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Enhancement of nutrient use efficiency and profitability of teosinte (*Euchlaena mexicana*) fodder production under different nutrient management practices

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Abstract
A field experiment of two years was undertaken during *kharif* (rainy) season of 2012 and 2013 at Forage Research and Management Centre of ICAR-National Dairy Research Institute (NDRI), Karnal on "Efficiency of Nutrient Utilization in Teosinte fodder production under nitrogenous and phosphatic fertilizer application" with the objective of assessing nutrient management practices on the basis of nutrient (N & P) uptake by plant, nutrient use efficiencies (NUEs) and profitable teosinte fodder production with the determination of green fodder yield (GFY), Net return(NR), benefit cost ratio, physical optimum dose (POD) and economical optimum dose (EOD).The experiment was laid out in split plot design with five doses of N (0, 40, 80, 120 and 160 kg ha^{-1}) in main plots and three P_2O_5 doses (0, 30 and 60 $kgha^{-1}$) in sub plots consisted of 3 replications. Teosinte cultivar 'Bihar local' was taken as a test fodder crop. The maximum nutrients (N&P) uptake, highest green fodder yield and maximum profit regarding net return and benefit cost ratio of teosinte fodder production were obtained with the application of 160 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1}. The results revealed that highest apparent recovery efficiency (ARE), Agronomic efficiency (AE), production efficiency (PE) and partial factor productivity (PFP) of nutrients (N&P) was obtained with the application of lowest rate of nutrients (40 kg N & 30 kg P_2O_5 ha^{-1}) for teosinte fodder production.

Keywords: Agronomic efficiency, economics, green fodder yield, nutrient use efficiency, nutrient uptake, teosinte fodder

Introduction
Cereal fodders are an important source for energy, protein and fiber for the maintenance and production of dairy animals. The feed and fodder contributes the major share i.e., 60 per cent of the total maintenance cost of livestock production (Kumawat *et al*., 2014) [9]. At current scenario, the green forage production needs to be increase at the rate of 1.69% per year but due to the neglectance by the farmers and others miscellaneous problems there is scarce in resources of animal feed like 35.6% green fodder, 10.95% dry crop residues (dry forages) and 44% concentrate feed ingredients (Vision 2050, IGFRI). Therefore, cereal fodder crops can be proved and play very crucial role in reducing this gap between demand and supply of forages. Cereal fodder like Teosinte (*Euchlaena mexicana*) is an excellent nutritious multicut fodder which gives high yield within 65-70 days. In India, teosinte is grown in 10,000 ha with green forage productivity of 30-50 t/ ha (Anonymous, 2019) [1]. But 62% and 49% of soils are deficient in nitrogen and phosphorus, respectively under the Indian conditions. Therefore, it could be saying that nutrient deficiencies along with imbalanced and non-judicious fertilizers application are the major constraint of fodder production. Hence, this experiment was undertaken for assessing the nutrient management of teosinte fodder production by recording of green fodder yield, nutrient content, nutrient use efficiencies and economics of production.

Materials and Methods
Site characteristics
Two years of experiment was conducted at research block of Forage Research and Management Centre (FRM&C), ICAR-National Dairy Research Institute, Karnal situated at 29º45' N latitude, 76°58' E longitude with an altitude of 245 m above mean sea level (MSL) during *kharif* season of 2012 and 2013. This site is located in north western zone of Haryana state and the climate of this zone is sub-tropical receiving 574 mm annual rainfall.

The soil fertility status of experimental field was characterized as neutral to alkaline pH (7.2), high bulk density (1.5 Mg m^{-3}), clay loam texture with low level of organic carbon (0.56%), low available N (190.5 kg ha^{-1}), medium available P_2O_5 (19.2 kg ha^{-1}) and high K_2O (270.8 kg ha^{-1}).

Experiment and Treatments

Fifteen treatments combinations of five doses of nitrogen (0, 40, 80, 120 and 160 kg N ha^{-1}) in main plots and three phosphorus doses (0, 30 and 60 kg P ha^{-1}) in sub-plots was investigated by replicating four times in split plot design. The field was divided into 60 plots and each one was 6.0 m x 4.5 m in size. Teosinte cultivar 'Bihar local' was planted at 30 cm apart with seed rate of 40 kg ha^{-1}. All treatments were allotted in these specified plots without any prejudice. Half dose of nitrogen and full dose of phosphorus were used during sowing through urea and single superphosphate (SSP), respectively. The remaining half dose of N was applied in 2 equal split doses at 30 & 45 days after sowing by broadcasting after irrigation.

Nutrient content & uptake

Kjeldahl method was followed for estimating of N content in plant sample in percentage (dry weight basis). Estimation of Phosphorus content in plant extract was carried out by following standard procedure (Richard, 1968). Nitrogen and phosphorus (kg ha^{-1}) uptake by plant was estimated by multiplying of dry matter (%) with respective nutrient content.

Yield & economics

Green fodder/biomass yield (q ha^{-1}) was recorded from different treatment by weighing through spring balance at field after harvesting and then economics of teosinte fodder was worked out to look into monetary benefits of different treatments for production. The gross monetary returns in rupees per ha were worked out on the basis of green biomass yield. However, Physical optimum dose (POD) and Economic optimum dose (EOD) was also worked out to define/know that how profitability of fodder production could be taken.

Nitrogen use efficiency

Various nitrogen efficiencies were calculated by employing the standard formula (Dixit *et al.*, 2017) [5]:

Apparent recovery efficiency (kg nutrient uptake per unit kg of nutrient applied) = $\frac{Ut-Uc}{Na}$

Agronomic efficiency (kg of green fodder yield increased per unit kg of nutrient applied) = $\frac{Yt-Yc}{Na}$

Production efficiency (kg of green fodder yield per unit kg of nutrient uptake) = $\frac{Yt-Yc}{Ut-Uc}$

Partial factor productivity (kg of green fodder yield per unit kg of N applied) = $\frac{y}{Na}$

Where,

Y = Green fodder yield (kg ha^{-1})

Yt = Green fodder/biomass yield at treated plot (kg ha^{-1})

Yc = Green fodder/ biomass yield at control plot (kg ha^{-1})

Ut = Nitrogen uptake at treated plot (kg ha^{-1})

Uc = Nitrogen uptake at control plot (kg ha^{-1})

Na = Nitrogen application (kg ha^{-1})

Statistical analysis

The replicated means were analyzed for ANOVA using MS excel. The calculated critical difference (CD) at 5% level determines the results were interpreted as significantly different from control.

Results and Discussion

Green fodder yield (GFY): Primary nutrient management (Nitrogen & Phosphorus) increased the green fodder yield (GFY) by 51.47-118.10% and 10.06-15.20%, respectively in teosinte fodder. It is quite obvious that 160 kg N and 60 kg P ha^{-1} significantly (P< 0.05) enhanced the GFY of 434.71 and 358.24 q ha^{-1} and lower production i.e., 199.32 and 310.97 q $ha^{-1}$was achieved, respectively. In control plot (No fertilizer) (Table 1& Figure 1).

Table 1: Green fodder yield, Nutrient (concentration and uptake) and Economics of Teosinte fodder production in relation to nitrogen and phosphorus application (mean of 2 yrs.)

Treatments Nitrogen levels (kg ha^{-1})	Green fodder Yield (q ha^{-1})	N content (%)	P content (%)	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	Net return (₹ ha^{-1})	Benefit: Cost
N_0	199.32	1.08	0.16	46.72	7.04	8,409	0.35
N_{40}	301.91	1.13	0.20	77.20	13.83	24,357	1.01
N_{80}	349.69	1.18	0.25	94.21	19.76	31,536	1.29
N_{120}	400.11	1.25	0.28	115.75	25.93	39,137	1.57
N_{160}	434.71	1.34	0.35	138.14	36.04	44,207	1.74
S.Em±	2.43	0.013	0.001	1.66	0.238	-	-
CD (P=0.05)	5.30	0.029	0.002	3.63	0.519	-	-
Phosphorus levels (kgha^{-1})							
P_0	310.97	1.17	0.23	84.45	17.59	26,273	1.11
P_{30}	342.24	1.19	0.24	95.35	20.23	29,772	1.19
P_{60}	358.24	1.22	0.27	103.41	23.74	30,828	1.16
S.Em±	2.65	0.008	0.0009	1.24	0.243	-	-
CD (P=0.05)	5.42	0.02	0.0019	2.53	0.50	-	-
CD (P=0.05) (NxP)	12.13	NS	NS	5.66	1.11	-	-

The increment of green fodder yield was attributed to increase of yield attributing characters like plant height and leaf number as nitrogen doses was increased (Desale *et al*., 2000; Ayub *et al*., 2007 and Bhilare *et al*., 2010) [4, 2, 3]. However, N fertilization also increased the photosynthetic assimilation in leaf area, weight and stem weight which directly influenced the green fodder yield (Singh 1999; Puri and Tiwana 2005) [15, 11]. Phosphorus fertilization to the crop enhanced growth rates and quick canopy development result in higher dry matter production which leads to high total biomass (Thomson and Siddique, 1997) [16]. Adequate supply of P enhanced carboxylation efficiency and stimulated RUBP carboxylase activity influenced the photosynthetic rate and eventually affects the above ground biomass (Jacob and Lawlor, 1992; Ghizaw *et al*., 1999; Yemane and Skjelvåg, 2003) [8, 7, 18].

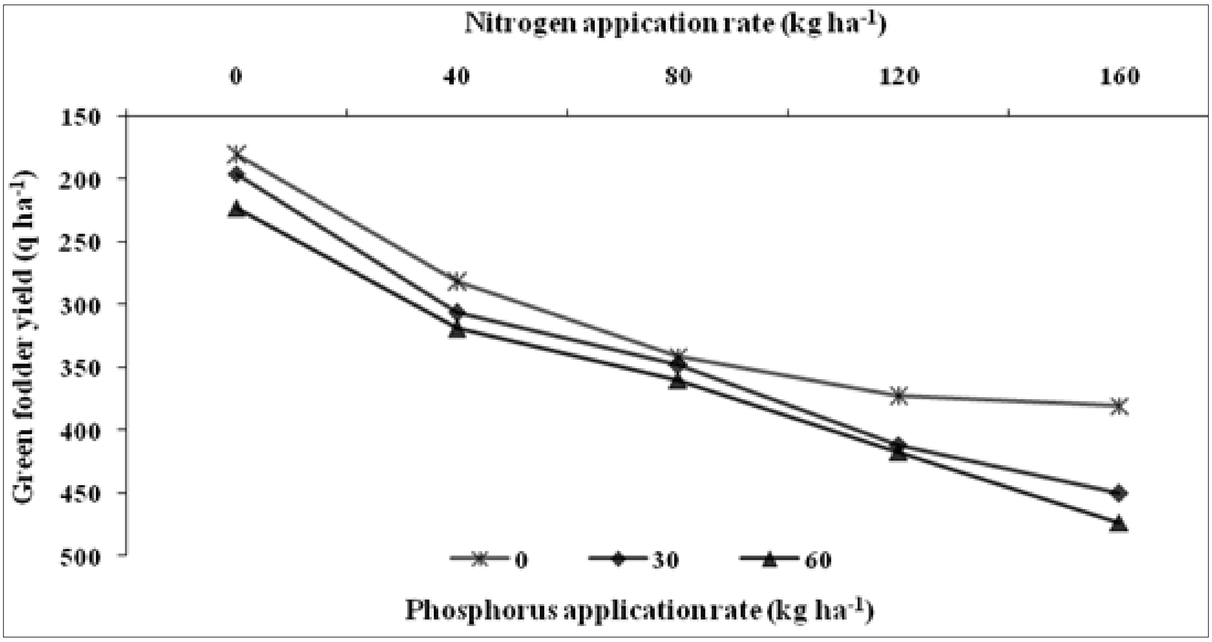


Fig 1: Interaction effect of Nitrogen and Phosphorus on Green fodder yield of teosinte (mean of 2 years)

Nutrient content and uptake

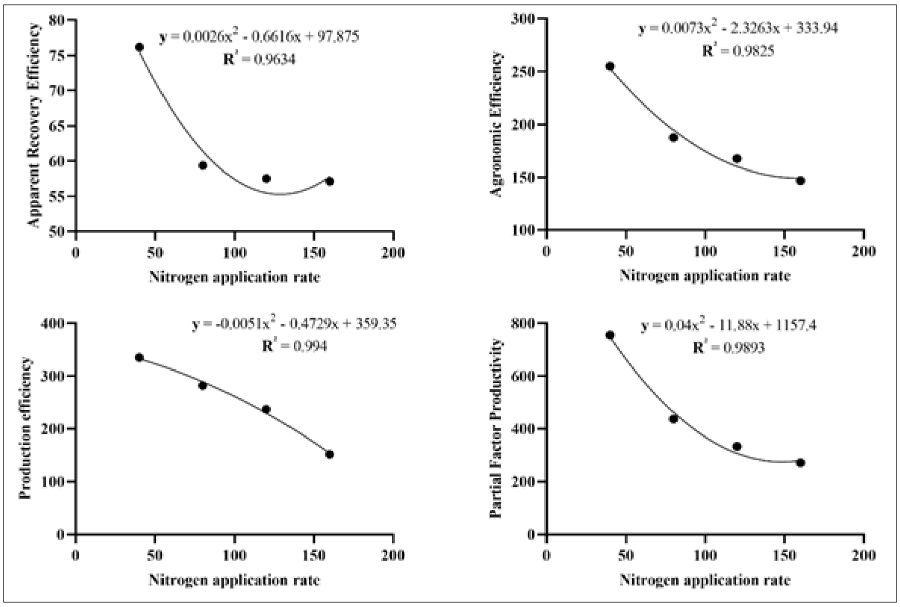
Use of different nutrients i.e., nitrogen and phosphorus (N & P) levels improved the nutrient content in teosinte fodder crops and also uptake of the fodder crop. It was found that supplying of 160 kg N ha^{-1} was significantly ($p< 0.05$) increased the N & P content (1.34 & 0.35%) as well as N & P uptake (138.14 & 36.04 kg ha^{-1}) by the teosinte crop, respectively. Whereas, Phosphorus fertilization of 60 kg ha^{-1} significantly ($p< 0.05$) enhanced the N & P content (1.22 & 0.27%) and N & P uptake (103.41 & 23.74 kg ha^{-1}) by the fodder crop, respectively. Interaction between N & P was significant ($p< 0.05$) regarding nutrient uptake by fodder.It was observed that improved in biomass yield of fodder crop had enhanced due to nutrient accumulation in vegetative parts of plant (Sims and Place, 1968; Ntamatungiro *et al.*, 1999) [14, 10].

Economics of Teosinte fodder production

Farmers always concern about the production i.e., crop yield which implicates that higher the production with maximum net return (Table 1). Here, monetary benefits represent the economics of this teosinte fodder production. It is observed that farmers can obtain net return ranged 24,357-44,207 INR ha^{-1} and significantly, it was also calculated that they are benefited by 1.74 per unit rupees invested in maximum.

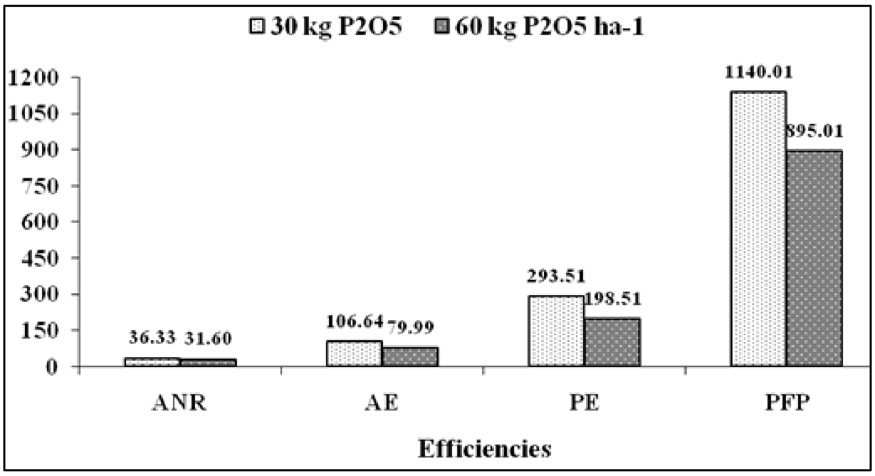
Nutrient use efficiency (NUE)

The highest and significant Apparent recovery efficiency (ARE), Agronomic efficiency (AE), Production efficiency (PE) and Partial factor productivity (PFP) were obtained at a lower rate of nutrients (N&P) and found to be at decreasing trends when nutrient doses was increased from 40 to 160 kg N ha^{-1} and 30 to 60 kg P ha^{-1} as depicted in figure 2-3. However, the coefficient of determination of different nutrient use efficiencies i.e., Apparent recovery efficiency (R^2=0.963); Agronomic efficiency (R^2=0.983); Production efficiency (R^2=0.994) and Partial factor productivity (R^2=0.989) were calculated as per the given nitrogen levels. The nitrogen recovery by teosinte showed a negative response, reducing the amount of N recovered according to increase of N dose which showed a quadratic effect on fodder reducing the nitrogen use efficiency (NUE) with the increasing dose of nitrogen (Restelatto *et al.*, 2015) [13]. Similar trend also be found for phosphorus. The application of different level of nutrient, the availability of nutrient to plants is different which showed the variation in fodder yield, consequently led to the decreased in different NUE with increase in nitrogen levels. These findings were in line with Dixit *et al.*, 2017 [5]; Fageria and Baligar, 2005 [6].



*Apparent recovery (%); Agronomic efficiency (kg fodder increased kg N applied^{-1}); Production efficiency (kg fodder kg N absorbed^{-1}); Partial factor productivity (kg fodder kg N applied^{-1}), Nitrogen application rate (kg ha^{-1})

Fig 2: Different Nitrogen use efficiency (NUE) influenced by several nitrogen level (Mean of 2 years)



*Apparent recovery (%); Agronomic efficiency (kg fodder increased kg P_2O_5 applied^{-1}); Production efficiency (kg fodder kg P_2O_5 absorbed^{-1}); Partial factor productivity (kg fodder kg P_2O_5 applied^{-1}), Phosphorus application rate (kgha^{-1})

Fig 3: Different Phosphorus use efficiency (PUE) influenced by two Phosphorus level (mean of 2 years)

Physical Optimum dose (POD) and Economic optimum dose (EOD)

The dose 199.47 kg ha^{-1} is physical optimum level of nitrogen for teosinte fodder. The maximum fodder yield can be calculated by substituting (X=199.47) in the response equation given in (Table 2) for nitrogen. Similarly, the dose 76.28 kg ha^{-1} is physical optimum level of phosphorus for teosinte fodder. The maximum fodder yield can be calculated by substituting (X=76.28) in the response equation given in (Table 2) for phosphorus. The dose 196.85 kg ha^{-1} is economic optimum level of nitrogen for teosinte fodder. The fodder yield at economic optimum dose can be calculated by substituting (X=196.85) in the response equation given in (Table 2) for nitrogen and finally advantage of this economic optimum dose of nitrogen can be obtained by calculating the net return. Similarly, the dose 72.97 kg ha^{-1} is economic optimum level of phosphorus for teosinte fodder. The fodder yield at economic optimum dose can be calculated by substituting (X=72.97) in the response equation given in (Table 2) for phosphorus and finally advantage of this economic optimum dose of phosphorus can be obtained by calculating the net return. The higher dose (Physical optimum dose) was responsible for the highest fodder biomass production. But, it is explored that higher N rates may not be necessary for maximum yield when the economic viability is considered. But that application rate is necessary or recommended for the particular crop species and climatic condition (Restelatto *et al.*, 2015) [13]. Farmers are more interested with economic optimum dose of fertilizer levels because this dose gave that much yield which have non-significant difference in yield from the earlier one and to motivate for the judicial amount of nutrients application. Besides of these, it is also reflecting that surplus dose creates polluted environment situation for example excessive nitrogen application cause nitrate toxicity (NO^{3-}) in the ground water also (Raun and Gordon, 1999) [12].

Table 2: Fodder yield response and optimum dose (Physical and Economical) of applied Nitrogen and Phosphorus level (pooled of 2 years)

Nutrient	Response equation	R^2 Value	*POD (kg ha^{-1})	*EOD (kg ha^{-1})
Nitrogen (N)	$y = -0.5953x^2 + 237.49x + 20430$	$R^2 = 0.99$	199.47	196.85
Phosphorus (P2O5)	$y = -0.8483x^2 + 129.68x + 31097$	$R^2 = 1$	76.28	72.97

*POD-Physical optimum dose; *EOD-Economic optimum dose

Conclusion

After experimental findings of the two years (the mean of 2 years data), it was concluded that highest green fodder yield, maximum profit in the form of net return and BC ratio (benefit cost ratio) and improved in nutrient content was assessed with the application of 160 kg N ha^{-1} and 60 kg P ha^{-1} for teosinte fodder cultivation. But in contrast, high nitrogen use efficiencies (NUEs) were worked out with 40 kg N & 30 kg P ha^{-1} (low levels of nitrogen and phosphorus application).

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Disclosure statement

There is no conflict among the authors.

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