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Quality characteristics and nutrient yield of fodder maize (*Zea mays*) as influenced by seeding density and nutrient levels in Indo-Gangetic Plains

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ABSTRACT

Productivity and quality traits of forage crops are largely affected by agronomic management at field conditions in different climatic strata. Therefore, the present field investigation was carried out during *kharif* season of 2014 and 2015 at ICAR-NDRI, Karnal to evaluate the effect of different planting densities and fertility levels on nutritive yields and quality of fodder maize (*Zea mays* L.). An experiment was laid out in split plot arrangement with three treatments in main-plot of planting densities of 60, 75 and 90 kg seed/ha and six treatments in subplot of nutrient levels, i.e. 0, 50, 75, 100, 125 and 150% recommended dose of fertilizer (RDF), i.e. 120 kg N/ha and 60 kg P_2O_5/ha. All the seed rates were found statistically at par for all the parameters except fiber fractions, i.e. neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) content, in which 60 kg/ha seed rate accumulated significantly lower fiber contents. However, numerically higher values of fodder yields and quality parameters were observed at lower planting density. Nutrient levels showed significant increase in fodder yields with increase in dose of fertility up to 125% RDF. The combined use of 60 kg/ha seed rate and 125% RDF obtained significant maximum green (61.7 t/ha) and dry fodder yield (14.1 t/ha). The results showed that use of 150% RDF improved CP content by 20.2%, ether extract by 20.1% and ash content by 23.3% over control. Further, the maize fodder supplied with 150% RDF attributed minimum level of fiber fractions and magnitude of reduction in NDF was 3.49%, ADF was 3.54% and that of ADL was 7.65% in comparison to 0% RDF. The combination of 60 kg/ha seed rate and 125% RDF obtained significant maximum CP (1542.1 kg/ha), EE (367.4 kg/ha) and ash yield (1280.0 kg/ha). The use of 150% RDF also resulted into improvement in the nutrient content to the tune of 20.2% in N and 12.5% in P and enhanced nutrient uptake by 50.5% of N and 41.9% that of P over control. It can be concluded that to realize higher productivity with enhanced quality of fodder maize with optimum density (60 kg/ha) and use of 125% of RDF are quite helpful, which will further strengthen and sustain the performance of livestock in terms of health and milk production.

Key words: ADF, ADL, CP, EE, Fodder maize, NDF, Yield

Maize (*Zea mays* L.) is one of the most versatile and multi utility cereal and commonly known as queen of cereals due to its highest genetic yield potential and wider adaptability under diverse agro-ecological conditions. Among cultivated forage crops, maize is most suitable crop for fodder as well as silage because of its high yielding ability and excellent nutritional profile. Besides, it is served as source of food, feed and industrial raw material and provides enormous opportunity for crop diversification, value addition and employment generation. Worldwide, maize is an ideal fodder crop because of its quick growing nature, succulency, palatability and excellent quality without any anti-nutritional factor; when harvested at any stage of crop growth.

Multi-environmental, cultural and genetic factors were reported to influence maize forage yield and quality. Among these plant density and nutrient management are of prime importance (Jat *et al*. 2017). Therefore, maize producers require more information on how balance nutrition and plant density can affect green fodder, dry matter yield and forage quality particularly fiber fractions. The farmers using higher plant density than the recommendation and use of fertilizers is also not matching with increased densities/seed rate. Forage maize responds differently to plant densities under different environmental and cultural factors, which influence maize forage yield and quality. Density affected positively to forage yield and most of its quality components (Carpici

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et al. 2010). However, in contrast to this Widdicombe and Thelen (2002) reported that crude protein content of forage maize was negatively associated with plant density. NDF was affected by plant densities in some studies (Iptas and Acer 2006) but it was unaffected in other studies (Cox and Cherney 2001). Stem percentages increased as plant densities increased. Hence, the relationships between plant density, yield and quality parameters are not static under all environmental conditions.

Likewise, optimum rate of nutrient depends on numerous variable factors such as environmental conditions, management systems including management of plant density (Cox and Cherney 2001, Hamid and Nasab 2001, Sahar *et al*. 2005, Carpici et al. 2010, Jat *et al*. 2013). NPK fertilization of maize influences DM yield by influencing leaf area index, leaf area duration and photosynthetic efficiency (Muchow 1988). There were positive effects of recommended fertilizer doses on DM yield and forage quality (Sahar *et al*. 2005). Furthermore, nutrient requirement of fodder crops may alter with change in plant densities. In recent past worldwide studies on maize focused mainly on production of maize for green fodder and silage. Hence, studies are required to establish relationship between plant density and nutrient levels to achieve attainable yield with good quality parameters of green fodder of maize and silage. With this hypothesis the current study was planned to access limited information about cause and effect relationship between plant densities and yield and nutritive quality of fodder maize with various fertility levels in agro climatic conditions of Indo-Gangetic Plain of India,

MATERIALS AND METHODS

A field experiment was conducted during *kharif* season of 2014 and 2015, at research farm (29º68' N, 76º99' E and at an altitude of 257 m above mean sea level) of Forage Research and Management Centre, ICAR-NDRI, Karnal, Haryana. The climate of the study area is semi-arid, with a mean annual rainfall of 650 mm (70-80% of which received during monsoon season) with the mean annual evaporation of 850 mm. The mean minimum, maximum temperature and total rainfall during this study period of *kharif* 2014 and 2015 (June- August) was 23.7ºC, 33.3ºC and 451 mm, respectively. The soil of experimental site (before *kharif* 2014) was sandy clay loam in texture with 7.8 pH, Walkley–Black C (0.61%), EC (0.32 dS/m), $KMnO_4$ oxidizable N (202.8 kg/ha), 0.5 M $NaHCO_3$ extractable P (20.4 kg/ha) and 1 N NH_4OAC extractable K (290.5 kg/ha). The experiment was laid out in split plot design with three seed rates 60 (S_1), 75 (S_2) and 90 (S_3) kg/ha in main plot and six fertility levels in subplots 0 (F_0), 50 (F_1), 75 (F_2), 100 (F_3), 125(F_4) and 150% (F_5) of recommended dose of fertilizer (RDF- 120 kg N+ 60 kg P_2O_5/ha) with three replications at fixed site. The each experimental unit consisted of 5.0 m × 3.4 m size plots.

The field was deep ploughed by chisel plough to break the hard pan below the plough layer and laser leveled before start of the experiment. The land preparation involved one ploughing each with cultivator, disc harrow and thereafter planking. During both the years the crop was sown on 5 June, 2014 and 1 June, 2015, respectively using seed rate as per the treatments with spacing of 30 cm row to row. As per treatments different percentages of recommended dose of fertilizers were applied. The full dose of P and half dose of N were applied at the time of sowing and remaining half N was top dressed as urea at 30 days after sowing. In view of best weed management, atrazine @ 1.0 kg a.i./ha was applied as pre-emergence (PE) to control weeds.

The crop was harvested manually at the age of 65 days when crop approached 50% flowering in the field. Fresh fodder yield was recorded and samples were collected and subjected to laboratory for analysis of different quality parameters. Plant samples collected at harvest were dried in hot air oven at 60°C for 48 hours. These oven-dried samples of plants were ground to pass through 40 mesh sieve in a Macro-Wiley Mill and used for chemical analysis. Finally milled sample were analyzed for DM (AOAC 2005, method 934.01), ash (AOAC 2005, method 942.05) and Kjeldahl nitrogen (AOAC 2005, method 984.13). Ether extract (EE) was analyzed according to AOAC (2005, method 920.39). Crude protein content in corn fodder was determined by multiplying the N concentration by 6.25. Neutral detergent fiber was assessed by the using procedures of Van Soest *et al*. (1991), without heat stable amylase and sodium sulfite for roughages. Acid detergent fiber was analyzed according to AOAC (2005, method 973.18). Both neutral detergent fiber and acid detergent fibers were expressed without residual ash. P in straw samples was analysed by vanadomolybdophosphoric acid yellow colour method (Prasad *et al*. 2006). Thereafter, the uptake of the N and P was calculated by multiplying their concentrations with respective plot yield of maize stover and expressed in kg/ha.

All data recorded were analyzed with the help of analysis of variance (ANOVA) technique (Gomez and Gomez 1984) for split-plot design using SAS 9.3 software (SAS Institute, Cary, NC). The least significant test was used to decipher the main and interaction effects of treatments at 5% level of significance ($P<0.05$).

RESULTS AND DISCUSSION

Effect on fodder yields

Seed rates did not show significant effect on both green and dry fodder yields of maize (Fig 1). However, the maximum green and dry fodder yields were reported with use of 60 kg/ha seed rate and successive increase in seed rate slightly reduce the fodder yields. Higher competition for available nutrients and other resources at higher seed rate leads to reduction in the fresh as well as dry fodder yield. Moreover, thin stem at higher plant density which makes plants susceptible to lodging and ultimately lower photosynthetic efficiency of plants and reduction in final fodder yield (Kumar *et al*. 2016). These outcomes of our study are in line with the results reported by Yilmaz *et al*. (2007). Fertility levels were significantly increase in dry

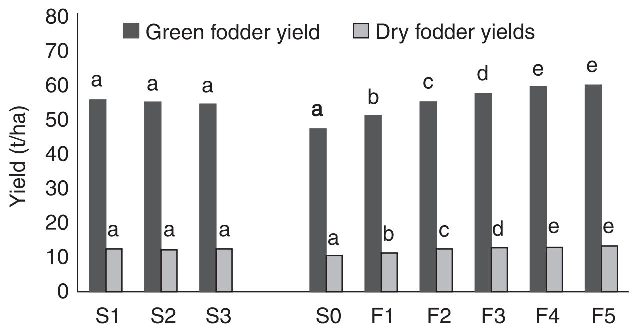

Fig 1 Main effect of plant density and fertility levels on green and dry fodder yield (t/ha) of fodder maize (Pooled basis).

and green fodder yields of maize with increase in fertility level up to 125% RDF (Fig 1). However, the maximum green and dry fodder yields were noted with 150% RDF, which remains at par with 125% RDF. Since, nitrogen along with phosphorus is known as important constituents for cell division and cell elongation. Their beneficial effect on the growth characters (Kumar *et al*. 2016), viz. plant height, number of leaf, leaf length and leaf width which might be improved photosynthetic source of plants that cumulatively contributed to higher fodder yields. The results of our study are in close association with the earlier results reported by Ayub *et al*. (2002) and Eltelib *et al*. (2006).

The interaction effect of plant density and fertility levels was also found significant and a crossover negative interaction noted in both green and dry fodder yields (Fig 2). Seed rate 60 kg/ha and fertility level (125% RDF) obtained significantly higher green (61.7 tonnes/ha) and dry fodder yield (14.1 tonnes/ha) on the basis of pooled analysis. Both green and dry fodder yields were showing declined trend at higher fertilizer rates. At lower seed rate (60 kg/ha) response to applied fertilizer was significant up to 125 % RDF while at higher plant density significant response was observed only up to 75% RDF. This means that at higher seed rate the efficiency of applied fertilizer will be reduced. The use of higher seed rate gave thinner stem (Kumar *et al*. 2016) and makes the plants more susceptible to lodging that disrupt the input output relationship of photosynthetic activity, which, further reflected in terms of lower fodder yields in this treatment. Similar results also reported by Carpici *et al*. (2010).

Effect on fodder quality

Effect of seed rates on forage quality parameters, i.e. crude protein content, ether extract and ash content of maize were found non-significant (Table 1). However, maize planted with lower seed rate (60 kg/ha) resulted into maximum values of aforesaid quality parameters. Patricio Soto *et al*. (2002) also reported similar results, but Widdicombe and Thelen (2002) observed that crude protein, ether extract and ash content of forage maize increased with increasing the plant density. The reduction in contents of these proximate parameters in our study at higher seed rates might be due to the fact that over competition of crowded plant population for available resources which left individual plants weaker that resulted to lodging of plants. Over competition and lodging of plants also make less energy available for conversion of nutrients into proximate parameters, viz. protein and fat. Increasing levels of fertility increases the forage quality parameters, i.e. crude protein content, ether extract and ash content (Table 1). The significantly higher value of these parameters recorded with the 150% RDF as compared to lower dose of fertilizer but remained at par with 125% RDF. The treatment supplied with 150% RDF improved CP content by 6.6, 9.3, 15.4 and 20.2%, ether extract by 6.2, 9.2, 15.1 and 20.1% and ash content by 9.9, 13.1, 21.3 and 23.3% over 100% RDF, 75% RDF, 50% RDF and 0% RDF, respectively. The higher crude protein content with higher dose of fertilizer may be due to the fact that optimum levels of nitrogen and phosphorus in the plants are known to enhance nitrogen uptake thus nitrogen plays a critical role in protein synthesis. Significant improvement of ash and ether extract content might be due to fact that the higher availability of major nutrients promote the growth and dry matter accumulation capacity of the plants and synergistic effect of phosphorus

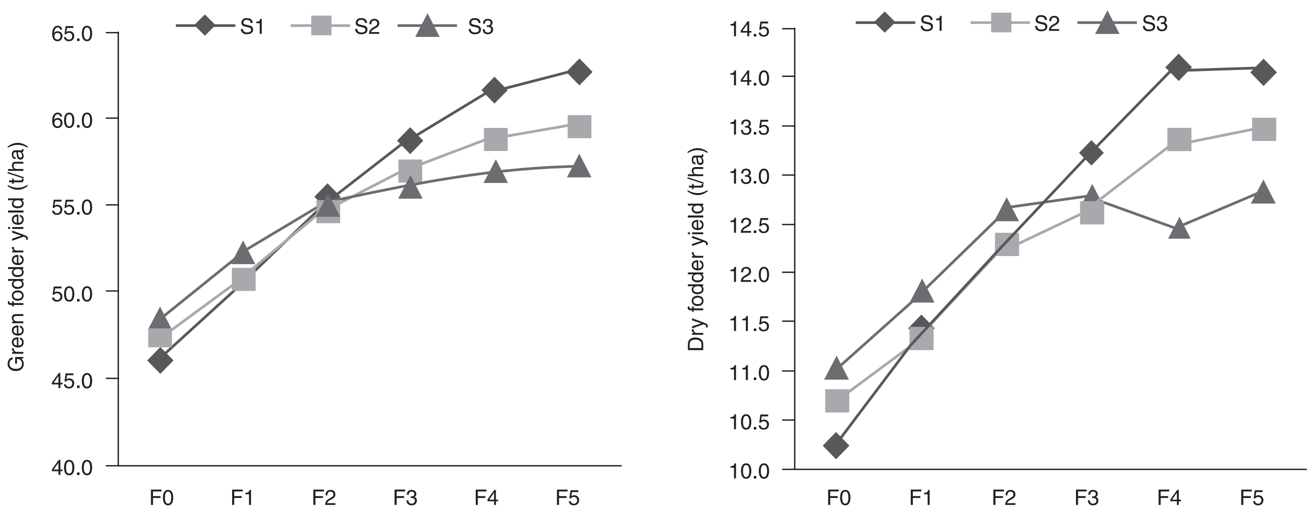

Fig 2 Interaction effect of plant density and fertility levels on green fodder yield (t/ha) of fodder maize (Pooled basis).

Table 1 Effects of seed rate and fertilizer levels on quality parameters, fiber fractions and nutrient yield (kg/ha) of fodder maize (Pooled basis)

Treatment	CP (%)	EE (%)	Ash (%)	NDF (%)	ADF (%)	ADL (%)	CP (kg/ha)	EE (kg/ha)	Ash (kg/ha)
Seed rate									
S_1-60 kg/ha	9.92	2.36	7.89	65.48	43.57	4.98	1260.61	300.32	1005.76
S_2-75 kg/ha	9.41	2.24	7.56	68.11	45.31	5.15	1165.69	277.65	937.84
S_3-90 kg/ha	9.21	2.19	7.67	69.59	46.31	5.32	1139.36	271.26	946.27
SEm±	0.59	0.14	0.39	0.69	0.48	0.04	128.78	30.78	98.43
CD(P=0.05)	NS	NS	NS	1.91	1.34	0.10	NS	NS	NS
Fertilizer rate									
F_0- Control	8.58	2.04	6.93	69.07	45.96	5.33	925.24	220.14	741.72
F_1-50 RDF*	8.94	2.13	7.05	68.51	45.64	5.28	1034.76	246.56	816.12
F_2-75 RDF	9.44	2.25	7.56	67.78	45.09	5.14	1172.33	279.14	939.38
F_3-100 RDF	9.68	2.31	7.78	67.38	44.82	5.14	1253.24	299.05	1007.79
F_4-125 RDF	10.12	2.41	8.36	66.96	44.53	5.10	1353.78	322.53	1120.57
F_5-150 RDF	10.32	2.45	8.55	66.66	44.33	4.92	1391.97	331.04	1154.14
SEm±	0.26	0.06	0.23	0.25	0.18	0.04	40.39	9.62	36.76
CD(P=0.05)	0.54	0.13	0.47	0.50	0.37	0.08	82.48	19.65	75.08

*RDF- Recommended dose of nitrogen and phosphorus, i.e. 120 kg N/ha + 60 kg P_2O_5/ha

on availability of nitrogen further add in the enhancement of these quality parameters. These results are in agreement with the findings of Iptas and Acar (2006).

Increasing plant densities increased the fiber fractions and the highest value of NDF (69.6%), ADF (46.3%) and ADL (5.3%) were recorded at 90 kg/ha seed rate (Table 1). However, maize planted with 60 kg/ha seed rate resulted into lowest values of these parameters. This treatment reported significant reduction in the fiber fraction, i.e. NDF, ADF, ADL in the magnitude of 3.9, 3.9, 3.3% and 5.9, 5.9, 6.5% over the maize planted using 75 and 90 kg/ha seed rate, respectively. The reduction in aforesaid fiber fraction may be due to the negative correlation with CP and EE as these were at maximum concentration at lower density. Further better ash and nutrient contents as well as uptake at lower plant density also favoured CP and EE rather than fiber fractions. Fiber fractions particularly ADL was found maximum with higher seed rate which might be due to the fact that with increase in plant density the surface area exposure of outer covering of stem was also increased. The validation of this hypothesis is reflected from maximum lignin content, i.e. ADL with higher plant density. NDF, ADF and ADL content of the fodder also significantly affected through fertility levels (Table 1) and showed declining trend with increase in fertility levels. The maximum NDF, ADF and ADL contents (pooled average basis) were reported with 0% RDF (66.7, 44.2, and 4.9 %), while lowest with 150% RDF (64.30, 41.56, and 5.20 %), respectively. However, these parameters of fodder maize fertilized with 125% RDF were found at par with 150% RDF. The maize fodder supplied with 150% RDF attributed minimum level of fiber fractions and magnitude of reduction in NDF was to the tune of 3.49, 2.70, 1.65, 1.07 and 0.45%, ADF was 3.54, 2.88, 1.67, 1.09 and 0.45% and that of ADL was 7.65, 6.79, 4.25, 4.25 and 3.62 % in comparison to 0% RDF, 50% RDF, 75% RDF, 100% RDF and 125% RDF, respectively. The results could be attributed to the fact that higher supply of nitrogen along with phosphorus resulted into higher protein synthesis and lowered the soluble carbohydrates which could be responsible for lower content of NDF, ADF and ADL in fodder of maize. Similar results also reported by Cox and Cherney (2001), Hamid and Nasab (2001) and Patricio Soto *et al*. (2002).

Effect on nutrient yields

The analysis of experimental data (pooled basis) shows that likewise nutrient contents, the effect of seed rate on nutrient yields, i.e. crude protein, ether extract and ash yield were also found non-significant (Table 1). However, maize planted with seed rate of 60 kg/ha yielded maximum CP (1260.6 kg/ha), EE (300.2 kg/ha) and ash yield (1005.8 kg/ha).It has been reported that with the increasing seed rate there was reduction in nutrient yields in both the years as well as pooled basis. Further, the nutrient yields parameters i.e. crude protein, ether extract and ash yield were also significantly affected through fertility levels and increasing trend of these parameters observed with increased fertility levels. The maize fodder received 150% RDF attributed maximum values of CP (1391.97 kg/ha), EE (343.23 kg/ha) and ash yield (1154.14 kg/ha). The application of 150% RDF resulted into enhancement in the nutrient yield with the magnitude of 2.8, 11.1, 18.7, 34.5 and 50.5 in CP; 2.6, 10.7, 18.6, 34.3 and 50.4% in EE and 3.0, 14.5, 22.9, 41.4 and 55.6% in ash yield over 125% RDF, 100% RDF, 75% RDF, 50% RDF and 0% RDF, respectively.

Moreover, the combined effects of seed rate and fertility levels on nutrient yield were also found significant. The combination of 60 kg/ha seed rate and fertility level (125%

RDF) obtained significant maximum CP (1542.1 kg/ha), EE (367.4 kg/ha) and ash yield (1280.0 kg/ha). At the lower seed rate (60 kg/ha) response to the applied fertilizer in terms of nutrient yields were found significant up to 125 % RDF while at higher plant density significant response was observed only up to 75% RDF. It means with the increasing seed rate, efficiency of applied fertilizer for nutrient yield was reduced. This may be due to fact that weaker stem at higher seed rate leads to lodging as well as reduction in photosynthetic activity, which, further reflected in lower nutrient yields with the use of higher seed rate. Further, the nutrient yields were calculated using dry matter yield and nutrient contents that is why it followed the same trend as that of dry matter yield. Similarly improvement in dry matter yield at lower plant density was also reported by Carpici *et al*. (2010).

Effect on N and P content and uptake

The chemical analysis of fodder maize showed that seed rate did not affect the content and uptake of the nitrogen and phosphorus (Table 2). However, the maize planted using 60 kg/ha seed rate resulted into maximum nitrogen (1.6%) as well as phosphorus content (0.21%). This treatment also showed superiority in term of nutrient uptake and recorded maximum nitrogen (201.7 kg/ha) and phosphorus uptake (27.5 kg/ha). Both content as well uptake of nitrogen and phosphorus reduced with increasing seed rate. However, the fertility levels had significant effect on nutrient contents as well as their uptake by fodder. The maize supplied with 150% RDF approached maximum nitrogen (1.7%) and phosphorus content (0.23%). However, it was remains at par with the treatment that received 125% RDF. Likewise content, the uptake of nitrogen and phosphorus reported to follow the similar trend (Table 2). The treatment supplied with 150% RDF resulted into maximum nitrogen (222.7 kg/ha) and phosphorus uptake (30.7 kg/ha). However, it remains at par with 125% RDF treatment. The use of 150% RDF resulted into improvement in the nutrient content with the tune of 2.0, 6.6, 9.3, 15.4 and 20.2% in nitrogen and 1.3, 5.6, 7.3, 11.5 and 12.5% in P and enhanced nutrient uptake by 2.8, 11.1, 18.7, 34.5 and 50.5% of N and 2.2, 10.1, 16.5, 30.1 and 41.9% that of P over 125% RDF, 100% RDF, 75% RDF, 50% RDF and 0% RDF, respectively.

Table 2 Effects of seed rate and fertilizer levels on N and P content (%) and uptake (kg/ha) in fodder maize (Pooled basis)

Treatment	N content (%)	P content (%)	N uptake (kg/ha)	P uptake (kg/ha)
Seed rate				
S_1-60 kg/ha	1.59	0.2170	201.70	27.49
S_2-75 kg/ha	1.51	0.2119	186.51	26.19
S_3-90 kg/ha	1.47	0.2136	182.30	26.28
SEm±	0.09	0.0062	20.61	2.13
CD(P=0.05)	NS	NS	NS	NS
Fertilizer rate				
F_0- Control	1.37	0.2021	148.04	21.59
F_1-50 RDF*	1.43	0.2039	165.56	23.56
F_2-75 RDF	1.51	0.2118	187.57	26.30
F_3-100 RDF	1.55	0.2154	200.52	27.83
F_4-125 RDF	1.62	0.2244	216.61	29.99
F_5-150 RDF	1.65	0.2273	222.72	30.65
SEm±	0.04	0.0036	6.46	0.71
CD(P=0.05)	0.09	0.0074	13.20	1.45

*RDF- Recommended dose of nitrogen and phosphorus, i.e. 120 kg N/ha + 60 kg P_2O_5/ha.

The combined effect of seed rate and fertility levels over nutrient uptake was also found significant. Use of 60 kg/ha seed rate with 125% RDF recorded maximum nitrogen (246.7 kg/ha) and phosphorus uptake (21.3 kg/ha). Perusal of data showed that at lower seed rate (60 kg/ha) response to applied fertilizer in terms of nitrogen and phosphorus uptake were significant up to 125 % RDF while at higher seed rate the significant response was observed only up to 75% of RDF dose. Similar results also reported by Aslam *et al*. (2011).

Our study demonstrated that use of 60 kg/ha along with application of 125% of RDF (150 kg N and 75 kg P_2O_5/ha) had significant effect on fodder and nutrients yields, quality and nutrient (NP) dynamics of maize fodder. Thus, it can be concluded that to realize higher productivity with enhanced quality of fodder maize optimum seeding density (60 kg/ha) and use of 125% of RDF dose are quite helpful, which will further strengthen and sustain the performance of livestock.

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