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Nitrogen Fertilization Strategies for Forage Maize Genotypes: Agronomic Performance, Nitrogen use Efficiency and Economic Assessment and Determination of Economical N Fertilizer Rate

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ABSTRACT

A field investigation was conducted using factorial experiment in Randomized Block design with seven genotypes and three nitrogen (N) levels (80, 120 and 160 kg N/ha) with three replications at Dr Rajendra Prasad Central Agricultural University, Pusa, Bihar, India during *kharif* season, 2022. The objective of the study was to assess the nitrogen use efficiency, productivity and profitability of forage maize genotypes under different N levels. Among, the genotypes, J-1006 and among N levels, application of 120 kg ha^{-1} registered the maximum green and dry fodder yield and crude protein yield (CPY). The highest partial factor productivity of N fertilizer (PFPN) was recorded with J-1006 (103.3 kg DM/kg N applied) and application of lowest dose i.e. 80 kg/ha (99.1 kg DM/kg N applied) among genotypes and N levels, respectively. J-1006 (Rs 78109 ha^{-1} and 3.62) and application of 120 kg N ha^{-1} (Rs 65716 ha^{-1} and 3.21) was profitable in terms of net returns and B:C ratio among genotypes and N levels, respectively. The economic optimum dose of N for tested fodder maize genotypes was found to be 139 kg/ha.

Keywords Forage maize, Nitrogen use efficiency, Green fodder yield, Profit, Quality.

INTRODUCTION

Agriculture and animal husbandry are always intermingled with each other in rural part of India (Samal *et al.* 2023). Similarly, animal husbandry is one of the important sectors for providing employment and income generation in the rural areas of Bihar and nearly one third of the rural economy is dependent on this sector (ICAR-IGFRI 2022). Total livestock population of Bihar is 36.5 million which contributes to 6.8% of the total livestock population of the nation and is the largest producer of milk in eastern region. Green fodder is an economic source of nutrients for dairy animals (Prajapati *et al.* 2023) and plays a vital role to reduce cost of milk production when included in ration. However, Bihar faces a deficit of 82.73 and 27.59% of green and dry fodder, respectively (ICAR-IGFRI 2022). There is an urgent need to aug-

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ment forage production which is already experiencing challenge from food crops for area expansion in order to cater the demands of rising livestock population in the state. So, increased efforts towards production and productivity enhancement could result in augmented green fodder availability ultimately resulting in increased profits of dairy farmers (Nanda *et al.* 2021). Hence, identifying location specific genotype and nutrient management especially N management could reduce green fodder deficit.

Maize (*Zea mays* L.) is known as queen of cereal because of its highest genetic yield potential among cereal crops. Further, it is also ideal fodder crop due to better nutritional value and palatability. It is also the common silage crop among livestock keepers in the world. It can produce highest green fodder yield with stipulated period among other cereal crops which can provide superior and palatable green fodder. Furthermore, it is a day neutral crop and hence it can be cultivated in any season to provide green fodder for livestocks. The green fodder yield potential of fodder maize can be altered by changing the agronomic practices through selection of high yielding genotype, plant density and irrigation and nutrient management. Further, location specific genotype has a direct effect on fodder yield. Nitrogen is one of the key nutrients for crop production (Maman *et al.* 2006). Improved biomass and fodder quality has been reported through N application (Bramhaiah *et al.* 2018, Sarkar *et al.* 2022). The finding of Satpal *et al.* (2022) suggests improvement of fodder maize yield and quality due to N application. Keeping these facts in mind the current experiment was carried out assess the nitrogen use efficiency, productivity and profitability of forage maize genotypes under varied N levels

MATERIALS AND METHODS

A field experiment was carried out during *kharif* season 2022 under AICRP on Forage Crops and Utilization at Dr Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India. Seven forage maize genotypes (DFH-2, COHM-8, HPQM-28, J-1006, African tall, AFH-7 and PFM-13) and three nitrogen (N) levels (80, 120 and 160 kg N/ha) were accommodated in factorial experiment in Randomized Block Design with three replications where forage maize genotypes and N levels were the first and second factor, respectively. The seeds were sown on 15.07.2022 at 30 cm row spacing using a seed rate of 50 kg/ha. Application of N was done as per the treatments. Half recommended dose of N was applied as basal and rest half of the recommended dose of nitrogen was applied at 30 days after sowing (DAS). Recommended dose of P (60 kg P_2O_5) and K (40 kg K_2O) was applied to all plots before sowing. Urea, DAP and MOP were the fertilizer sources for nitrogen, phosphorus and potassium, respectively. Rest of the cultural operations was carried out as per recommended package of practices. In this study, forage maize was harvested for green fodder when the crop reached 50% tasselling. Fresh weight was measured from the net plot green fodder yield (GFY) was noted. Green fodder of 500 g was taken and kept in hot air oven at 70 ± 2°C temperature to determine the dry matter content for getting dry fodder yield (DFY). Total N of the dried plant sample was determined and it was multiplied by the DFY to get nitrogen uptake. The nitrogen content was multiplied by 6.25 for obtaining crude protein (CP) content. Crude protein yield (CPY) was obtained through multiplication of CP% and DFY. The nitrogen use efficiency was calculated according to Nanda and Nilanjaya (2022) as follows:

PFPN (DMY/kg N applied) = DFY (kg/ha)/ANA (kg/ha)
Where DFY is dry fodder yield in fertilized plot (kg/ha)
ANA is the amount of fertilizer nitrogen applied (kg/ha)

The nitrogen utilization efficiency (NutE) was worked out as per Rostamza *et al.* (2011) and Nanda and Nilanjaya (2022) as follows

NUtE (kg DM/kg N uptake) = DFY (kg/ha)/NU (kg/ha)
Where DFY is the dry fodder yield (kg/ha) and NU is the nitrogen uptake (kg/ha)

The economic evaluation of forage maize production was done considering the cost of inputs from sowing to harvesting and prevailing market price for maize green fodder. Statistical analysis of data was done as per ANOVA for factorial Randomized Complete Block Design (Gomez and Gomez 1984). The response of green forage yield to N fertilizer levels was fitted to quadratic equation ($Y = a + bX + cX^2$) in microsoft excel software with Y as green forage yield in q/ha, a as the intercept and b and c as regression co-efficients. Calculation of the economical N fertilizer rate was done as per Ali and Habib (2022) as follows:

$$\text{Economical N fertilizer rate (kg/ha)} = \frac{\text{Cost of N fertilizer per kg}}{\text{Price of green fodder per quintal}} \times \left(\frac{1}{2c}\right) - \left(\frac{b}{2c}\right)$$

RESULTS AND DISCUSSION

Growth parameters

Genotypes markedly influenced plant height, leaf: stem ratio (LSR), dry matter content of fodder maize (Table 1). The highest plant height (244.7 cm), LSR (0.53) and dry matter content (21.78%) was recorded with DFH-2, African tall and J-1006, respectively. However, these three genotypes recorded statistically similar plant height. The LSR with African tall was substantially higher than other genotypes. The dry matter content of J-1006 was at par with that of HPQM-28 and PFM-13. These findings are in line with the findings of Satpal *et al.* (2022) who also found genotypic variation among fodder maize genotypes for plant height and LSR. Appying 120 kg N/ha recorded the maximum plant height, LSR and dry matter content which was significantly greater than application of 80 kg N/ha. Further enhancement in N dose to 160 kg significantly reduced the plant height and dry matter content. Increased plant height, LSR and dry matter content due to N application have also been reported (Satpal *et al*. 2022).

Table 1.. Growth parameters of fodder maize as affected by genotypes and nitrogen application.

Treatments	Plant height (cm)	L: S ratio	Dry matter (%)
Genotypes			
DFH-2	244.7	0.36	19.19
COHM-8	221.7	0.36	20.01
HPQM-28	201.7	0.42	21.68
J-1006	235.1	0.30	21.78
African tall	233.5	0.53	20.07
AFH-7	209.6	0.44	20.04
PFM-13	213.0	0.36	20.35
SEm ±	4.2	0.01	0.57
LSD (p= 0.05)	12.0	0.03	1.62
N levels (kg/ha)			
80	216.7	0.37	19.94
120	232.8	0.41	21.86
160	218.8	0.40	19.53
SEm ±	2.7	0.01	0.37
LSD (p= 0.05)	7.8	0.02	1.06

Fodder yield, productivity and quality

Green and dry fodder yield, production efficiency (green and dry fodder) and fodder quality (crude protein content and crude protein yield) were markedly influenced by genotypes (Table 2). Genotype J-1006 had the maximum green fodder (539.3 q ha^{-1}) and dry fodder yield (117.5 q ha^{-1}), production efficiency in terms of green (8.02 q ha^{-1} day^{-1}) and dry (1.75 q ha^{-1} day^{-1}) fodder which was at par with African tall in terms of GFY (512.8 q ha^{-1} day^{-1}) and DFH-2 in terms of production efficiency of green fodder (7.47 q ha^{-1} day^{-1}). The highest crude protein content was noted with DFH-2 (7.74%) which was at par with HPQM-28, J-1006 and African tall. However, the crude protein yield of J-1006 (8.8 q/ha) was markedly greater than other genotypes. These findings are in line with those of Satpal *et al*. (2022) who also found

Table 2. Yield, quality and production efficiency of fodder maize as affected by genotypes and nitrogen application.

Treatments	GFY (q ha^{-1})	DMY (q ha^{-1})	GFY (q ha^{-1}day^{-1})	DMY (q ha^{-1}day^{-1})	CP (%)	CPY (q ha^{-1})
Genotypes						
DFH-2	419.7	80.6	7.47	1.43	7.74	6.2
COHM-8	420.7	83.9	6.54	1.30	7.37	6.2
HPQM-28	388.8	84.4	6.14	1.33	7.56	6.4
J-1006	539.3	117.5	8.02	1.75	7.46	8.8
African tall	512.8	102.9	7.34	1.47	7.54	7.8
AFH-7	417.0	83.6	6.73	1.35	7.18	6.0
PFM-13	444.6	90.7	6.54	1.34	7.35	6.7
SEm ±	14.1	3.8	0.22	0.06	0.11	0.3
LSD (p= 0.05)	40.2	10.9	0.64	0.17	0.32	0.9
N levels (kg/ha)						
80	398.4	79.3	6.11	1.22	7.19	5.7
120	477.3	104.4	7.44	1.62	7.56	7.9
160	471.2	92.2	7.36	1.44	7.62	7.0
SEm ±	9.2	2.5	0.15	0.04	0.07	0.2
LSD (p= 0.05)	26.3	7.1	0.42	0.11	0.21	0.6

genotypic variation among fodder maize genotypes for green and dry fodder yield, CP content and CPY. Applying 120 kg N/ha recorded the highest green (477.3 q ha^{-1}) and dry (104.4 q ha^{-1}) fodder yield, production efficiency in terms of green (7.44 q ha^{-1} day^{-1}) and dry (1.62 q ha^{-1} day^{-1}) fodder and crude protein yield (7.9 q ha^{-1}) which was comparable with 160 kg N/ha with respect to GFY (471.2 q ha^{-1}) and production efficiency in terms of green fodder (7.36 q ha^{-1} day^{-1}). However, crude protein content increased with enhancement in N application up to 160 kg ha^{-1} (7.62%) which was at par with that of 120 kg N ha^{-1}.

Nitrogen uptake and use efficiency

Nitrogen uptake and nitrogen use efficiency indices (PFPN and NUtE) were markedly influenced by genotypes (Fig. 1). The highest nitrogen uptake was recorded with J-1006 (140.5 kg ha^{-1}) which was significantly higher than rest of the genotypes whereas the genotype AFH-7 recorded the lowest N uptake (96.2 kg ha^{-1}). These findings are in line with those of Satpal *et al.* (2022) who also found genotypic variation among fodder maize genotypes for nitrogen uptake. The highest PFPN (103.3 kg DM/kg N applied) was noted with J-1006 which was substantially greater than other genotypes whereas genotype DFH-2 (72.1 kg DM/kg N applied) recorded the lowest value. Regarding NUtE, the genotype AFH-7 recorded the highest value (87.2 kg DM/kg N uptake) which was comparable with the genotypes PFM-13, COHM-28 and J-1006. Variation among genotypes with respect

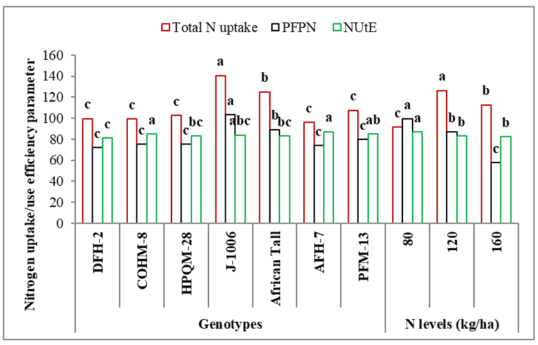

Fig. 1. Nitrogen uptake and its use efficiency by fodder maize as affected by genotypes and nitrogen application. Bars with at least a common letters are not significantly different from each other as per LSD test.

to PFPN of fodder maize has been reported by Satpal *et al.* (2022). With increasing the N levels, the total N uptake increased significantly up to 120 kg N/ha. Further enhancement in N application reduced the N uptake significantly. The highest PFPN (99.1 kg DM/kg N applied) was noted with application of least amount of N (80 kg N ha^{-1}) and PFPN evidenced a decline with enhancement of N levels from 80 to 160 kg N ha^{-1}. The maximum NutE of 87.0 kg DM/kg N uptake was achieved with application of 80 kg N/ha which reduced to 82.2 kg DM/kg N uptake at 160 kg N ha^{-1}. These findings are in line with those of Nanda and Nilanjaya (2022) in forage pearl millet where increase in N application reduced PFPN and NUtE. Declining PFPN with enhancement in N dose was because of smaller rate of increase in dry matter yield per incremental dose of N.

Production economics and economical N fertilizer rate

Gross returns, net returns and B:C ratio were markedly affected by genotypes and nitrogen dose (Table 3). The maximum gross (Rs 107850 ha^{-1}) and net returns (Rs 78109 ha^{-1}) and B:C ratio (3.62) was noted with J-1006 which was at par with African tall. These findings are in line with those of Satpal *et al.* (2022) who also found genotypic variation among

Table 3. Production economics of fodder maize as affected by genotypes and nitrogen application.

Treatments	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
Genotypes			
DFH-2	83932	54191	2.82
COHM-8	84132	54391	2.83
HPQM-28	77769	48028	2.61
J-1006	107850	78109	3.62
African Tall	102553	72812	3.44
AFH-7	83394	53653	2.80
PFM-13	88920	59179	2.99
SEm ±	2814	2814	0.09
LSD (p= 0.05)	8044	8044	0.27
N levels (kg/ha)			
80	79690	50471	2.73
120	95457	65716	3.21
160	94232	63969	3.11
SEm ±	1842	1842	0.06
LSD (p= 0.05)	5266	5266	0.18

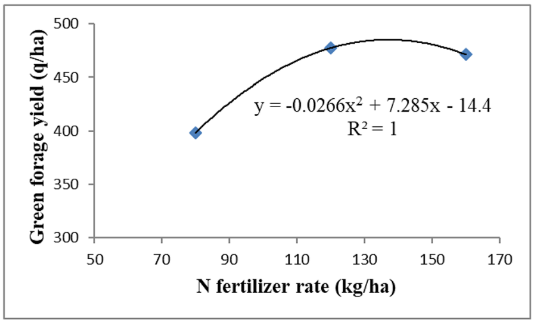

Fig. 2. Fitted quadratic response of green forage yield to applied fertilizer N for tested fodder maize genotypes.

fodder maize genotypes for production economics. Nitrogen application enhanced the gross (Rs 95457 ha^{-1}) and net returns (Rs 65716 ha^{-1}) and B: C ratio (3.21) up to 120 kg/ha. Further, increase in N application recorded similar gross and net returns and B:C ratio. Optimal N fertilizer application is the need for maximizing the framers profit while minimizing the environmental hazards associate with excess N fertilization. Economical N fertilizer rate is the point where change in input cost equals change in value of the produce (Kyveryga *et al*. 2007). The economical optimum N fertilizer rate for fodder maize was found to be 139 kg/ha in the present investigation keeping the cost of N fertilizer per kg as Rs 12.87 and price of green fodder per quintal as 200 (Fig. 2).

Correlation among important parameters

The correlation between important parameters (Fig. 3) depicted that dry matter yield was positively and

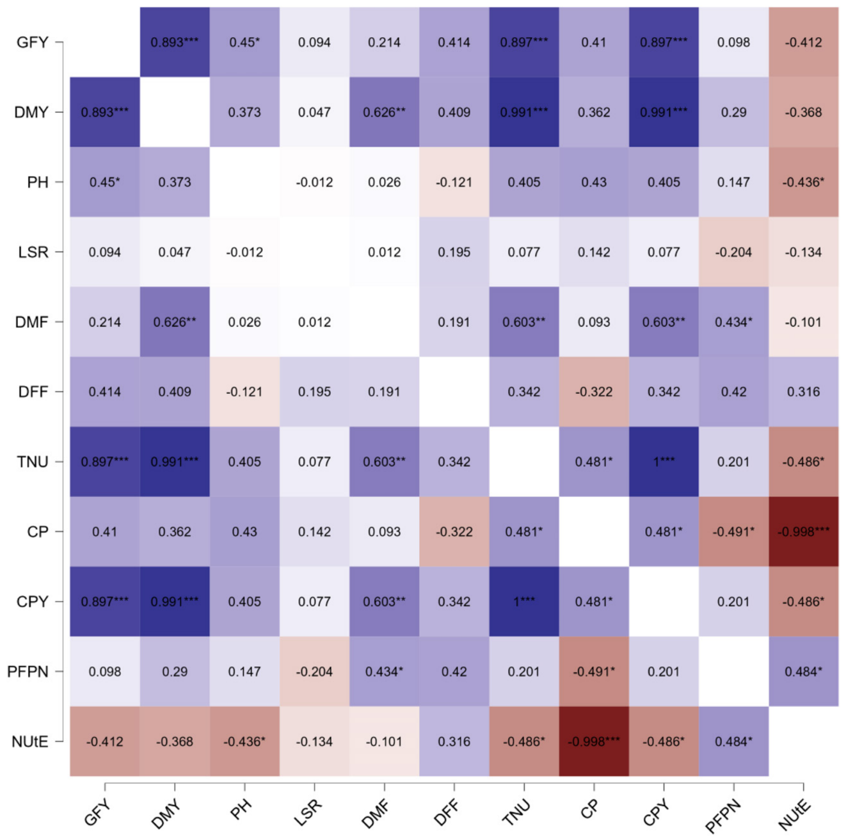

Fig. 3. Correlation among different studied parameters. * p < .05, ** p < .01, *** p < .001; GFY- Green forage yield, DMY, Dry matter yield, PH-Plant height, LSR- Leaf: Stem ratio, DMF- Dry matter fraction, DFF- Days to 50% flowering, TNU- Total nitrogen uptake, CP- Crude protein, CPY- Crude protein yield, PFPN- Partial factor productivity of N fertilizer, NutE- Nitrogen utilization efficiency.

significantly correlated with nitrogen uptake (0.991), crude protein yield (r = 0.991), green forage yield (r = 0.893) and dry matter fraction (r = 0.626). NUtE had a negative and significant correlation with crude protein content (r = -0.998) but positive and significant correlation with PFPN (r = 0.484). Samonte *et al.* (2006) also observed that nitrogen utilization efficiency had a negative correlation with plant nitrogen content and grain protein content. Similarly, PFPN was positively and significantly correlated with DM fraction (r = 0.434) and negatively and significantly correlated with crude protein content (r = -0.491).

CONCLUSION

Findings of the present investigation indicated that genotype J-1006 with application of 120 kg N/ha produced higher yield and quality with profitability for fodder maize under North Bihar condition. The economical optimum N fertilizer rate for tested fodder maize genotypes was found to be 139 kg/ha.

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