
Nutrient-management practices												
N_0	787^{C}	521^{C}	1308^{D}	90.8^{C}	56.3^{C}	147.1^{C}	269.3^{C}	170.9^{C}	440.2^{C}	52.8^{C}	30.3^{C}	83.1^{D}
N_1	1289^{B}	791^{B}	2079^{C}	147.6^{B}	83.5^{B}	231.1^{B}	435.3^{B}	253.2^{B}	688.5^{B}	87.1^{B}	45.3^{B}	132.4^{C}
N_2	1438^{A}	912^{A}	2350^{A}	165.4^{A}	93.3^{A}	258.7^{A}	495.6^{A}	301.3^{A}	796.9^{A}	95.7^{A}	52.1^{A}	147.8^{A}
N_3	1363^{AB}	879^{A}	2242^{B}	158.4^{A}	91.7^{A}	250.1^{A}	471.4^{A}	291.0^{A}	762.5^{A}	90.0^{AB}	50.3^{A}	140.3^{B}
SEm±	43	26	45	4.3	2.9	4.5	16.1	7.3	18.5	3.0	1.4	3.1
LSD (P=0.05)	91	55	96	8.9	6.0	9.5	33.9	15.3	38.9	6.2	2.9	6.4

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

(AE_{npk}) and recovery efficiency (RE_{npk}), were determined (Fig. 2). Results revealed that, the maximum PFP_{npk}, AE_{npk} and RE_{npk} were obtained when oats sown after maize cv. African Tall (47.8, 16.7 kg/kg and 72.6% respectively), while minimum PFP_{npk} was obtained by residual effect of 'P 3396' variety (45.27, 16.51 kg/kg and 65.68% respectively). With respect to nutrient-management, application of N_2 practice recorded the maximum PFP_{npk}, AE_{npk} and RE_{npk} amongst all. Enhancement in these nutrient-use indices owing to the application of N_2 practice was 1.44, 1.65 and 1.76 folds over N_1 and 1.05, 1.15 and 1.17 folds over N_3 respectively. The higher nutrient-use efficiencies, i.e. PFP_{npk}, AE_{npk} and RE_{npk}, with combined use of FYM or PGPR, Panchagavya and reduced dose of chemical fertilizers might be ascribed to their higher dry-matter yield and nutrient uptake. Our results supporte findings of Singh *et al*. (2020).

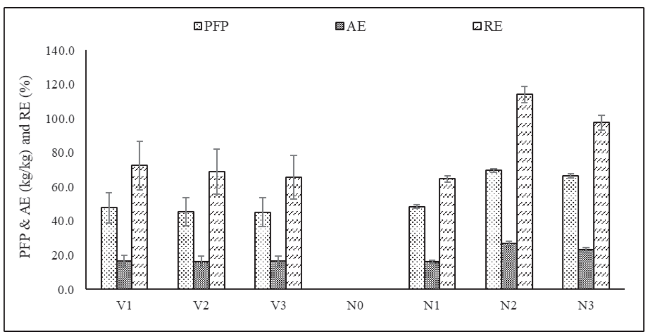

Fig. 2. Nutrient-use efficiencies of oats as influenced by residual effect of fodder maize varieties and nutrient management practices (mean of 2 years)
PFP, Partial factor productivity; AE, agronomic efficiency; RE, recovery efficiency; V_1, african Tall; V_2, 'J 1006'; V_3, 'P 3396'; N_0, control; N_1, 100% RDF; N_2, 75% RDF + PGPR + Panchagavya spray; N_3, 50% RDF + 25% FYM + PGPR + Panchagavya spray
Capped lines shows the standard error of mean

CONCLUSION

Based on the 2 years experiment, it can be concluded that different maize varieties were statistically similar to exhibit the residual effect on nutrient content and uptake in fodder oats. Application of 75% RDF + PGPR + Panchagavya spray and 50% RDF + 25% FYM + PGPR + Panchagavya spray significantly enhanced the nutrient content and uptake of fodder oats over the control. The maximum nutrient-use efficiencies (partial factor productivity, agronomic efficiency and recovery efficiency) were also found under the application of 75% RDF + PGPR + Panchagavya spray, while the least were noted under 100% RDF through chemical fertilizers.

REFERENCES

Bandyopadhyay, K.K., Misra, A.K., Ghosh, P.K. and Hati, K.M. 2010. Effect of integrated use of farmyard manure and chemical fertilizers on soil physical properties and productivity of soybean. *Soil and Tillage Research* **110**: 115–125.

Chesnin, L. and Yien, C.H. 1950. Turbidimetric determination of available sulphates. *Soil Science Society of America Journal* **15**: 149–151.

Fageria, N.K. and Baligar, V.C. 2003. Methodology for evaluation of lowland rice genotypes for nitrogen use efficiency. *Journal of Plant Nutrition* **26**(6): 1315–1333.

Fageria, N.K. and Baligar, V.C. 2005. Enhancing nitrogen use efficiency in crop plants. *Advances in Agronomy* **88**: 97–185.

Fixen, P., Brentrup, F., Bruulsema, T., Garcia, F., Norton, R. and Zingore, S. 2014. Nutrient/ fertilizer use efficiency: measurement, current situation and trends. (In) *Managing Water and Fertilizer for Sustainable Agricultural Intensification*, pp. 8–38. Drechsel, P., Heffer, P., Magen, H., Mikkelsen, R. and Wichelns, D. (Eds.), IFA, IWMI, IPNI and IPI.

Hanlon, E.A. 1998. Elemental determination by atomic absorption spectrophotometry. (In) *Handbook of Reference Methods for Plant Analysis*, pp. 157–164. Kalra, Y.P. (Ed.), CRC Press, Boca Raton, USA.

IGFRI. 2018. *Vision 2050*. p. 4. ICAR – Indian Grassland and Fodder Research Institute, Jhansi, Uttar Pradesh, India.

Jackson M.L. 1973. *Soil Chemical Analysis*. p. 498. Prentice Hall of India Pvt. Ltd, New Delhi.

Johnston, A.E., Poulton, P.R. and Coleman, K. 2009. Soil organic matter: its importance in sustainable agriculture and carbon dioxide inuxes. *Advances in Agronomy* **101**: 1–57.

Kumar, D., Singh, M., Kumar, S., Meena, R.K. and Kumar, R. 2021. Fodder quality and nitrate estimation of oats grown under different nutrient management options. *Indian Journal of Dairy Science* **74**(4): 331–337.

Meena, H., Singh, M.K., Meena, R. and Meena, R.N. 2019. Effect of seed rate and integrated nutrient management on growth, yield and economics of direct-seeded hybrid rice (*Oryza sativa*). *Indian Journal of Agronomy* **64**(3): 324–329.

Nalini, N., Vani, K.P., Devi, K.B.S. and Babu, P.S. 2020. Effect of integrated nutrient-management and dates of sowing on nutrient uptake and yield of pearl millet (*Pennisetum glaucum*). *Indian Journal of Agronomy* **65**(3): 331–336.

Pandey, K.C. and Roy, A.K. 2011. *Forage Crops Varieties*. p. 16. ICAR – Indian Grassland and Fodder Research Institute, Jhansi, Uttar Pradesh India.

Pandey, M. 2018. Effect of integrated nutrient management on yield, quality and uptake of nutrients in oat (*Avena sativa*) in alluvial soil. *Annals of Plant and Soil Research* **20**(1): 1–6.

Prasad, R., Shivay, Y.S., Kumar, D. and Sharma, S.N. 2006. *Learning by Doing Exercises in Soil Fertility* (A practical manual for soil fertility). p. 68. Division of Agronomy, Indian Agricutlural Research Institute, New Delhi.

Rathod, D.D., Rathod, P.H., Patel, K.P. and Patel, K.C. 2013. Integrated use of organic and inorganic inputs in wheat-fodder maize cropping sequence to improve crop yields and soil properties. *Archives of Agronomy and Soil Science* **59**(11): 1439–1455.

Richards, L.A. 1968. Diagnosis and improvement of saline and alkali soils. *Agriculture Handbook* **60**: 210–220.

Saleem, M., Zamir, M.S.I., Haq, I., Irshad, M.Z., Khan, M.K., Asim, M., Zaman, Q., Ali, I., Khan, A. and Rehman, S. 2015. Yield and quality of forage oat (*Avena sativa* L.) cultivars as affected by seed inoculation with nitrogenous strains. *American Journal of Plant Sciences* **6**: 3,251–3,259.

Singh, M.K., Singh, R.N., Singh, S.P., Yadav, M.K. and Singh, V.K. 2010. Integrated nutrient management for higher yield, quality and profitability of baby corn (*Zea mays*). *Indian Journal of Agronomy* **55**(2): 100–104.

Singh, P., Benbi, D.K. and Verma, G. 2020. Nutrient management impacts on nutrient use efficiency and energy, carbon, and net ecosystem economic budget of a rice–wheat cropping system in Northwestern India. *Journal of Soil Science and Plant Nutrition* **21**: 559–577.

Swaminathan, C., Swaminathan, V. and Vijayalakshmi, K. 2007. *Panchagavya - boon to organic farming*. pp. 1–94. International Book Distributing Co., Lucknow, Uttar Pradesh, India.

Vejan, P., Abdullah, R., Khadiran, T., Ismail, S. and Boyce, A.N. 2016. Role of plant growth promoting rhizobacteria in agricultural sustainability – A review. *Molecules* **21**(5): 573–589.

Vennila, C., Sankaran, V.M. and Ananthi, T. 2019. Effect of integrated nutrient management on productivity and economics of bajra napier hybrid grass (*Pennisetum purpureum* × *Pennisetum glaucum*). *Indian Journal of Agronomy* **64**(2): 232–237.

Yes Bank. 2018. *Making Indian Dairy Farming Competitive – The Small Farmer Perspective*. pp. 11–15. Food and Agribusiness Research Management, Yes Bank. February 2015.