



Productivity and quality enhancement in fodder maize (*Zea mays*) cultivars through nutrient management strategies

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ABSTRACT

The present study has been carried out in *kharif* 2018 and 2019 at ICAR- National Dairy Research Institute, Karnal, with three maize (*Zea mays* L.) cultivars (V_1 : African Tall, V_2 : J-1006; V_3 : P-3396) and four nutrient management strategies (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 revealed that maize cv. J-1006 and African Tall produced significantly high and low dry fodder yield, respectively. Significantly high crude protein (CP), ether extracts (EE) and total ash (TA) yields were recorded with J-1006 during both years. In comparison of nutrient management strategies, the application of 75% RDF + PGPR + Panchagavya spray (N_2) recorded significantly high dry fodder, CP, EE and TA yields. The foliar spray of Panchagavya along with reduced dose of chemical fertilizers, PGPR and/ or FYM (N_2 and N_3) to fodder maize significantly reduced the fibre fractions and improved the nutritive values/ energy (DMI, DMD, TDN and NEI). Our results suggest that selection of J-1006 cultivar and application of 75% RDF + PGPR + Panchagavya spray (N_2) enhances fodder productivity, quality and reduces the fibre fractions.

Keywords: Cultivars, Fodder quality, Panchagavya, PGPR, Productivity

In India 75% farmers are small and marginal holders and livestock is the main source of livelihood for a majority of the rural population (Khamkar 2016). Productivity of the Indian cattle is lower than global average (Anonymous 2020). The main reasons for low productivity are: fodder deficit, availability of poor-quality fodder, genetic potential of breeds, etc. Fodder quality is also as much important as fodder production because 80–90% of nutrient requirements of livestock are met from fodder crops. Currently, India is facing 24.6 and 19.9% deficit of crude protein (CP) and total digestible nutrients (TDN), respectively. The projected scenario of CP and TDN for future 20.78 and 17.52% in 2030 and 16.81 and 15.47% in 2050, respectively (Anonymous 2020). Therefore, enhancement in qualitative fodder production is the way to meet the present and future needs of CP, TDN and dry fodder yield. Agronomically, the fodder productivity and quality can be improved by

selection of suitable crop, cultivars and nutrient management strategies. Cereal crops are well known for higher productivity. Maize (*Zea mays* L.) is a popular fodder for *kharif* and is characterized by a very high yield potential, which is expressed by both biomass production and grain yield (Kumar *et al.* 2019). Fodder maize is free from toxin, thus, can be safely fed to animals at any crop growth stage (Kumar *et al.* 2016).

Being a cereal, nutrient management in maize is an important aspect under Indian soil especially in NW-IGP of India where intensive cereal-cereal cropping system dominates. Inclusion of organic manures results in significant improvement in crop productivity and soil fertility (Bandyopadhyay *et al.* 2010). Plant growth-promoting rhizobacteria (PGPR) augments the growth and yield. Panchagavya containing macro and micronutrients, growth regulatory substances and beneficial microbes, could help in supplying adequate plant nutrients and thus, improving the fodder quality and productivity (Kumar *et al.* 2021). Considering these facts, in the nutrient source (Panchagavya) was prepared and integrated with FYM, PGPR, present study and reduced dose of chemical fertilizers was used.

MATERIALS AND METHODS

Site description: The field experiment was conducted during *kharif* 2018 and 2019 at Research Farm of Agronomy

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Section, ICAR–National Dairy Research Institute, Karnal. The soil of experimental field had pH 7.61, 0.312 dS/m electrical conductivity and 0.63% organic carbon. Available N, P and K were 192.4, 29.71 and 195.7 kg/ha, respectively. The weather conditions during both years of study were congenial to maize growth (supplementary Table 1).

Experimental design, treatments and crop management: The experiment was conducted in split plot design with three replications. In main plot, three cultivars (V_1 : African Tall; V_2 : J-1006; V_3 : P-3396) and in sub-plots, four nutrient management strategies (N_0 : Control; N_1 : 100% RDF; N_2 : 75% RDF + PGPR + Panchagavya spray; N_3 : 50% RDF + 25% FYM + PGPR + Panchagavya spray) were taken for study. Recommended dose of FYM was applied @10.0 t/ha at the time of sowing (as per respective treatments). Recommended dose of fertilizers (N, P_2O_5 and K_2O) were applied @100, 60 and 40 kg/ha through urea, single super phosphate and muriate of potash. Half of N and full dose of P_2O_5 and K_2O was applied as basal and remaining half dose of nitrogen was applied at 26 days after sowing (DAS). Panchagavya was prepared using five cow byproducts along with other ingredients and applied as two foliar spray at 25 and 40 DAS. Seed rate of 45 kg/ha was taken and treated with Mancozeb 75% WP @3 g a.i./kg seeds followed by PGPR (as per treatment) @120 ml/ha seeds and were sown using Pora method.

Fodder sample collection and their quality analysis: Green fodder samples were dried in hot air oven at $65 \pm 5^\circ C$ till constant weight attained. The loss in moisture content after drying was estimated and then, dry fodder yield was calculated. The dried samples were grounded (Wiley mill) for quality analysis. Crude protein (CP), ether extract (EE) and total ash (TA) yields were calculated by multiplying their content (AOAC 2005) with dry fodder yield. The fibre fraction, viz. neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were estimated using Van Soest *et al.* (1991) method. Total carbohydrate (T-CHO) was calculated as sum total of CP, EE and TA subtracted from 100. Structural (SC) and non-structural carbohydrates (NSC); nutritional value/ energy, viz. digestible crude protein (DCP), dry matter intake (DMI), dry matter digestibility (DMD), total digestible nutrients (TDN) and net energy for lactation (NEL) were estimated using following equations:

$$NSC (\%) = 100 - [CP\% + EE + (NDF\% - NDICP\%) + TA\%] \quad (\text{Das et al. 2015})$$

$$SC (\%) = T-CHO\% - NSC\% \quad (\text{Das et al. 2015})$$

$$DCP (\%) = (0.929 \times CP\%) - 3.52 \quad (\text{Demarquilly and Weiss 1970})$$

$$DMI (\%) = \frac{120}{NDF\%} \quad (\text{Horrocks and Vallentine 1999})$$

$$DMD (\%) = 88.9 - (0.779 \times ADF\%) \quad (\text{Horrocks and Vallentine 1999})$$

$$TDN (\%) = (-1.291 \times ADF\%) + 101.35 \quad (\text{Horrocks and Vallentine 1999})$$

$$NEL (\text{Mcal/kg}) = [1.044 - (0.0119 \times ADF\%)] \times 2.205 \quad (\text{Horrocks and Vallentine 1999})$$

A conversion factor of 4.184 was used to convert the values of Mcal/kg to MJ/kg.

Statistical data analysis: Experimental data were analyzed with help of analysis of variance (ANOVA) technique for split plot design using statistical analysis system (SAS) software on ICAR-Indian Agricultural Statistics Research Institute (IASRI) server. Significance among treatment mean differences for various parameters were analyzed by least significant differences (LSD) at 0.05 probability level. Pearson correlations (two tailed) were determined using SPSS software and significance of differences between means were determined at $P=0.05$ and 0.01.

RESULTS AND DISCUSSION

Dry fodder, crude protein, ether extract and total ash yield: Different cultivars significantly affected dry fodder yield (Table 1). Cultivar J-1006 and African Tall recorded highest and lowest dry fodder yield, respectively, during both years. P-3396 cultivar was found to be statistically at par with rest of cultivars. Significant differences among cultivars for dry fodder yield could be ascribed to variation in dry matter content and green fodder yield resulting from dissimilarities in genetic makeup of these cultivars and their responses to climatic conditions. Our results are in contrast with Brar *et al.* (2016). Further results indicated that CP, EE and total ash yields were also influenced significantly by cultivars (Table 1). Cultivars J-1006 and P-3396 showed significantly higher CP, EE and TA yields during 2018 compared to African Tall. While in 2019, the growing of J-1006 cultivar recorded significantly higher CP, EE and total ash yields compared to African Tall, but it was at par with P-3396. The highest CP, EE and TA yields with J-1006 followed by P-3396 among all the three cultivars were ascribed to their higher content and dry fodder yield. These cultivars also recorded superior quality fodder over African Tall (Table 2) which might be due to their specific genetic make-up that caused variation among cultivars for fodder quality traits.

Nutrient management strategies caused significant variations on dry fodder yield (Table 1). The foliar spray of Panchagavya along with 75% RDF and PGPR (N_2) showed significantly higher dry fodder yield compared to N_0 and N_3 , and it was at par with N_1 during 2018. While in 2019, the application of 75% RDF + PGPR + Panchagavya spray (N_2) reported maximum dry fodder yield among all nutrient management strategies. Significant variations in CP, EE and TA yields were also noted due to different nutrient management strategies (Table 1). Application of 75% RDF + PGPR + Panchagavya spray (N_2) recorded highest CP, EE and TA yields amongst all nutrient management strategies during 2018 and 2019. Further comparison showed that N_3 was found at par with N_1 treatment for these attributes, except EE yield during 2019 wherein N_3 showed superiority over N_1 . The inoculation of maize seeds with PGPR enhances

Table 1 Effect of cultivars and nutrient management strategies on dry fodder, crude protein, ether extract and total ash yields of fodder maize during 2018 and 2019

Factor	2018				2019			
	DFY (t/ha)	CPY (%)	EEY (%)	TAY	DFY (t/ha)	CPY (%)	EEY (%)	TAY
<i>Cultivars</i>								
African Tall	9.68 ^B	8.60 ^B	1.81 ^B	6.70 ^B	9.82 ^B	8.85 ^B	1.86 ^B	6.92 ^B
J-1006	12.28 ^A	11.81 ^A	2.44 ^A	9.09 ^A	12.62 ^A	12.28 ^A	2.53 ^A	9.42 ^A
P-3396	10.90 ^{AB}	10.66 ^A	2.18 ^A	8.31 ^A	10.99 ^{AB}	10.80 ^{AB}	2.22 ^{AB}	8.48 ^{AB}
SEd(±)	0.37	0.36	0.07	0.28	0.46	0.50	0.12	0.41
LSD (P=0.05)	1.44	1.41	0.27	1.12	1.80	1.96	0.46	1.62
<i>Nutrient management strategies</i>								
N ₀	8.17 ^C	7.13 ^C	1.49 ^C	5.25 ^C	7.74 ^C	6.62 ^C	1.39 ^D	4.87 ^C
N ₁	11.63 ^{AB}	10.89 ^B	2.19 ^B	8.66 ^B	11.92 ^B	11.19 ^B	2.25 ^C	8.97 ^B
N ₂	12.53 ^A	12.37 ^A	2.56 ^A	9.54 ^A	12.96 ^A	12.99 ^A	2.69 ^A	10.01 ^A
N ₃	11.48 ^B	11.03 ^B	2.33 ^B	8.68 ^B	11.96 ^B	11.78 ^B	2.49 ^B	9.23 ^B
SEd(±)	0.31	0.31	0.07	0.21	0.28	0.30	0.07	0.22
LSD (P=0.05)	0.93	0.92	0.22	0.63	0.84	0.90	0.20	0.65

N₀, Control; N₁, 100% RDF; N₂, 75% RDF + PGPR + Panchagavya spray; N₃, 50% RDF + 25% FYM + PGPR + Panchagavya spray; DFY, Dry fodder yield; CPY, Crude protein yield; EEY, Ether extract yield; TAY, Total ash yield. Same letter within each column indicate non-significant difference among the treatments using LSD test (P<0.05).

the crop yield through N fixation, phytohormone production, viz. IAA, cytokinin and GA₃, siderophore production, P and K solubilization, etc. The Panchagavya contains all essential nutrients, plant growth hormones, vitamins and secondary metabolites (Khan *et al.* 2017), hence, its foliar spray might have enabled the maize to produce more yield. Adequate supply of macro as well as micronutrients throughout crop growth period by applying inorganic and organic nutrient sources might be the reason for higher dry fodder production. Significantly higher values of CPY, EEY and TAY under N₂ treatment were associated to higher dry fodder yield and their respective content.

Fibre fractions: Different cultivars did not show significant variations on fibre fractions, i.e. NDF, ADF and ADL content (Fig 1). Though, nutrient management strategies caused significant variations in fibre fractions, except ADF in 2018 (Fig 1). The NDF content was significantly lowered due to nutrient application (N₁, N₂ and N₃) compared to control during both years. In 2019, the use of N₂ and N₃ treatments showed significant reduction in ADF content compared to N₀, but was at par with N₁. In context of ADL content, significantly low values were obtained with N₂ and N₃ treatments compared to N₀ during 2018. While in 2019, all the nutrient treatments (N₁, N₂

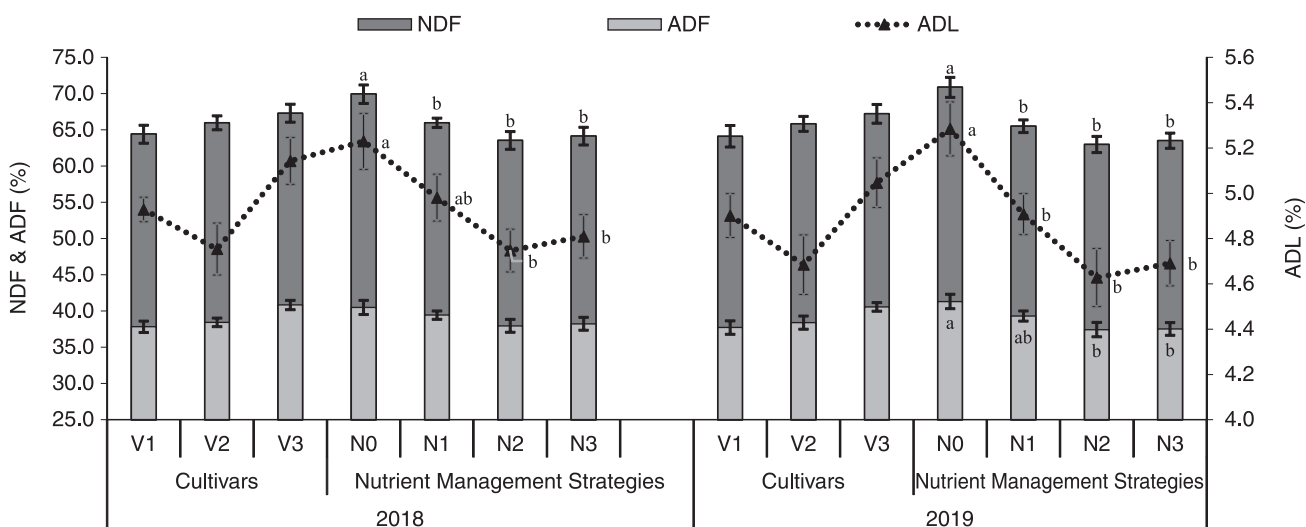


Fig 1 Effect of cultivars and nutrient management strategies on fibre fractions of fodder maize.

Table 2 Effect of cultivars and nutrient management strategies on nutritional values of fodder maize during 2018 and 2019

Factor	2018					2019				
	DCP	DMI	DMD	TDN	NEI	DCP	DMI	DMD	TDN	NEI
	(%)				MJ/kg	(%)				MJ/kg
<i>Cultivars</i>										
African Tall	4.68 ^B	1.87	59.43	52.51	5.48	4.78 ^B	1.88	59.51	52.65	5.49
J-1006	5.36 ^A	1.82	58.95	51.72	5.41	5.42 ^A	1.83	58.99	51.79	5.42
P-3396	5.50 ^A	1.79	57.09	48.63	5.15	5.51 ^A	1.79	57.29	48.96	5.18
SEd(±)	0.15	0.03	0.54	0.90	0.08	0.13	0.03	0.61	1.01	0.09
LSD (P=0.05)	0.61	NS	NS	NS	NS	0.52	NS	NS	NS	NS
<i>Nutrient management strategies</i>										
N ₀	4.57 ^C	1.72 ^B	57.35	49.07	5.19	4.41 ^C	1.70 ^B	56.72 ^B	48.01 ^B	5.10 ^B
N ₁	5.15 ^B	1.82 ^A	58.17	50.42	5.30	5.20 ^B	1.83 ^A	58.27 ^{AB}	50.59 ^{AB}	5.31 ^{AB}
N ₂	5.62 ^A	1.89 ^A	59.33	52.34	5.46	5.75 ^A	1.91 ^A	59.74 ^A	53.02 ^A	5.52 ^A
N ₃	5.38 ^{AB}	1.88 ^A	59.11	51.99	5.43	5.59 ^A	1.89 ^A	59.67 ^A	52.91 ^A	5.51 ^A
SEd(±)	0.11	0.03	0.53	0.87	0.07	0.11	0.03	0.59	0.98	0.08
LSD (P=0.05)	0.34	0.09	NS	NS	NS	0.34	0.08	1.76	2.92	0.25

N₀, Control; N₁, 100% RDF; N₂, 75% RDF + PGPR + Panchagavya spray; N₃, 50% RDF + 25% FYM + PGPR + Panchagavya spray; DCP, Digestible crude protein; DMI, Dry matter intake; DMD, Dry matter digestibility; TDN, Total digestible nutrients; NEI, Net energy for lactation. Same letter within each column indicate non-significant difference among the treatments using LSD test (P<0.05).

and N₃) showed statistically similar and low ADL content than N₀. Since, fibre fractions, viz. NDF, ADF and ADL are negatively correlated with CPY, EEY and TAY, it may be one reason for lowering the fibre fractions. On the other hand, integrated use of organic and inorganic nutrient sources 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 reduces the fibre fractions significantly (Yadav *et al.* 2007).

Carbohydrate fractions: The T-CHO content (Fig 2) significantly varied with cultivars, but NSC and SC content remained statistically unchanged. Cultivars J-1006 and P-3396 showed significantly lower T-CHO content compared to African Tall during 2018 and 2019. In case of nutrient management strategies (Fig 2), significantly low T-CHO content was noted with N₂ and N₃ treatments during both years. The NSC content was not influenced significantly during 2018. While in 2019, all the applied nutrient treatments (N₁, N₂ and N₃) showed significantly higher NSC content compared to control. The reverse trend of NSC was noted for SC content during 2018 and 2019. Carbohydrate fractionation showed that higher CP accumulation under plots receiving N₂ and N₃ treatments resulted lower T-CHO content. These could be due to the fact that CPY and T-CHO content are very strongly and negatively correlated with each other. Further, studies revealed that NSC content was significantly higher under nutrient applied treatments (N₁, N₂ and N₃) compared to control and the trend was reverse to SC. Das *et al.* (2015) also reported that NSC is more digestible than SC and it follows the trend similar to CP.

Nutritional values/energy: Data (Table 2) showed that

DCP content was significantly influenced by cultivars, but other parameters remained statistically unaffected. Cultivars J-1006 and P-3396 were found at par and recorded higher DCP content compared to African Tall during 2018 and 2019. In case of nutrient management strategies (Table 2), N₂ treatment significantly improved the DCP content compared to N₀ and N₁ during 2018. Nevertheless in 2019, the use of N₂ and N₃ strategies were found at par and recorded significantly higher DCP content compared to N₀ and N₁. For dry matter intake (DMI), all the applied nutrient treatments were observed to be at par and showed significantly higher values compared to control during 2018 and 2019. Nutrient management strategies did not cause significant differences on DMD, TDN and NEI during 2018. Though in 2019, N₂ and N₃ treatments significantly improved the DMD, TDN and NEI content compared with control. The DMI and TDN are negatively correlated with NDF content. Hence, decrease in the NDF content led to higher DMI and TDN. The DMD and NEI are negatively correlated with ADF content. Hence, the reduction in fibre content under INM plots (N₂ and N₃) led to enhanced DMI, DMD, TDN and NEI (Table 2). The higher value of these fodder quality parameters due to lower fibre fractions were also reported by Salama and Zeid (2016).

Correlation studies: Correlation studies during 2018 (data in supplementary file) indicated that relationship between DFY vs. CPY (r=0.977), EEY (r=0.980), TAY (r=0.975) was strong positive; vs. NDF (r= -0.459), ADL (r= -0.545) was moderate negative; vs. T-CHO (r= -0.745) was strong negative; vs. DCP (r=0.674) was strong positive; vs. DMI (r=0.442) was moderate positive and significant at P<0.01. While in 2019, results showed that correlation between DFY vs. CPY (r=0.981), EEY (r=0.977), TAY

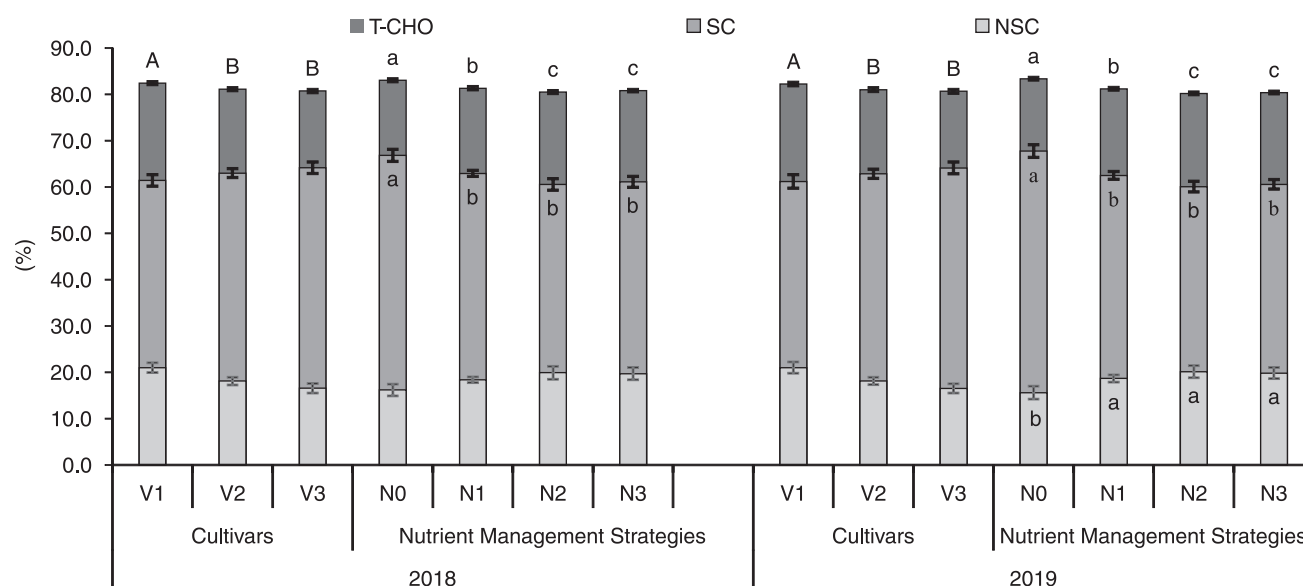


Fig 2 Effect of cultivars and nutrient management strategies on carbohydrate fractions of fodder maize. V1: African Tall; V2: J-1006; V3: P-3396; N0: Control; N1: 100% RDF; N2: 75% RDF + PGPR + Panchagavya spray; N3: 50% RDF + 25% FYM + PGPR + Panchagavya spray; T-CHO: Total carbohydrates; NSC: Non-structural carbohydrates; SC: Structural carbohydrates; Vertical bars/ lines labelled with different upper- and lower-case letters shows the significant variations among cultivars and nutrient management strategies, respectively using LSD ($P=0.05$); Capped lines indicate the standard error of mean.

($r=0.982$) was strong positive; vs. NDF ($r=-0.485$), ADF ($r=-0.489$), ADL ($r=-0.662$) was moderate negative; vs. T-CHO ($r=-0.819$), DCP ($r=0.764$) was strong positive; vs. TDN ($r=0.489$), DMI ($r=0.462$) was moderate positive and significant at $P<0.01$.

From the present study, it is concluded that selection of J-1006 cultivar and application of 75% RDF + PGPR + Panchagavya spray enhances fodder productivity, quality and reduces the fibre fractions.

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