

COMPARING FODDER PRODUCTION OF MAIZE VARIETIES UNDER VARIED NITROGEN LEVELS

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ABSTRACT. Maize (*Zea mays* L.) plays a significant role as a fodder crop, supporting rural populations and livestock. Unfortunately, in Pakistan, there is a shortage of green fodder due to the unbalanced use of fertiliser and improper selection of maize varieties for fodder production. This research aimed to address the need for quality fodder by studying the effects of nitrogen (N) on new maize varieties, ultimately enhancing livestock production and agricultural sustainability. The experiment took place in the summer of 2022 at the Cereal Crop Research Institute in Pakistan. Adopting an RCB design with three replications, fodder maize varieties (Jalal, Kaptan and Jumbo) were tested with four N levels (0, 100, 150, 200 kg N ha⁻¹) applied during sowing, knee (V4), and silking stages. The data upon analysis revealed that different maize varieties had a significant impact on the studied parameters. Maize varieties affected days to tasselling and silking, with the Jumbo variety recording the longest duration (59 and 62,

respectively). Similar results were observed for days to milking, with the Jumbo variety taking the longest time (80 days). It also recorded a higher leaf number (11.5), leaf area (478 cm²) and leaf area index (3.4). Fresh fodder (67,777 kg ha⁻¹) and dry fodder yield (23,424 kg ha⁻¹) were higher for the Jumbo variety. In terms of N application, tasselling (59) and silking (62) took more days when 150 and 200 kg N ha⁻¹ was applied compared to the control. Compared to the control plots (83 days), 200 kg N delayed the milking stage by 10 days. A higher but statistically similar leaf count, leaf area and leaf area index were recorded with 150 and 200 kg N ha⁻¹. The plant height of maize was also higher, with 150 (196 cm) and 200 kg N ha⁻¹ (202 cm). Lastly, a higher fresh fodder and dry fodder yield was associated with 150 and 200 kg N ha⁻¹. Based on these results, the Jumbo variety, with the application of 150 kg N ha⁻¹, is recommended for cultivation for economic feasibility and to obtain a higher fodder yield of maize.



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INTRODUCTION

Maize (*Zea mays* L.), a vital member of the Poaceae family, plays a crucial role as a cereal and fodder crop, supporting the rural population and livestock in Pakistan. It ranks as the third most important cereal crop in the country and second in Khyber Pakhtunkhwa province. In recent years, maize cultivation has expanded to 1418 thousand hectares, with production reaching 8.465 million tonnes, thanks to increased cultivation and improved seed varieties. Maize is highly versatile, serving as food, feed, fodder and industrial raw material and is known for its nutritional value and safety for livestock. It is a high-yielding crop vital for Pakistan's food security, although its yield depends on factors such as nutrients and water availability. Green fodder from maize is especially crucial for sustainable and economical dairy farming, considering the growing population and climate challenges in the region. High-quality fodder is essential for improving animal nutrition, increasing milk production and ensuring the overall health and breeding efficiency of livestock (Naik *et al.*, 2012). Green fodder plays a vital role in dairy nutrition, impacting livestock growth, reproduction and overall productivity (Younas and Yaqoob, 2005). Unfortunately, in Pakistan, there is a significant shortage of green fodder, meeting only a third of livestock's needs. This shortage negatively affects animal performance, particularly in Khyber Pakhtunkhwa province, where the daily provision of green fodder per

animal falls below 2 kg. To promote sustainable dairy farming practices and enhance livestock production, it is crucial to address this shortage and ensure a consistent supply of quality green fodder. This scarcity can be attributed to the prevailing climate change scenario and land limitations (Ahmad *et al.*, 2018). Nitrogen (N) increases rapid growth and improves the vegetative growth of fodder. Nitrogen is crucial for improving fodder digestibility and increasing the N content in maize. Maize is a high-demand crop, particularly for N, as it plays a pivotal role in essential growth processes, including photosynthesis, mineral absorption and water uptake (Li *et al.*, 2018). Inadequate N levels during tasselling and silking stages can significantly reduce maize yield, but the exact N requirement depends on factors such as maize variety, soil type, location and expected yield. Due to the tendency of N to leach and volatilise, it should be applied in split doses (Hu *et al.*, 2021). Nitrogen is a fundamental component of various plant compounds, including proteins, amino acids and vitamins (Yousaf *et al.*, 2021). For a 1-tonne maize yield, the soil should ideally provide 20–25 kg of N (Kitchen *et al.*, 2022). Proper N fertilisation can improve crop growth rate and kernel quality, but insufficient N during the vegetative stage may cause premature maturation and reduced kernel filling (Hammad *et al.*, 2015; Sharifi and Namvar, 2016), leading to stunted crop growth and limited assimilate supply during critical growth stages. The scarcity of N leads to a reduced kernel count and weight. Increasing N fertiliser application with precise timing enhances

leaf area, kernels and cobs per plant, ultimately improving yield and fodder palatability. Nitrogen availability influences kernel weight through alterations in the source–sink relationship (Hisse *et al.*, 2019). Crop yield is significantly determined by varietal factors, while improper fertiliser usage, weed management, water supply, and pest and disease pressures negatively impact maize production. The adoption of fodder-producing varieties is essential for maximising production and protecting farmers from risks (La Rovere *et al.*, 2014). Selecting maize cultivars adapted to different climates and suitable for fodder production is a major concern, particularly for small-scale farmers in developing countries who often rely on low-yield crop types vulnerable to drought, heat, disease and other stressors. The utilisation of adequate management techniques and the planting of suitable maize varieties that are adapted to local climatic conditions can lead to increased fodder yield (Hamdan *et al.*, 2022a, b). Modern and improved maize varieties are known to produce significantly higher yields, better quality and more consistent results (Dudwal *et al.*, 2021). With proper management techniques and varieties suited to local climatic conditions, yield can be boosted. Moreover, changing climatic conditions have negatively impacted Pakistan’s agricultural sector, making it crucial to screen out suitable maize varieties to fulfill fodder demand. In comparison to conventional agriculture, combining a genetically superior variety with sound management practices can enhance crop output, leading to higher fodder yields (Pant *et al.*, 2022).

Considering the aforementioned significance, this research strategically aimed to scrutinise the impacts of varying N levels on distinct maize varieties, with a particular focus on determining the optimum N dose and maize variety for fostering optimal fodder production.

MATERIALS AND METHODS

Experimental site and design

The experiment was conducted at the Cereal Crop Research Institute, Pirsabak, Khyber Pakhtunkhwa, Pakistan, in the summer of 2022. The trial was designed following a randomised complete block design (RCBD) with three replications. Three distinct fodder maize varieties, Jalal, Kaptan and Jumbo (a candidate line), were evaluated across four N application levels, namely 0, 100, 150 and 200 kg ha⁻¹. The experiment commenced in the first week of August, with maize crops sown in plots measuring 15 m². To establish a consistent and uniform seedbed, the field underwent initial ploughing using a cultivator, followed by further refinement with a rotavator. The broadcast seeding method was adopted for planting. Seeds were planted at a rate of 80 kg per hectare. Nitrogen fertilisation was administered at three critical stages of development: during sowing, at the knee stage (V4) and at silking. Irrigation was managed throughout the experiment, with an initial round in the first week after sowing and subsequent irrigation scheduled based on the specific requirements of the maize crop. The crop was harvested at the milking stage to ensure the best fodder quality.

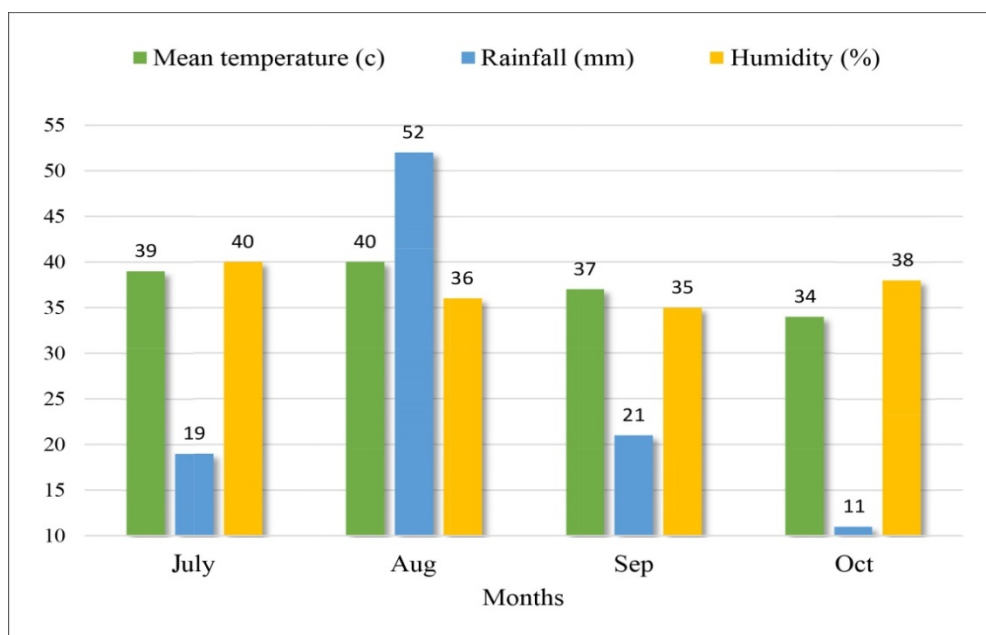


Figure 1 – Weather data for summer 2022 during the maize growing season

Phenological data

Days to emergence were quantified by measuring the time it took from sowing until approximately 75% of the plants within each experimental unit had emerged. Days to tasselling were determined by calculating the number of days between the sowing date and the moment when 75% of the plants within each plot had developed tassels. Similarly, days to silking represented the duration between the sowing date and the day when 75% of the plants within each plot had produced silk. Finally, the days to milking were calculated by tracking the number of days from sowing until the maize cobs reached the milking stage.

Yield and yield-related traits

Emergence m^{-2} data were collected by assessing all seedlings within a 1-m^2 area at 5 randomly chosen positions within each plot, with the results

averaged for accuracy. The number of leaves per plant was determined at the physiological maturity stage by randomly selecting five plants within each plot and calculating the average number of leaves per plant. The leaf area cm^{-2} was determined by selecting five random leaves and measuring their length and width using a measuring device. The leaf area index (LAI) was calculated using the formula $LAI = (\text{Leaf area plant}^{-1} / \text{Ground area})$. Plant height (cm) was measured when the plants reached physiological maturity, with the height of five randomly chosen plants within each experimental unit measured from the soil surface to the apex of the tassel using a metre stick. In terms of yield parameters, both fresh fodder yield ($kg\ ha^{-1}$) and dry fodder yield ($kg\ ha^{-1}$) were determined. For fresh fodder yield, a $1\ m^{-2}$ area was harvested, and the herbage weight was

Comparing fodder production of maize varieties under varied nitrogen levels

recorded using a digital scale, which was then converted into kilograms per hectare. Dry fodder yield was obtained by harvesting a 1 m⁻² area and properly sun-drying the herbage for 15 days. The dried herbage weight was measured using a digital scale and converted into kilograms per hectare.

Statistical analysis

The data were analysed statistically using an analysis of variance approach tailored to suit the RCB design of the study. The computed means were subsequently compared utilising the least significant difference (LSD) test at a significance level of 0.05 when the calculated F-values were significant (Jan *et al.*, 2010).

RESULTS

Crop phenology

The data analysis showed that N levels (NL) had no significant impact on days to emergence, but various maize varieties (V) affected the emergence time, with Jalal and Kaptan taking longer (8 days) than Jumbo (7 days). In

terms of tasselling, both NL and V, along with their interaction, played significant roles, with Jumbo having the longest tasselling time (59 days) and Kaptan and Jalal the shortest (53 and 55 days). NLs of 200 and 150 kg ha⁻¹ resulted in the longest tasselling times (59 and 58 days, respectively), while 100 kg ha⁻¹ and the control plots had the shortest times (53 days).

Days to silking were influenced by both NL and V, with Jumbo having the longest silking time (62 days) and Kaptan and Jalal the shortest (56 and 58 days, respectively). The application of 200 and 150 kg N ha⁻¹ led to the longest silking times (62 and 61 days, respectively), while 100 kg N ha⁻¹ and the control plots had the shortest times (56 days).

Regarding days to milking, Jumbo took the most time (80 days), followed by Kaptan (77) and Jalal (75), and 200 kg N ha⁻¹ resulted in the longest milking time (83), followed by 150 kg N ha⁻¹ (79), 100 kg N ha⁻¹ (74) and control plots (73), as shown in *Table 2*.

Table 1 – Days to emergence, tasselling, silking, milking, emergence (m²) and leaves per plant as affected by variety and nitrogen level

Treatments	Days to emergence	Days to tasselling	Days to silking	Days to milking	Emergence (m ²)	Leaves per plant
Varieties						
Jalal	8 ^a	55 ^b	58 ^b	75 ^c	22 ^c	10.2 ^c
Kaptan	8 ^a	53 ^b	56 ^b	77 ^b	26 ^b	10.7 ^b
Jumbo	7 ^b	59 ^a	62 ^a	80 ^a	28 ^a	11.5 ^a
LSD _(0.05)	1	2.15	1.89	1.26	4.58	0.37
Nitrogen levels (kg ha⁻¹)						
0	8	53 ^b	56 ^b	73 ^c	26	10 ^c
100	8	53 ^b	56 ^b	74 ^c	27	10.6 ^b
150	8	58 ^a	61 ^a	79 ^b	26	11.3 ^a
200	8	59 ^a	62 ^a	83 ^a	23	11.3 ^a
LSD _(0.05)	ns	2.49	2.19	1.46	ns	0.42
V×NL interaction	ns	**	**	**	ns	ns

*** = very highly significant at P ≤ 0.05, ** = highly significant at P ≤ 0.05 and * = significant at P ≤ 0.05

Yield and yield attributes

The data analysis revealed that NL had no significant effect on maize emergence m^{-2} and the interaction between NL and maize varieties (V) also showed no significant impact (*Table 2*). However, maize varieties significantly influenced emergence m^{-2} , with Jumbo displaying the highest emergence (28), followed by Kaptan (26) and Jalal (22). When it came to leaves per plant, both NL and varieties had a significant impact, but their interaction was not significant.

Among the varieties, Jumbo recorded the highest leaf count (11.5), followed by Kaptan (10.7) and Jalal (10.2). Among NLs, 200 and 150 $kg\ ha^{-1}$ resulted in more leaves per plant (11.3 each), followed by 100 $kg\ ha^{-1}$ (10.6), while the control plots had the fewest leaves per plant (10). Leaf area per plant was profoundly affected by both NL and V, with the Jumbo variety exhibiting the largest leaf area (478), followed by Kaptan (421) and Jalal (371).

Among the NLs, 200 and 150 $kg\ ha^{-1}$ resulted in the greatest leaf area per plant (453 and 450, respectively), while 100 $kg\ N\ ha^{-1}$ (402) and control plots (387) had smaller leaf areas. In terms of leaf area index, Jumbo had the highest leaf area index (3.4), while Kaptan and Jalal had lower values (2.7 and 3, respectively). The application of 200 and 150 $kg\ N\ ha^{-1}$ resulted in the highest leaf area index (3.4 and 3.6, respectively), while 100 $kg\ N\ ha^{-1}$ (2.8) and control plots (2.3) had lower values.

Plant height was significantly affected by both NL and V, with the Jumbo variety reaching the tallest height (221 cm), followed by Kaptan (176 cm)

and Jalal (175 cm). The application of 200 and 150 $kg\ N\ ha^{-1}$ led to taller plants (202 cm and 196 cm, respectively), while 100 $kg\ N\ ha^{-1}$ (188 cm) and control plots (177 cm) had shorter plants. Both NLs and maize varieties significantly influenced fresh fodder yield, and their interactions also played a significant role.

The Jumbo variety yielded the highest fresh fodder (67,777 $kg\ ha^{-1}$), trailed by Kaptan (64,646 $kg\ ha^{-1}$) and Jalal (62,423 $kg\ ha^{-1}$). Regarding NLs, the application of 200 and 150 $kg\ N\ ha^{-1}$ resulted in the highest fresh fodder yields (71,801 and 71,057 $kg\ ha^{-1}$, respectively), followed by 100 $kg\ ha^{-1}$ (61,760 $kg\ ha^{-1}$) and control plots (55,177 $kg\ ha^{-1}$).

The interaction indicated that fresh fodder yield increased across all varieties as the NLs increased from 0 to 200 $kg\ N\ ha^{-1}$. Similarly, both NL and V had a positive impact on dry fodder yield, with a significant interaction effect. Jumbo had the highest dry fodder yield (23,424 $kg\ ha^{-1}$), followed by Kaptan (20,342 $kg\ ha^{-1}$) and Jalal (17,321 $kg\ ha^{-1}$). Concerning NLs, applying 200 and 150 $kg\ N\ ha^{-1}$ resulted in the highest dry fodder yields (26,201 and 26,151 $kg\ ha^{-1}$, respectively), compared to 100 $kg\ ha^{-1}$ (16,567 $kg\ ha^{-1}$) and the control plots (12,529 $kg\ ha^{-1}$).

DISCUSSION

The experimental findings regarding maize growth and yield under varying NLs for fodder production revealed some key points. NLs had no significant impact on maize emergence time or emergence m^{-2} , but different

Comparing fodder production of maize varieties under varied nitrogen levels

maize varieties showed variations in the days to emergence and emergence m². In contrast to our findings, Szabó *et al.* (2023) found that N fertiliser influenced maize emergence time. However, Hammad *et al.* (2022) found that the time taken for maize to emerge was significantly influenced by the exposure of the crop to various temperatures but not by NL. Tasselling and silking stages were influenced by both NL and maize

varieties, with the Jumbo variety taking 6 and 4 more days for tasselling compared to Kaptan and Jalal varieties, respectively, and similar variations were noted in silking. This aligns with Azam *et al.* (2007), who observed differences in tasselling and silking days among maize varieties. Sher *et al.* (2012) stated that the inheritance of days to tasselling and silking was operated by non-additive gene action.

Table 2 – Leaf area, leaf area index, plant height, fresh fodder yield and dry fodder yield as affected by varieties and different nitrogen levels

Treatments	Leaf area (cm ²)	Leaf area index	Plant height (cm)	Fresh fodder yield (kg ha ⁻¹)	Dry fodder yield (kg ha ⁻¹)
Varieties					
Jalal	371 ^c	3.0 ^b	175 ^b	62423 ^c	17321 ^c
Kaptan	421 ^b	2.7 ^b	176 ^b	64646 ^b	20342 ^b
Jumbo	476 ^a	3.4 ^a	221 ^a	67777 ^a	23424 ^a
LSD(0.05)	39	0.46	6	1527	291
Nitrogen levels (kg ha⁻¹)					
0	387 ^b	2.3 ^c	177 ^c	55177 ^c	12529 ^c
100	402 ^b	2.8 ^b	188 ^b	61760 ^b	16567 ^b
150	450 ^a	3.6 ^a	196 ^a	71057 ^a	26151 ^a
200	453 ^a	3.4 ^a	202 ^a	71801 ^a	26201 ^a
LSD(0.05)	45	0.42	7.5	1763	336
VxNL interaction	***	ns	**	**	***

*** = very highly significant at $P \leq 0.05$, ** = highly significant at $P \leq 0.05$ and * = significant at $P \leq 0.05$

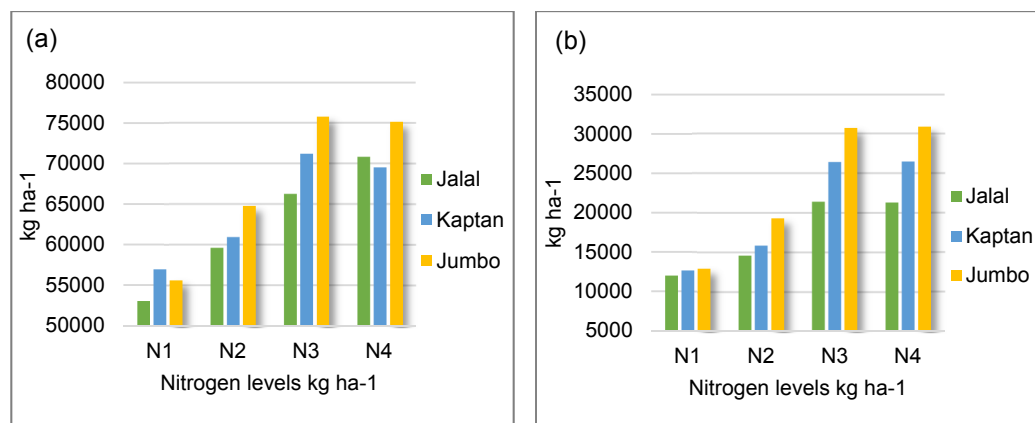


Figure 2 – Interaction between N levels and maize varieties for (a) fresh fodder and (b) dry fodder yield (kg ha⁻¹)

Furthermore, higher NLs (150 and 200 kg N ha⁻¹) resulted in taking more days for tasselling compared to the control plots, a finding consistent with Adhikari *et al.* (2021), who also noted the impact of NLs on tasselling and silking. In contrast, Dawadi and Sah (2012) reported a reduction in silking days, with an increase in N concentration from 120 to 200 kg N ha⁻¹.

Application of 200 kg N ha⁻¹ delayed the days to milking for all varieties compared to control plots that reached the milking stage 10 days earlier. This aligns with the findings of Liu *et al.* (2020), who observed that increasing NLs could delay days to milking and, hence, maturity.

The Jumbo variety took 5 more days to reach milking compared to Jalal, consistent with Shrestha *et al.* (2016), who also noted variations in milking days among maize varieties. Maximum plant height was achieved with 200 kg N ha⁻¹, which is in line with Amin (2011), who reported increased plant height with higher N rates.

The Jumbo variety exhibited taller plants compared to other varieties, similar to the findings of Njodi *et al.* (2019), who observed varying plant heights among maize varieties at different growth stages.

Additionally, both NLs and varieties significantly influenced leaf number, leaf area per plant and leaf area index. Consistently, the Jumbo variety exhibited the highest values across these parameters, with variations in leaf number attributed to genetic makeup (Liu *et al.*, 2020).

Leaf area and leaf area index also showed variations among maize

varieties, as observed by Orebo *et al.* (2021) and Raza *et al.* (2021), who stated that the environmental conditions and the genetic makeup of the crop variety had a huge impact on crop morphology.

Higher levels of N, particularly 150 and 200 kg N ha⁻¹, significantly increased leaf-related parameters, as N can impact photosynthesis rates per leaf area, primarily enhancing the leaf area per plant and consequently leading to a higher leaf area index. This aligns with the findings of Zhang *et al.* (2014) and Imran *et al.* (2015), who reported that increased NLs could boost leaf count, leaf area and leaf area index in maize.

Another study by Imran *et al.* (2015) found that NLs had a significant effect on leaf area index, with the application of N at a rate of 210 kg N ha⁻¹, producing the maximum leaf area index, which was statistically at par with 180 and 150 kg N ha⁻¹.

Additionally, both fresh fodder yield and dry fodder yield were significantly influenced by NLs and maize varieties, with the Jumbo variety consistently yielding the highest, followed by Jalal and Kaptan. Genetic diversity likely contributed to these differences, as found by Basit *et al.* (2018), who noted variations in yield parameters among maize varieties. Among NLs, 150 and 200 kg N ha⁻¹ outperformed the other treatments, recording 23% and 52% more fresh and dry fodder yields, respectively, compared to the control plots.

This increase in yield with higher N application can be attributed to the more efficient utilisation of N and other environmental resources by maize crops,

Comparing fodder production of maize varieties under varied nitrogen levels

ultimately leading to greater biomass production. The increase in fresh fodder yield with higher NLs can be attributed to improvements in plant height and the number of leaves per plant, in line with the findings by Ullah *et al.* (2015).

Similar results were reported by Aslam *et al.* (2011) and Khan *et al.* (2014a, b), who found that the highest maize fresh and dry fodder yields were achieved with the application of the highest N doses.

CONCLUSIONS

From the findings of our experiment, it is clear that N is indeed a non-replaceable component that plays a crucial role in the growth and development of maize crops.

We concluded that various NLs significantly impacted the growth and yield-related traits of fodder maize. Taller plants and higher fresh fodder and dry fodder yields were obtained at 150 and 200 kg N ha⁻¹, which were statistically at par with each other.

In addition to NLs, introducing new and developed maize varieties is crucial for meeting the increasing demands of fodder.

The comparison of fodder maize varieties revealed significant results. The highest emergence, plant height, days to milking, fresh yield and dry fodder yield were obtained for the Jumbo variety compared to the Kaptan and Jalal varieties.

Overall, the Jumbo variety, along with 150 and 200 kg N ha⁻¹ resulted in the highest fodder yield and its related attributes.

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