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Response of Maize Forage Yield and Quality to Nitrogen Fertilization and Harvest Time in Semi−arid Northwest China

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Authors' contributions

This work was carried out in collaboration between all authors. Authors SL and LL designed the study and wrote the protocol. Authors SY and SL wrote the first draft of the manuscript. Author LL performed the statistical analysis and author SL did the literature searches. Authors SL, SY and LL did proof reading, restructured and managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Aim: Maximizing the soil nutrient of grain and forage maize production is vital to guarantee enough grains and fodder supply to meet the human and livestock demand. This study was done to investigate the effect of nitrogen fertilization and harvest time on growth, yield and quality of fodder maize (*Zea mays L.).*
Study Design: The experimental design was a randomized complete block design with four treatments replicated three times.
Place and Duration of Study: Field experiment was conducted in 2014, 2015 and 2016 cropping

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seasons at the Dingxi Experimental Station, Gansu Province Northwest China.
Methodology: The treatments were fertilizer rates applied planting at 0. 100, 200, and 300 kg ha^{-1} (referred to as N_0, N_{100}, N_{200}, and N_{300}, respectively).
Results: It was found out that N_{300} treatment increased forage yield at 60 days after sowing (DAS) (by 127, 48 and 15%), at 90 DAS (by 83, 45 and 16%), at 120 DAS (by 78, 41 and 13%) and at 153 DAS (by 86, 46 and 14%) as compared to N_0, N_{100} and N_{200} respectively. Application of N_{300} increased grain yield by 79, 56 and 8% compared to N_0, N_{100} and N_{200} respectively; and also increased crude protein (%) across years and growth stages, respectively, by 42, 19 and 3%. At a lesser magnitude, application of N_{200} also increased forage and grain yield compared to N_0. Acid detergent fibre and neutral detergent fibre was decreased with N fertilization (i.e., N_{100}, N_{200} and N_{300}) compared with N_0, which consequently increased relative feed value.
Conclusion: From this study, N_{300} treatment appear to be the optimal rate of N fertilization for improved forage yield and quality of maize in the semi−arid Loess Plateau.

Keywords: Maize; nitrogen rates; quality; time of harvest; yield.

1. INTRODUCTION

Maize (*Zea mays L.*) is a very important forage source for livestock nutrition and the third most cultivated forage crop after alfalfa [1]. Recently, China's corn production is one of the world's largest, driven mainly by growth in animal feed consumption, while consumption of staple grains is growing at a more moderate rate [2]. Livestock is an important livelihood strategy in most countries [3] providing food and industrial products. Despite their importance, livestock are usually undernourished due to lack of feeds of sufficient quality and quantity; the consequences of which are low production, increased disease susceptibility, higher mortality rates and reduced fertility. This is typical of smallholder livestock production systems on the Loess plateau where livestock are kept by traditional farmers. Improvement in the management of crop−livestock systems is important for the livelihoods of small scale farmers [4] especially with the increases in demand for livestock products and the associated favorable prices [5]. Many management systems, including N fertilization and plant density influence the yield and quality of forage maize [6]. Nitrogen fertilization is one of the major strategies to increase production for the increasing worldwide demand for food [7]. Nitrogen is the most deficient nutrient in forage crops and improving the nitrogen content in the soil is an important factor for growing quality forages. Adequate supply of plant available nitrogen will ensure higher photosynthetic activity and vigorous vegetative growth. The used of nitrogen fertilizer therefore, plays an important role in the establishment of viable feed sources [8]. Iqbal et al. [9] reported a significant effect on forage quality, when nitrogen was applied either through inorganic or organic means. Increasing the rate of N application has been reported to increase crude protein, while reducing acid detergent fiber [10]. Moreover, [11] found that application of nitrogen gave a significant additional increase in crude protein contents of forage oats. However, [12] reported that organic and inorganic fertilizer application had no significant effects on acid detergent fiber and neutral detergent fiber.

Several researches have been conducted on N fertilization effect on maize grain yield but little is known about the effect of N fertilizer on forage yield and quality of maize, particularly in the semi−arid Loess Plateau. We assumed that application of nitrogen at different rate would affect forage yield and quality. In this context, the objectives of this study were to: (i) determine grain yield under different nitrogen application rates (ii) verify any associated effect on forage yield and quality; and (iii) evaluate changes in forage quantity and quality at different harvesting stages of maize.

2. MATERIALS AND METHODS

2.1 Study Site

The field experiments were conducted in 2014, 2015 and 2016 at the Dingxi Experimental Station (35º28′N, 104º44′E and elevation 1971 m), Gansu Province Northwest China. The site had sandy loamy soil with pH of 8.3, low fertility soil organic carbon below 7.63 g kg^{-1} and Olsen P below 13.3 mg kg^{-1}. An initial soil analysis from 0 to 30 cm soil depth of the trial site produced the following nutrients: 0.86 to 1.30 g kg^{-1} total nitrogen and 0.80 to 1.25 g kg^{-1} total phosphorus. The Long−term annual rainfall at the experimental site averages 391 mm ranging from 246 mm in 1986 to 564 mm in 2003 with about 54% received between July and September. Annual accumulated temperature > 10ºC is 2239ºC. This article reports the experimental data for the 2014, 2015 and 2016 cropping seasons. In–crop rainfall recorded at the site during the course of the experiment was 280 mm in 2014, 274 mm in 2015 and 227 mm in 2016 (Fig.1).

2.2 Experimental Design

The experiment was a randomized complete block design with three replications. There were a total of twelve plots, each measuring 3.3 m × 8.5 m (28 m^2) with alternate wide and narrow ridges (0.7 m and 0.4 m wide, respectively), which is a common practice in the region. Four nitrogen rates: no nitrogen (N_0), nitrogen at 100 kg ha^{-1} (N_{100}), nitrogen at 200 kg ha^{-1} (N_{200}) and nitrogen at 300 kg ha^{-1} (N_{300}) were used as treatments. Application of N fertilizer at a rate of 300 kg ha^{-1} before sowing is the commonest farmer practice. Nitrogen fertilizer was applied using urea (46% N) in two splits, as follows: ⅓ of the full N rate corresponding to the treatment at sowing and the remaining ⅔ at 90 days after sowing. All treatments received a blanket application of phosphorus (P) at a rate of 150 kg ha^{-1} P as P_2O_5. Pre–plant N and P fertilizers were applied by hand and incorporated by ploughing followed by harrowing, whilst in–crop season N was applied using a hand–held drill device. All plots were mulched with plastic films at sowing to increase soil temperature, speed–up germination, and to reduce evaporative losses. Plastic film mulching is an innovative technology used in maize to facilitate crop establishment and increase productivity in arid environments [13]. The maize (*Zea mays* L., cv. Funong 821) from China was sown using a row spacing of 0.55 m to achieve a density of 52,000 plants ha^{-1}. The crop was planted on 29, 25 and 30 April and harvested on 2 October, 25 September and 30 September in 2014, 2015 and 2016, respectively.

2.3 Growth Parameters

Growth attributes measured were number of leaves and plant height. Five plants were chosen randomly from each plot at jointing (60 days after sowing (DAS), flowering (90 DAS), milking (120 DAS) and maturity (153 DAS) stages [14]. The number of leaves per plant was obtained from average of five plants. Plant height was measured from the five plants harvested.

2.4 Forage Yield

Five plants were randomly chosen from each treatment plot, and cut to the ground level for determination of forage yield at jointing or seedling (60 days after sowing (DAS)), flowering (90 DAS), milking (120 DAS) and maturity (153 DAS) stages. The forage yield were determined on dry weight basis by oven−drying at 80 °C for 48 hours and then to a constant weight.

2.5 Dry Matter Distribution

At maturity, five plants were randomly chosen from each treatment plot, and cut to the ground level for determination of dry matter distribution at 60, 90, 120, and 153 DAS. The plants were divided into various parts and fresh weight of the parts was taken using an electronic balance in a laboratory at Dingxi experimental station. The plant parts were then put into large brown envelopes and oven dried at 80°C for 48 hours and then to a constant weight.

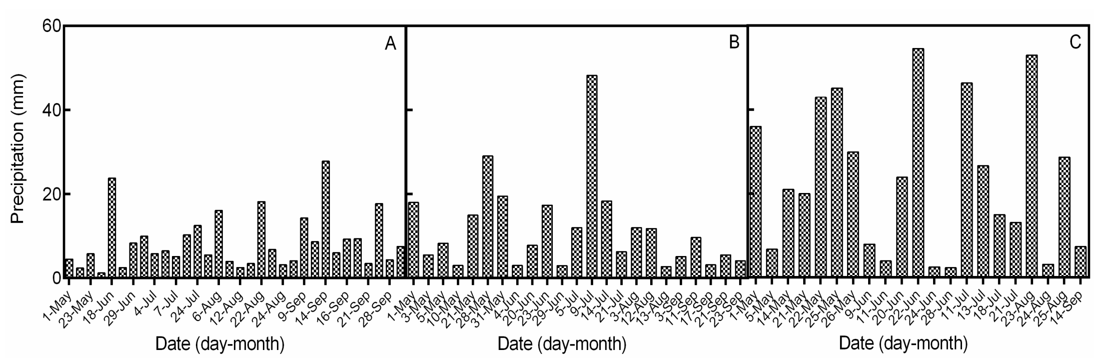

Fig. 1. Daily precipitation for 2014 (A), 2015 (B) and 2016 (C) cropping season

2.6 Acid Detergent Fiber and Neutral Detergent Fiber

Forage nutrient quality were assess at 60, 90, 120, and 153 DAS. The plant material were grounded to pass through 1 mm sieve, stored in plastic vials at room temperature until quality analyses were conducted for percent acid detergent fiber (ADF) and neutral detergent fiber (NDF). For determination of NDF and ADF contents, the Soest procedure was used [15]. All compositional data were calculated on a dry matter basis.

2.7 Relative Feed Value

Relative feed value (RFV) equation was developed by the Hay Marketing Task Force of the American Forage and Grassland Council [16]. The Relative Feed Value index (RFV) estimates digestible dry matter (DDM) from ADF, and calculates the dry matter (DM) intake potential (as a percent of body weight, BW) from NDF; and was calculated as follows:

$$DDM= (88.9- (.779*\%ADF) \quad (1)$$

$$DMI= (120/\%NDF) \quad (2)$$

Combining Eqs. (1) and (2)

$$RFV=DDM*DMI/1.29 \quad (3)$$

Where DDM is the digestible dry matter; DMI is the dry matter intake; ADF is acid detergent fiber and NDF is the neutral detergent fiber [17].

2.8 Grain Yield

At physiological maturity, maize plants were hand−harvested form 13.2 m^2 (4 m × 3 m) area in each plot. Physiological maturity was determined by the calendar method (using crop phenology) and physical observation (black layer visible, fully ripe; kernels hard and shiny) according to the standardized maize development stage [14]. The grains were separated, weighed and the grain yield (kg ha^{-1}) for each treatment was extrapolated.

2.9 Statistical Analysis

The effects of the treatments and years on the measured parameters were evaluated using the general linear model−univariate procedure from SPSS 22.0 software (Chicago, USA) with the treatment and year as fixed effect and random effect, respectively, and measured traits as dependent variables in this study. Least significant difference (LSD) at $P < 0.05$ was used for means separation.

3. RESULTS

3.1 Number of Leaves and Plant Height

The results revealed that number of leaves and plant height were significantly affected ($P <$ 0.05) by the applied different nitrogen rates in all three year seasons and at all growth stages (Table 1). The highest number of leaves and plant height were obtained by N_{300}, followed by N_{200}, N_{100} and then N0 treatments. This resulted to N_{300} increasing number of leaves by 18, 17, 10 and 11% at 60, 90, and 120 and 153 days after sowing, respectively compared to N_0. Similarly, N_{300} increased plant height averaging at 19, 21, 15 and 19% at 60, 90, 120 and 153 days after sowing, respectively compared to N_0. To a lesser extent, N_{200} increased number of leaves and plant height compared to N_0. The highest nitrogen application rate (N_{300}) resulted in non−significantly higher number of leaves and plant height compared to the next highest N rate of N_{200}.

3.2 Forage Yield

The effect of treatment on forage yield at different growth stages is shown in Table 2. Analysis of variance indicated that the main effect of year and N rate was significant (P<0.05) across harvests (Table 2). However, interaction between year and nitrogen were not significant (P<0.05). The N_{300} showed the greatest forage yield, followed by N_{200}, N_{100} and then N_0. This resulted into N_{300} increasing forage yield by 132, 84, 75 and 94% at 60, 90, 120 and 153 days after sowing, respectively, compared to N_0. Forage yield was found to increase with plant growth across treatment in all the years, i.e., results obtained were on average 9.31 g $plant^{-1}$, 184.11 g $plant^{-1}$, 302.88 g $plant^{-1}$ and 407.06 g $plant^{-1}$ at 60, 90, 120 and 153 DAS, respectively. The most rapid maize growth period was from 60 to 90 DAS as deduced from comparing percentage increase across treatment and year's from 60 to 90, 90 to 120 and 120 to 153 DAS. Nitrogen application could enhance agronomic, morphological and physiological traits of maize such as shoot development, photosynthesis, foliage emergence and dry matter accumulation.

Table 1. Effect of different nitrogen fertilization on number of leaves and plant height of maize in 2014, 2015 and 2016 cropping season. Mean values ± SE (n = 3), and means comparison based on least significant difference (LSD) (P < 0.05)

Treatments	Number of leaves				Plant height (cm)			
	Days after sowing (DAS)							
	60	90	120	153	60	60	120	153
2014 season								
N_0	7.3	10.2	10.9	9.0	62.4	184.1	201.0	186.0
N_{100}	7.7	10.8	10.7	9.9	65.6	191.2	205.0	199.5
N_{200}	7.4	10.6	10.8	10.2	69.0	201.2	216.2	206.3
N_{300}	7.8	11.3	11.0	10.4	70.2	203.7	220.1	207.7
LSD at 5%	**0.83**	**0.47**	**0.60**	**0.61**	**7.03**	**10.80**	**4.58**	**5.25**
2015 season								
N_0	5.9	10.4	11.1	7.1	54.3	161.7	179.4	172.3
N_{100}	5.9	11.9	11.9	8.2	54.7	183.4	193.3	191.1
N_{200}	6.2	12.4	12.4	8.6	58.1	182.6	211.1	192.7
N_{300}	7.3	12.8	12.8	9.8	65.2	190.7	215.4	192.3
LSD at 5%	**1.04**	**0.82**	**0.70**	**0.99**	**16.02**	**6.12**	**8.85**	**8.99**
2016 season								
N_0	5.1	10.0	9.3	8.4	47.7	148.8	194.2	160.9
N_{100}	5.2	11.1	10.7	9.1	49.2	166.4	218.5	193.0
N_{200}	5.2	10.8	11.0	9.2	56.0	179.2	220.3	201.8
N_{300}	6.6	11.7	10.7	9.3	60.4	205.3	224.5	217.0
LSD at 5%	0.35	0.71	0.51	0.33	8.98	20.04	9.80	19.89

N_0 − no nitrogen; N_{100}− nitrogen at 100 Kg ha^{-1}; N_{200}− nitrogen at 200 Kg ha^{-1} and N_{300}− nitrogen at 300 Kg ha^{-1}

Table 2. Effect of different nitrogen fertilization on forage yield (g plant-1) of maize in 2014, 2015 and 2016 cropping season. Mean values ± SE (n = 3), and means comparison based on least significant difference (LSD) (*P* < 0.05)

Treatment	Days after sowing (DAS)			
	60	90	120	153
Year				
2014	9.94	207.40	345.66	464.12
2015	9.28	180.40	289.33	401.64
2016	8.72	164.55	273.65	355.42
LSD (0.05)	**0.62**	**4.15**	**8.96**	**22.58**
Nitrogen (N)				
N_0	5.35	128.89	221.48	271.47
N_{100}	8.49	164.79	262.47	367.51
N_{200}	10.94	205.50	340.24	462.32
N_{300}	12.46	237.29	387.33	526.94
LSD (0.05)	**0.71**	**4.79**	**10.35**	**26.07**
Year	**	***	***	***
Nitrogen	***	***	***	***
Y x N	Ns	ns	ns	ns

N_0 − no nitrogen; N_{100}− nitrogen at 100 Kg ha^{-1}; N_{200}− nitrogen at 200 Kg ha^{-1} and N_{300}− nitrogen at 300 Kg ha^{-1}

3.3 Dry Matter Distribution at Maturity

The effect of nitrogen rate application on dry matter distribution at maturity is presented in Table 3. The results on dry matter distribution followed the same trend across years with the highest obtained in grain (56.32%), followed by stem (20.65%), cob leaf (11.30%), leaf (10.41) and then spike or tassel (1.42%). The result is clear that more dry matter was partitioned into the grains at maturity comparing percentages.

3.4 Forage Quality

3.4.1 Effect of nitrogen rate on crude protein

Crude protein in 2014 (A) and 2015 (B) showed significant ($P < 0.05$) differences in all the growth stages (Fig. 2). The effect of N rate on crude protein was significant at all harvest across years and followed the trend: $N_{300}>N_{200}>N_{100}>N_0$. This resulted to a significant increase of 33 and 14% at 60 DAS; 36 and 14% at 90 DAS; 55 and 23% at 120 DAS; 60 and 41% at 153 DAS under N_{300} compared with N_0 and N_{100} respectively. Application of N_{200} also significantly increased crude protein compared with N_{100} and N_0, but to a lesser extent relative to N_{300}.

3.4.2 Effect of nitrogen rate on acid detergent fiber

The acid detergent fiber (ADF) content increased with maturity; also, ADF in the stem was higher compared to the leaf at 90, 120 and 153 DAS (Table 4). Increased nitrogen rate decreased ADF content across growth stages and years in leaf and stem. Nitrogen at 300 kg ha^{-1} (N_{300}) decreased ADF across growth stages and years compared to N_0. Increased nitrogen rates influenced ADF content in the grain which resulted to a decrease of 13 and 10% in N_{300} and N_{200}, respectively in 2014 and 12 and 6%, respectively in 2015 compared with N_0.

3.4.3 Effect of nitrogen rate on neutral detergent fibre

Neutral detergent fibre (NDF) decreased in soils that received N fertilization compared with the control (N_0) (Table 5). The N_{300} and N_{200} treatments decrease NDF in the leaf and stem at 60 DAS (by 5 and 6%), at 90 DAS (both at 4%), at 120 and 153 DAS (by 3 and 4%) compare to the control (N_0). Application of N_{300} and N_{200} also decreased NDF in grain in both 2014 and 2015 compared to N_{100}, although at a lesser magnitude.

3.4.4 Effect of nitrogen rate on relative feed value

Nitrogen rates influenced RFV in both the 2014 and 2015 study year (Fig. 3). Relative feed value decreased with maturity with 60 DAS having the greatest (145.76, 147.25) and 153 DAS recording the lowest (65.99, 64.89) in 2014 and 2015, respectively. Increased nitrogen rates increased RFV with N_{300} recording the highest and N_0 recording the lowest. Application of N_{200} and N_{300} increased RFV between 6−9% at 60 DAS and 9−10% at 153 DAS.

Table 3. Effect of nitrogen rate on dry matter distribution at maturity

Treatment	Leaf		Stem		Spike/tassel		Cob		Grain	
	(g)	(%)	(g)	(%)	(g)	(%)	(g)	(%)	(g)	(%)
2014 season										
N_0	30.5	10.2	70.8	23.7	4.0	1.3	25.0	8.4	168.1	56.3
N_{100}	37.6	9.2	88.7	21.7	5.5	1.3	39.4	9.6	238.2	58.2
N_{200}	44.7	8.8	101.5	20.1	7.5	1.5	50.0	9.9	302.4	29.7
N_{300}	51.7	9.1	113.4	19.9	8.7	1.5	61.6	10.8	334.6	58.7
2015 season										
N_0	33.9	12.5	55.6	20.5	3.5	1.3	37.6	13.9	140.5	51.8
N_{100}	43.8	11.7	76.6	20.4	5.2	1.4	55.2	14.7	194.1	51.8
N_{200}	49.3	10.1	86.9	17.8	6.2	1.3	71.4	14.7	273.4	56.1
N_{300}	56.3	10.3	98.4	18.1	7.4	1.4	81.7	15.0	301.3	55.3
2016 season										
N_0	30.9	11.8	56.4	21,6	4.2	1.6	24.9	9.5	144.9	55.5
N_{100}	40.4	11.2	78.6	21.9	5.2	1.4	36.9	10.3	198.5	55.2
N_{200}	45.7	9.9	91.4	19.8	7.0	1.5	48.8	10.5	270.0	58.3
N_{300}	53.1	10.1	102.6	19.6	7.8	1.5	59.4	11.4	300.2	57.4

N_0 − no nitrogen; N_{100}− nitrogen at 100 Kg ha^{-1}; N_{200}− nitrogen at 200 Kg ha^{-1} and N_{300}− nitrogen at 300 Kg ha^{-1}

Table 4. Effect of nitrogen fertilization on acid detergent fibre (ADF) at different growth stages in 2014 and 2015 cropping season. Mean values ± SE (n = 3), and means comparison based on least significant difference (LSD) (P < 0.05)

Treatment	Days after sowing (DAS)								
	60		90		120		153		
	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Grain
2014 season									
N_0	23.2	22.5	32.8	34.8	34.7	39.4	43.7	44.4	25.0
N_{100}	23.3	23.4	33.4	34.2	35.1	38.1	42.3	42.4	23.5
N_{200}	22.4	21.4	31.6	33.6	33.5	36.9	38.3	40.6	22.6
N_{300}	22.6	20.6	30.4	32.8	30.6	36.1	38.3	40.6	22.1
LSD (0.05)	**1.22**	**1.42**	**1.66**	**2.36**	**2.08**	**2.94**	**1.78**	**2.03**	**0.59**
2015 season									
N_0	22.1	23.3	33.8	35.0	36.2	40.1	43.4	45.2	23.6
N_{100}	22.3	22.8	32.0	33.4	34.2	36.8	40.2	43.2	23.0
N_{200}	20.3	22.6	31.2	31.0	33.6	35.0	40.3	40.4	22.2
N_{300}	20.9	20.4	30.9	31.1	32.9	34.7	39.8	40.7	21.0
LSD (0.05)	**1.01**	**1.29**	**1.58**	**1.14**	**3.05**	**1.84**	**1.78**	**1.31**	**0.54**

N_0 − no nitrogen; N_{100}− nitrogen at 100 Kg ha^{-1}; N_{200}− nitrogen at 200 Kg ha^{-1} and N_{300}− nitrogen at 300 Kg ha^{-1}

Table 5. Effect of nitrogen fertilization on neutral detergent fibre (NDF) at different growth stages in 2014 and 2015 cropping season. Mean values ± SE (n = 3), and means comparison based on least significant difference (LSD) (*P* < 0.05)

Treatment	Days after sowing (DAS)								
	60		90		120		153		
	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Grain
2014 season									
N_0	47.6	48.9	59.1	64.4	66.5	69.7	75.4	78.5	50.1
N_{100}	46.3	48.0	58.7	61.4	64.1	67.6	75.0	77.6	49.4
N_{200}	44.5	46.1	59.1	61.2	64.3	69.0	73.6	76.4	47.9
N_{300}	45.3	46.8	57.6	59.4	62.9	68.0	72.3	75.6	47.8
LSD (0.05)	**0.57**	**1.46**	**1.41**	**2.12**	**2.26**	**2.42**	**0.48**	**0.62**	**0.74**
2015 season									
N_0	50.0	50.9	61.9	63.3	68.5	70.7	76.2	79.3	50.2
N_{100}	48.6	48.3	59.8	62.2	67.3	69.9	75.8	78.3	49.6
N_{200}	47.7	46.5	59.6	61.7	66.5	68.7	73.7	77.7	48.0
N_{300}	46.4	45.6	61.0	62.1	67.0	68.8	73.0	77.0	48.4
LSD (0.05)	**0.72**	**1.77**	**1.28**	**0.86**	**0.70**	**0.73**	**0.54**	**0.55**	**0.54**

N_0 − no nitrogen; N_{100}− nitrogen at 100 Kg ha^{-1}; N_{200}− nitrogen at 200 Kg ha^{-1} and N_{300}− nitrogen at 300 Kg

4. DISCUSSION

The decreased number of leaves and plant height with no fertilization may be due to the N inputs being lower than the maize N requirement, resulting in soil N depletion [18] hence, stunted growth. Mae [19] has reported reduced number of leaves under N−limiting conditions. The significant increase in number of leaves and plant height with increased nitrogen application, particularly N_{300} can be attributed to increase nitrogen uptake and its associated role in chlorophyll synthesis and increased photosynthetic activities resulting to enhanced plant growth. In this study, the differences in forage yield between treatments at 60 DAS could be related to the variations in the quantity of N fertilizer applied at sowing. The reason is that the right amount applied at sowing *ha^{-1}*. promoted early establishment of the crop. Improvements in plant characters such as height and number of leaves help improve fodder yield.

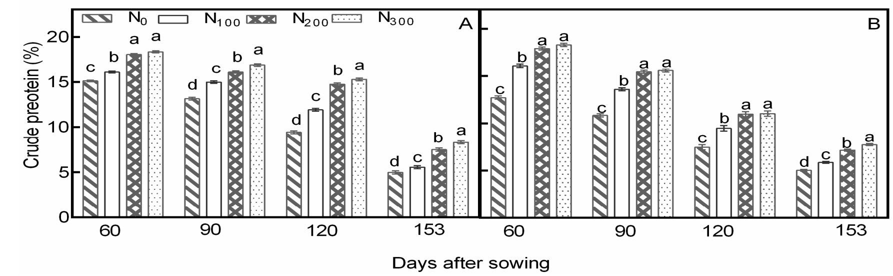

Fig. 2. Effect of nitrogen fertilization on crude protein in 2014 (A) and 2015 (B) cropping season

Vertical bars denote the standard error of means. Means comparison was done using least significant difference (LSD) (p<0.05). Figure with the same letters within the same days after sowing are not significantly different. N_0 − no nitrogen; N_{100}− nitrogen at 100 Kg ha^{-1}; N_{200}− nitrogen at 200 Kg ha^{-1} and N_{300}− nitrogen at 300 Kg ha^{-1}

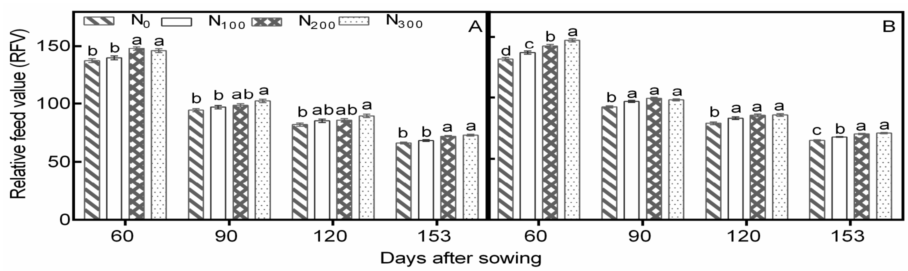

Fig. 3. Effect of nitrogen fertilization on relative feed value in 2014 (A) and 2015 (B) cropping season

Vertical bars denote the standard error of means. Means comparison was done using least significant difference (LSD) (p<0.05). Figure with the same letters within the same days after sowing are not significantly different. N_0 − no nitrogen; N_{100}− nitrogen at 100 Kg ha^{-1}; N_{200}− nitrogen at 200 Kg ha^{-1} and N_{300}− nitrogen at 300 Kg ha^{-1}

Forage yield has been reported to have a significant and positive correlation with plant growth components such as height and number of leaves [20]. Greater forage yield by N_{300} at all the stages of harvesting over the three years of the study may be attributed to the available N and higher N uptake. An adequate N supply at flowering is fundamental to maintain a high number of photosynthetic active leaves, to delay leaf senescence and to raise the number of fertilized ovules [21]. In the present study, ⅔ N applied 90 DAS consistently increased forage yield under N_{300} and finally grain yield. This finding is in agreement with previous studies [22,23] which reported that the increase in maize yield relies on the consistent improvement of dry matter accumulation, especially during the postsilking stage, because the promotion of dry matter accumulation postsilking is significant for increasing the final kernel number and kernel weight [24]. During early growth of maize the leaf and stem is the major sink for dry matter distribution, but at maturity and as found in this study the grain assumed this role and contained ≈56% of the total dry matter of the maize plant. Increased forage yield in those treatments (N_{200} and N_{300}) translated into increased grain yield compared with the unfertilized plots (N_0).

Harvesting time and N availability is an important factor that contributes to forage quality. In the current study, the forage quality increased with increased N rate and decreased with maturity. Plant nutrition, particularly nitrogen fertilization had a significant effect on forage quality [9]. Crude protein is one of the major nutritious compounds in livestock feeding, and its deficiency in forage could reduce livestock production yield [25]. In the current study, crude protein content decreased with maturity. A decrease in protein contents with maturity has also been reported previously in maize [26]. Acid detergent fibre (ADF) and neutral detergent fibre (NDF) are good indicators of forage quality. With increase maturity, the plant structural carbohydrates, as measured by the ADF and NDF fractions in this study increased. Acid detergent fiber is an appropriate index to determine forage digestibility whereas NDF in the feed is an indication of cell wall quantity [25]. In the current study, nitrogen fertilization decreased ADF and NDF; indicating an improvement in overall forage digestibility and could possible cause an increase in dry matter intake. The highest ADF and NDF content was observed in the non−fertilized treatments, and it tends that as nitrogen fertilizer level increased the ADF and NDF content decreased. The result is in line with Magani [27]. The authors found that nitrogen fertilization significantly decreased acid and neutral detergent fibers. In the current study, increased ADF and NDF with maturity resulted to reduced RFV; low forage quality index results in three losses; decrease in dry matter intake, nutrient content and digestibility.

5. CONCLUSION

This study demonstrates the influence of nitrogen fertilization on forage yield and quality at different stages of maize development. Nitrogen at 300 kg ha^{-1} optimized the eco–physiological response of the crop, which was confirmed by the results of the number of leaves and plant height. Such responses to N inputs translated into increased forage yield and grain yield. The highest forage yield was observed at maturity over the three study years. Application of N_{300} and to a lesser extent N_{200} decreases acid detergent fibre and neutral detergent fibre, but increased crude protein compared to unfertilized plots. Application of N fertilizer at a rate of 300 kg ha^{-1} demonstrated increases in forage yield and quality in the Western Loess Plateau. The results derived from this study also provide a background dataset, which may be used to guide further research in N application rate above 300 kg ha−1.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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