The Pharma Innovation Journal 2022; 11(2): 2442-2447

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(2): 2442-2447
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www.thepharmajournal.com
Received: 08-11-2021
Accepted: 18-01-2022

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Nutritional values of forages in the maize-oats cropping sequence under various nutrient management practices

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Abstract
The present experiment was conducted during 2018-19 and 2019-20 with three maize varieties (V_1: African Tall, V_2: J-1006; V_3: P-3396), varietal residual effects on oats cv. Kent and 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) using split plot design. Results showed that different varieties could not show significant variations on fodder quality traits (Neutral detergent insoluble crude protein-NDICP, acid detergent insoluble crude protein-ADICP, acid insoluble ash, cellulose, hemi-cellulose and cell content). However, nutrient management practices showed significant variations on these parameters of maize. Integrated application of organic and inorganic nutrient sources (N_2: 75% RDF + PGPR + Panchagavya spray) showed significant lower NDICP, ADICP, acid insoluble ash, organic matter, cellulose and hemi-cellulose; and higher cell content as compared to control. Residual effect of fodder maize varieties could not show significant variations on quality traits of fodder oats. Among the nutrient management, the application of 75% RDF + PGPR + Panchagavya spray produced significantly lower NDICP and ADICP; and higher digestible energy (DE), total digestible nutrients (TDN), net energy for lactation (NEl) and relative feed quality (RFQ). System productivity was also not affected by main plot treatments; while, application of N_2 practice to both maize and oats significantly enhanced the dry matter, crude protein, ether extract and total ash yields compared with control and 100% RDF. Overall, it can be concluded that application of 75% RDF + PGPR + Panchagavya spray (N_2) is viable option to produce higher system productivity with better quality.

Keywords: Fodder quality, panchagavya, PGPR, system productivity

Introduction

Livestock is a major source of livelihood security for the poor in most of the developing countries. In India, where over 75 per cent farmers are small and marginal holders, livestock is the main source of livelihood for a majority of the rural population (Khamkar, 2016) [9]. India has the largest number of livestock (536.76 million) in the world (Anonymous, 2020b) [2] and also continues to be the largest producer of milk in world which was 187.75 million tonnes during 2018-19 (Anonymous, 2020c) [1], but its productivity is still lower than global average (Anonymous, 2018a) [4]. Since, the genetic factors account for only 30 per cent improvement in productivity of cattle while, feed and fodder accounts for 70 per cent; therefore, feed and fodder management concern is utmost important (Singh, 2016) [17]. Green fodder is one of the major components of animal feed (Kumar *et al*., 2018) [14]. The performance of animals as well as the economics of milk production is heavily dependent on the quantity of nutritious forage fed to milch animals.

Fodder insufficiency has been a challenging issue in India as it is essential for higher productivity of livestock (Kumar *et al*. 2021b) [12]. The area under fodder crops in India lies between 4.2 to 5.0 per cent of gross cropped area since 1970-71 and it was 4.6 per cent during 2014-15 (Anonymous, 2018b) [3]. At the present time, India faces a net deficit of 35.6, 10.95 and 44 per cent green fodder, dry crop residues and concentrate feed ingredients, respectively (Anonymous, 2018a) [4]. To meet the current deficit of fodder, it has to be met either from improving productivity, utilizing untouched feed resources, increasing land area or through imports (Anonymous, 2018a) [4]. Since, increment in land area may not be possible due to human pressure for food crops, imports could have higher cost and untouched feed resources are already being utilized as dry roughages; therefore, the increment in fodder productivity is the only approach to achieve the need of fodder.

Fodder productivity can either be improved by genetically or by agronomic interventions. Selection of suitable crop/ cultivars and efficient nutrient management are major aspect in fodder production (Kumar *et al*. 2022a) [11] that could enhance the fodder productivity along with their good quality.

Materials and Methods

Location description: The experiment was carried out during *Kharif–Rabi* seasons for two consecutive years (2018-19 and 2019-20) at Research Farm of Agronomy 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. Soil of the experimental field was fairly neutral (7.61 pH) having 0.312 dS m^{-1} electrical conductivity and rated as medium, low, high and medium for organic carbon, available N, P and K (0.63%, 192.4, 29.71 and 195.7 kg ha^{-1}), respectively. The weather conditions during both years of study were congenial to both crops.

Experimental design, treatments and crop management: The experiment was laid out in split plot design with three replications. In main plots, three varieties of fodder maize (*viz*., African Tall, J-1006 and P-3396) were taken during *Kharif* season, while residual effect of these varieties on oats cv. Kent were studied during *Rabi* season. While in sub plots, four nutrient management practices (*viz*., N_0: control, N_1: 100% RDF, N_2: 75% RDF + PGPR + Panchagavya and N_3: 50% RDF + 25% FYM + PGPR + Panchagavya) were applied for both crops. Recommended dose of FYM was applied @ 10.0 t ha^{-1} at the time of sowing to both crops (as per respective treatments). The N, P_2O_5 and K_2O were applied @ 100, 60 and 40 kg ha^{-1} for maize and @ 120, 40 and 40 kg ha^{-1} for oats through urea, single super phosphate and muriate of potash, respectively. For maize, half dose of N was applied as basal and remaining half was applied at 26 DAS. For oats, one third of N was applied as basal and remaining two third was applied in two equal amounts at 32 DAS and three days after first cut. Though, full dose of P_2O_5 and K_2O was applied as basal for both crops. Panchagavya prepared using five cow by-products along with certain other ingredients was applied at 25 and 40 DAS in maize and 25, 40 and 85 DAS in oats through foliar spray. Seed rates of 45 and 80 kg ha^{-1} were taken and treated with Mancozeb 75% WP @ 3 g a.i. kg^{-1} and Bavistin 50% WP @ 2 g *a.i.* kg^{-1} seeds followed by PGPR (as per treatment) @ 120 ml ha^{-1} seeds for maize and oats, respectively. Seeds were sown using Pora method after shade drying around half an hour.

Proximate analysis: Fodder samples of maize at harvest and oats at I and II cuts were collected, dried in oven at 65±5 °C until attains a constant weight and grounded (Wiley mill) to pass through one mm screen for nutritional analysis (AOAC, 2005) [5]. Crude protein was estimated using Kjeldahl method by multiplying N content with 6.25 factor, ether extract was analyzed using Soxhlet's extraction apparatus and total ash content was analysed by charring the sample on heater in pre-weighed silica crucible followed by ignition in muffle furnace at 550°C for 2-3 hrs (AOAC, 2005) [5]. Acid insoluble ash was measured using total ash and diluted HCl with continuous washing using hot distilled water followed by boiling, filtering, decarbonization and ignition (AOAC, 2005) [5]. The yield of crude protein, ether extract and total ash was calculated by multiplying their respective content and dry fodder yield.

Neutral detergent fibre (NDF) and acid detergent fibre (ADF) obtained using Van Soest *et al.* (1991) [19] method was used to estimate the insoluble protein fractions of fibre *viz*., neutral detergent insoluble crude protein (NDICP) and acid detergent insoluble crude protein (ADICP) (Licitra *et al.*, 1996) [15]. Organic matter (OM), cellulose, hemi-cellulose and cell content were determined by subtracting the total ash content from 100, ADL from ADF, ADF from NDF, NDF from 100, respectively.

Nutritional/ energy values: Total digestible nutrients (TDN) represent the energy content and digestibility of feed/ fodder. The energetic requirements for maintenance and milk production are expressed as net energy for lactation (NEl). TDN and Nel were determined according to the following equation (Horrocks and Vallentine, 1999) [8]:

$$\text{TDN (\%)} = (-1.291 \times \text{ADF\%}) + 101.35$$
$$\text{NEl (Mcal kg}^{-1}) = [1.044 - (0.0119 \times \text{ADF\%})] \times 2.205$$
$$\text{NEl (MJ kg}^{-1}) = \text{NEl (Mcal kg}^{-1}) \times 4.184$$

Relative forage quality (RFQ) denotes the fibre digestibility to estimate intake as well as total digestible nutrients (energy) of the forage. This is the unit less fodder quality parameters and were determined using equation given by Undersander *et al*. (2010).

$$\text{RFQ} = \frac{\text{DMI (\%)} \times \text{TDN (\%)}}{1.23}$$

Digestible energy (DE) is the difference between gross energy intake and the amount of energy excreted in the faeces and calculated using equation given by Fonnesbeck *et al*. (1984) [7].

$$\text{DE (Mcal kg}^{-1}) = 0.27 + [0.0428 \times \text{DMD (\%)}]$$
$$\text{DE (MJ kg}^{-1}) = \text{DE (Mcal kg}^{-1}) \times 4.184$$

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

Results and Discussion

Quality parameters of fodder maize

Results (Table 1) indicated that neutral detergent insoluble crude protein (% DM and CP) content of fodder maize remained statistically unaffected due to different varieties. However, nutrient management practices caused significant variations on these parameters. NDICP (% DM) content was significantly reduced due to the use of N_2 and N_3 practices (2.92 and 2.96%) over control (3.08). With respect to NDICP (% CP), significantly lower value was noted under N_2 and N_3 practices (29.56 and 30.54%) than N_0 (35.86%) and N_1 (32.14%). Similarly, acid detergent insoluble crude protein (ADICP) content (based on % DM and CP) of maize was not affected significant due to varieties. While, the application of N_2 and N_3 practices (1.32 and 1.35%, respectively) were statistically at par with each other and both recorded significantly lower value of ADICP (% DM) over N_0 and N_1. Alike ADICP (% DM), the adoption of N_2 and N_3 (13.38 and 13.90%, respectively) considerably decreased the ADICP (% CP) content over N_0 (17.38%) and N_1 (15.09%). In case of acid insoluble ash, non-significant differences observed due to varieties. Though, the use of N_3 was at par with N_2 and both recorded remarkably lower value (1.45 and 1.46%, respectively) than N_1 and N_0.

Organic matter (OM) content was significantly varied among different maize varieties as well as nutrient management practices. Among varieties, significantly lower OM content was found with P-3396 (92.43%) compared to African Tall (93.09%). Amongst nutrient management practices, the application of N_1, N_2 and N_3 (92.52, 92.34 and 92.38%, respectively) were found statistically at par with each other and lower than N0 (92.65%).

Cellulose, hemi-cellulose and cell content of fodder maize was not differed significantly among varieties. However, nutrient management practices showed significant variation. Significantly lower cellulose content was attained through applying the N_2 and N_3 (33.01 and 33.13%) over N0 (35.65%). The use of N_2 and N_3 practices decreased the hemi-cellulose content significantly over control (29.50%). Significantly higher cell content was obtained by applying the N_2 practice (36.73%) which was at par with N_3 (36.18%) over control. Integrated use of FYM, PGPR and panchagavya along with reduced dose of chemical fertilizers could lead to faster mineralization/ solubilization of fixed/ organically bound nutrients to available form which enhanced their uptake by crops. The higher uptake of essential nutrients particularly N significantly reduced the fibre fractions. Secondary parameters of fodder quality play key role in estimation of their nutritive value as well as digestibility. The adequate and continuous supply of essential plant nutrients under INM plots led to better growth and development which in turn reduced fibre fractions and thereby, enhanced the fodder quality. Our results are in line with earlier findings of Salama and Zeid (2016) [16] and Kumar *et al*. (2022a) [11].

Table 1: Effect of variety and nutrient management practices on nutritional values of fodder maize (mean of two years)

Treatments	NDICP		ADICP		Acid insoluble ash (%)	Organic matter (%)	Cellulose (%)	Hemi-cellulose (%)	Cell content (%)
	(% DM)	(% CP)	(% DM)	(% CP)					
Variety									
African Tall	2.92	33.05	1.34	15.17	1.48	93.09^{A}	32.86	26.49	35.74
J-1006	2.95	31.01	1.38	14.53	1.50	92.65^{AB}	33.70	27.49	34.09
P-3396	3.10	32.01	1.46	15.12	1.59	92.43^{B}	35.61	26.55	32.74
S.Ed(±)	0.07	1.09	0.04	0.63	0.03	0.16	0.91	1.14	1.47
LSD (*P*=0.05)	NS	NS	NS	NS	NS	0.45	NS	NS	NS
Nutrient management practices									
N_0	3.08^{A}	35.86^{A}	1.49^{A}	17.38^{A}	1.63^{A}	93.65^{A}	35.65^{A}	29.50^{A}	29.60^{C}
N_1	3.00^{AB}	32.14^{B}	1.41^{B}	15.09^{B}	1.54^{B}	92.52^{B}	34.44^{AB}	26.36^{B}	34.26^{B}
N_2	2.92^{B}	29.56^{C}	1.32^{C}	13.38^{C}	1.46^{C}	92.34^{B}	33.01^{B}	25.57^{B}	36.73^{A}
N_3	2.96^{B}	30.54^{C}	1.35^{C}	13.90^{C}	1.45^{C}	92.38^{B}	33.13^{B}	25.94^{B}	36.18^{AB}
S.Ed(±)	0.05	0.66	0.03	0.34	0.02	0.10	0.83	0.92	1.16
LSD (*P*=0.05)	0.10	1.39	0.05	0.72	0.05	0.20	1.75	1.93	2.43

Note: N_0: Control; N_1: 100% RDF; N_2: 75% RDF + PGPR + Panchagavya spray; N_3: 50% RDF + 25% FYM + PGPR + Panchagavya spray.

Quality parameters of fodder oats

Results (Table 2) revealed that NDICP and ADICP (% DM and CP) content remained statistically unaffected due to residual effect of different maize varieties at both cuts. With respect to nutrient management, NDICP (% DM) content was significantly influenced only at second cut. Application of N_2 and N_3 practices (4.94 and 4.91%, respectively) showed remarkably lower NDICP (% DM) content at second cut than control (5.18%). Though, NDICP (% CP) content was significantly differed with INM practices at both cuts. All the nutrient treatments considerably reduced the NDICP (% CP) content over control (46.12 and 53.93%, respectively) at both cuts. Similarly, significantly lower ADICP (% DM) content at first and second cut was obtained with N_2 (2.42 and 2.70%, respectively) and N_3 (2.41 and 2.71%, respectively) practices than control, but remained at par with N_1. For ADICP (% CP) content, significantly lower value at both cuts was obtained with N_2 (19.64 and 19.99%, respectively) and N_3 (24.60 and 25.05%, respectively) practices than N_1 and N_0.

Residual effect of fodder maize varieties could not show significant variations on digestible energy (DE), total digestible nutrients (TDN), net energy for lactation (NEl) and relative feed quality (RFQ) of fodder oats at both cuts (Table 3). However, nutrient management practices showed significant effects on these parameters. At first cut, N_2 (12.61 MJ kg^{-1}) was found statistically similar to N_3 practice (12.60 MJ kg^{-1}) and showed significantly higher DE in comparison to N_1 and N_0. However, at second cut, N_3 and N_2 practices (12.40 MJ kg^{-1} for both) statistically enhanced the DE of fodder oats over N_1 and N_0 (12.22 and 11.93 MJ kg^{-1}, respectively). Application of 100% RDF (N_1) showed significantly higher DE over control at both cuts. In case of TDN, significantly higher value was obtained with N_2 practice (60.29%) at first cut which was at par with N_3 (60.16%) than rest of both treatments. At second cut, N_3 and N_2 practices (58.36 and 58.34%, respectively) were at par with each other and both showed considerably higher TDN over N_1 and N_0 practices. In case of NEl, the N_2 practice (6.14 MJ kg^{-1}) was recorded at par with N_3 practice (6.13 MJ kg^{-1}) and noted prominently higher values over N_1 and N_0 at first cut. While at second cut, N_2 and N_3 practices (5.97 and 5.98 MJ kg^{-1}) were statistically at par and both were found appreciably higher for NEl as compared to N_1 and N_0 (5.83 and 5.60 MJ kg^{-1}, respectively). Likewise, the use of N_2 and N_3 practices (115.1 and 114.5) performed statistically similar and produced higher RFQ over N_1 and N_0 (109.6 and 99.5, respectively). Similar trend was also noticed at second cut.

Addition of organic nutrient sources to soil (FYM and PGPR) along with reduced dose of chemical fertilizers could have provided essential nutrients to crop throughout growing period, hence crops remained free from stress. In addition to this, the foliar application of panchagavya enhanced the quality characters of fodder oats because it contains considerable amounts of N which could have been utilized for the protein synthesis and also other essential plant nutrients in panchagavya could have helped in succulent growth. Similar results were also reported by Kumar *et al*. (2021a) [10] and Kumar *et al*. (2022b) [13].

Table 2: Neutral and acid detergent insoluble crude protein of oats as influenced by residual effect of fodder maize varieties and nutrient management practices (mean of two years)

Treatments	Neutral detergent insoluble crude protein				Acid detergent insoluble crude protein			
	(% DM)	(% CP)	(% DM)	(% CP)	(% DM)	(% CP)	(% DM)	(% CP)
	I Cut		II Cut		I Cut		II Cut	
Residual effect of maize varieties on oats cv. Kent								
African Tall	4.82	40.82	5.00	47.25	2.43	20.60	2.74	25.84
J-1006	4.88	41.42	5.00	47.32	2.46	20.93	2.76	26.10
P-3396	4.89	42.84	5.07	49.60	2.49	21.80	2.79	27.33
S.Ed(±)	0.09	1.40	0.10	1.56	0.06	0.71	0.08	1.14
LSD (*P*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management practices								
N_0	4.97	46.12^{A}	5.18^{A}	53.93^{A}	2.55^{A}	23.57^{A}	2.85^{A}	29.59^{A}
N_1	4.86	41.77^{B}	5.05^{AB}	47.97^{B}	2.47^{AB}	21.24^{B}	2.79^{AB}	26.46^{B}
N_2	4.81	39.13^{C}	4.94^{B}	44.90^{C}	2.42^{B}	19.64^{C}	2.70^{B}	24.60^{C}
N_3	4.80	39.74^{BC}	4.91^{B}	45.43^{BC}	2.41^{B}	19.99^{C}	2.71^{B}	25.05^{C}
S.Ed(±)	0.06	1.11	0.09	1.35	0.05	0.51	0.05	0.60
LSD (*P*=0.05)	NS	2.33	0.20	2.84	0.10	1.08	0.10	1.26

Note: N_0: Control; N_1: 100% RDF; N_2: 75% RDF + PGPR + Panchagavya spray; N_3: 50% RDF + 25% FYM + PGPR + Panchagavya spray

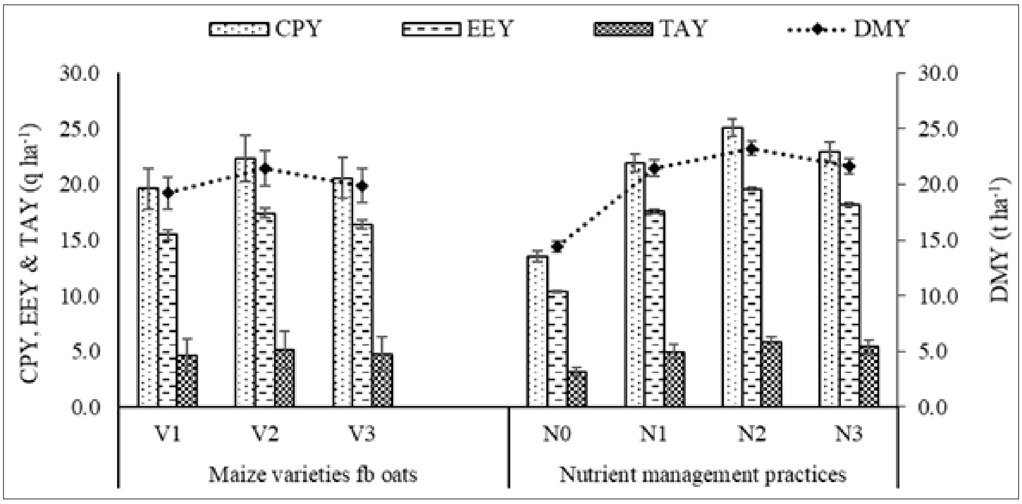
Table 3: Digestible energy, total digestible nutrients, net energy for lactation and relative feed quality of oats as influenced by residual effect of fodder maize varieties and nutrient management practices (mean of two years)

Treatments	Digestible energy (MJ kg^{-1})		Total digestible nutrients (%)		Net energy for lactation (MJ kg^{-1})		Relative feed quality	
	I Cut	II Cut	I Cut	II Cut	I Cut	II Cut	I Cut	II Cut
Residual effect of maize varieties on oats cv. Kent								
African Tall	12.51	12.29	59.36	57.35	6.06	5.89	110.8	101.4
J-1006	12.49	12.22	59.14	56.67	6.04	5.83	109.7	99.4
P-3396	12.45	12.20	58.79	56.49	6.01	5.82	108.5	99.0
S.Ed(±)	0.11	0.10	0.98	0.96	0.08	0.08	2.5	1.0
LSD (*P*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management practices								
N_0	12.28^{C}	11.93^{C}	57.23^{C}	53.93^{C}	5.88^{C}	5.60^{C}	99.5^{C}	88.7^{C}
N_1	12.44^{B}	12.22^{B}	58.72^{B}	56.69^{B}	6.01^{B}	5.83^{B}	109.6^{B}	100.4^{B}
N_2	12.61^{A}	12.40^{A}	60.29^{A}	58.34^{A}	6.14^{A}	5.97^{A}	115.1^{A}	105.1^{A}
N_3	12.60^{AB}	12.40^{A}	60.16^{AB}	58.36^{A}	6.13^{AB}	5.98^{A}	114.5^{A}	105.5^{A}
S.Ed(±)	0.08	0.06	0.71	0.56	0.06	0.05	2.0	1.2
LSD (*P*=0.05)	0.16	0.13	1.48	1.17	0.13	0.10	4.2	2.5

Note: N_0: Control; N_1: 100% RDF; N_2: 75% RDF + PGPR + Panchagavya spray; N_3: 50% RDF + 25% FYM + PGPR + Panchagavya spray

System quality parameters

Data presented in Figure 1 indicated that main plot treatments showed non-significant variation on crude protein, ether extract, total ash and dry matter yields of fodder maize-oats cropping system. While, nutrient management practices showed significant differences on system productivity and quality traits. Application of N_2 practice to both maize and oats significantly enhanced the dry matter, crude protein, ether extract and total ash yields compared with absolute control and 100% RDF through chemical fertilizer. Better growth under integrated nutrient management could be attributed to higher system productivity as well as nutritional yields. These results are in close conformity with findings of Dwivedi *et al*. (2016) [6] in sorghum-wheat and pearl millet-wheat cropping system.



Note: V_1: African Tall *fb* Kent; V_2: J-1006 *fb* Kent; V_3: P-3396 *fb* Kent; 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 indicate the standard error of difference

Fig 1: Dry matter, crude protein, ether extract and total ash yields of system as influenced by maize varieties fb oats and nutrient management practices (mean of two years)

Conclusion

On the basis of two-year experimentation, it can be concluded that growing of maize cv. J-1006 and application of 75% RDF + PGPR + Panchagavya help in enhancing the fodder quality and productivity.

Acknowledgments

Authors are grateful to ICAR-National Dairy Research Institute, Karnal (India) for providing necessary assistance and financial support throughout this study. Authors also thank to ICAR-Indian Agricultural Statistical Research Institute, New Delhi (India) to provide access for analysing data at SAS software.

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