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Optimizing Productivity of Buffel and Sudan Grasses Using Optimal Nitrogen Fertilizer Application under Arid Conditions

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Abstract: Most arid and semiarid areas are bare and greatly infested with intrusive wild species. Buffel grass (*Cenchrus ciliaris* L.) and Sudan grass (*Sorghum sudanense* Piper.) are the supreme drought-tolerant grasses that are commonly grown in dry regions. Besides water, nitrogen (N) is a vital element limiting the growth, yield, and herbage quality of such grasses since it has key roles in physiological and biochemical functions in plants. Hence, this study aimed at assessing the performance of Buffel and Sudan grasses under nitrogen fertilization in Mandera County. This study comprised a field trial laid as a split plot in a randomized complete block design with grasses being assigned to the main plots, whereas N rates (0, 35, 70, 105, and 140 kg N ha⁻¹) occupied the subplots. Data were collected on growth parameters (plant height, leaf length, number of leaves per plant, leaf width, stem girth, and tiller number), yield parameters (shoot weight, root weight, and aboveground biomass yield—DBY), and quality attributes (acid detergent fiber—ADF, crude protein—CP, and neutral detergent fiber—NDF). Across the seasons, plant height progressively increased with increasing N rates up to a maximum of 141 and 246 cm for Buffel grass and Sudan grass, respectively, which were associated with a 105 kg N ha⁻¹ rate. Nonetheless, there was no noteworthy enhancement in plant height (142 and 246 cm) with an additional upsurge in N fertilizer rate to 140 kg N ha⁻¹ relative to the one of 105 kg N ha⁻¹. Regarding the leaf length, Sudan grass had longer and wider leaves at all treatment levels than the Buffel grass. Plant height, leaf length, width, and the number of leaves per plant increased with increasing N level up to the rate of 140 kg N ha⁻¹, though this was not statistically different from the rate of 105 kg N ha⁻¹ for both kinds of grass. The results revealed that Sudan grass contained higher crude protein than Buffel grass at all levels of treatments (10.33 and 8.80% at the rate of 105 kg N ha⁻¹, respectively). More so, crude protein content was found to be higher in plots where N application was performed than in the control plots. There were great associations between the dependent variables (DBY, ADF, NDF, and CP) and independent variables (plant height, leaf length, No. of leaves, leaf width, stem girth, and No. of tillers), with the coefficient of regression ranging from 0.56 to 0.96 for Buffel grass and 0.59 to 0.96 for Sudan grass. Findings from this study indicate that for optimal growth, yield, and nutrient content benefits, Buffel and Sudan grasses ought to be grown using nitrogen fertilizer at a 105 kg N ha⁻¹ rate.



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Keywords: aridity; synthetic fertilizer; crude protein; acid detergent fiber; neutral detergent fiber

1. Introduction

Fodder production in drought-prone areas is a key limiting factor to livestock production [1–4]. A dry spell can seriously affect the ecosystem and agricultural productivity of an area and hence harm the local economy. Water scarcity comes about when the available sources fail to satisfy the long-term requirements of a region [1]. Responding to recurrent droughts and associated disasters, different players have been endorsing fodder cultivation as an approach to increase animal feed availability, with the goal being to provide enough forage to sustain the domestic livestock in the dry periods and as a supplementary source of revenue through the selling of grass seeds for reseeded and hay [5,6].

Due to fodder scarcity, local pastoralist communities are forced to practice cultivation and irrigated farming in places such as along river Dawa in Mandera County, a practice that has been in existence since 1984 [7]. Here, residents practice irrigated fodder cultivation using water pumps to caution against severe droughts, which cause high livestock mortality. In a case study by the Enhanced Livelihood in Mandera Triangle (ELMT) program, it was found that fodder production is a potential income-generating activity along River Dawa. This is utilized as a supplementary feed, hence improving the productivity of agro-pastoral livestock as long as storage facilities are available, and producers have the income to enable them to store their forage during the dry periods. Nonetheless, the choice of grass to be used as fodder is key for optimal livestock production. Reduced grasslands in semi-arid areas have forced livestock farmers to explore different choices such as intensification through planting fodder grasses so that they meet the animal feed requirements [5,8,9].

Buffel grass (*C. ciliaris*) is among the grasses commonly grown for fodder and as a cover crop in arid and semiarid lands (ASALs) [5]. The grass originated from southern Asia and larger parts of Africa, from where it spreads to different parts of the world. Its cultivation is still being promoted globally; hence, further invaded areas by the grass are more likely to increase in the future [10]. The grass is not only a supreme drought-tolerant grass among the ones commonly grown in dry areas, but also the most significant grass pasture in tropical regions [11]. The establishment of this grass is relatively easy, and it produces high forage yields ranging between 4 and 18 t ha^{−1} of dry matter when cultivated without fertilizer application, and up to 24 t ha^{−1} with proper fertilizer use [11].

Sudan grass (*S. sudanense*) is another important annual grass in ASALs with slender culms native to Southern Egypt and Sudan. This grass is a favorable forage crop especially in dry regions since it can tolerate water scarcity and has a high ability to produce more biomass yield [12]. It is a suitable forage crop for cultivation under irrigation systems in arid and semi-arid regions [13]. Sudan grass has several dependable characteristics, which include drought and heat tolerance, high-yielding potential, excellent water use efficiency, less susceptibility to diseases, and a high response to nitrogen fertilization [14].

Proper growth and development of plants, including grasses, cannot be achieved if nitrogen lacks among the supplied nutrients since it has a vital role in the physiological and metabolic functions of the plant [15]. About 78% of the nitrogen in the atmosphere is in inert form (N₂), which does not benefit the plants, therefore not taken directly. Nitrogen is a constituent of the plant's metabolism system that is linked to protein synthesis. Subsequently, to increase crop productivity, the application of nitrogen fertilizer is obligatory and cannot be avoided [16–18]. An optimal nitrogen rate leads to increased photosynthetic processes, and a higher leaf area index, in conjunction with the total assimilation rate [19–21]. High leaf area per plant and above-ground biomass are key determining factors in fodder production [22]. For the previous fifty years, yield in different plants has been increasing because of nitrogen use along with improved agronomic management practices [23]. All crops, including grasses, need nitrogen nutrition for energetic growth and development [21]. The use of nitrogen fertilizers in a judicious way ensures maximum

herbage harvest of superior quality [15]. Nonetheless, its overuse should be avoided [24]. Nitrogen conveys the dark green coloration in plants and stimulates stem and leaf growth as well as promoting the growth and elongation of roots. It boosts early rapid growth and increases the crude protein content of forage crops in addition to increasing uptake and utilization of other available nutrients such as phosphorus and potassium [25,26].

Lack of sufficient nitrogen causes slow growth, leaf chlorosis, and restricted bud lateral growth, with the deficiency symptoms first appearing on older foliage [11,27]. Additionally, suboptimal nitrogen application leads to a straight decrease in crop yield [28]. On the contrary, excess nitrogen application results in adverse effects on plants, whereby the leaves become extra dark green, and the shoots become more succulent. Therefore, proper plant growth and development need optimal nitrogen supply. In this regard, this study seeks to evaluate the optimal level of N for Buffel and Sudan grasses in dry regions.

2. Materials and Methods

2.1. Description of the Experimental Site

This study was conducted in Mandera County, which is located in North Eastern Kenya. The County borders Somalia towards the East and Ethiopia towards the North. It is located between latitudes 2.18° N and 4.26° N and longitudes 39.79° E and 41.81° E with an elevation range of 400–970 m above sea level. Field trials were laid out during short rains running from late October to early December of 2021, and long rains in 2022 (March–May) cropping seasons.

The area receives low and unreliable rainfall, with long rains being experienced from March to May and short rains between October and November. During the short rains of 2021, the mean maximum temperature was roughly 33 °C with a range of 30 to 35 °C, whereas the minimum temperature had an average value of 22 °C with a range of 20 to 23 °C (Figure 1). The season had a cumulative rainfall of 234 mm with November and October receiving the highest (115 mm) and least (44 mm) rainfall, respectively. On the other hand, the 2022 long rains season was wetter with amassed rainfall of 306 mm, of which 66% was received in April (107 mm) and May (96 mm). The maximum mean temperature for this season declines exponentially from the uppermost (38 °C) value to the lowest (31 °C), which was recorded in June. Based on the minimum mean temperature, March and April were slightly warmer (23.5 °C) compared with May and June, which had an average value of 21.5 °C.

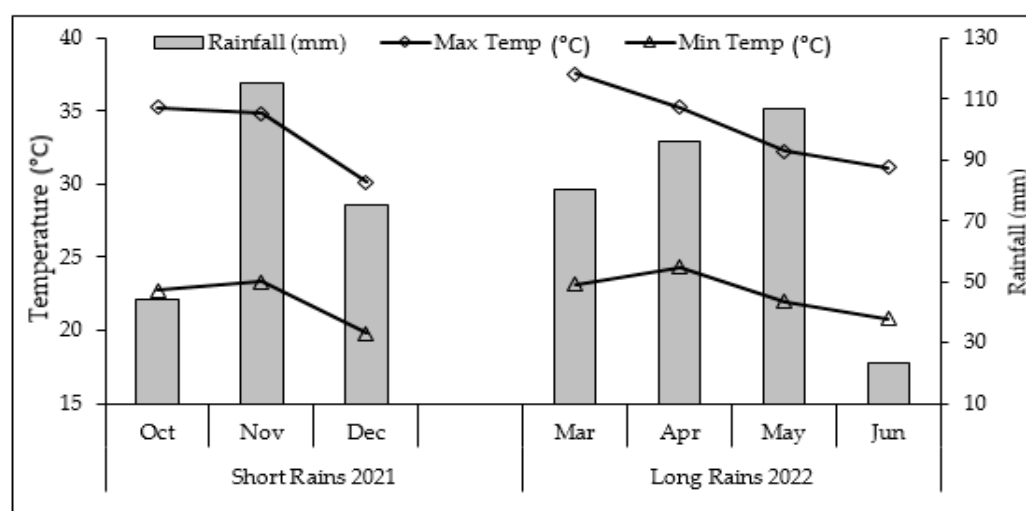


Figure 1. Average temperature and total monthly rainfall for the study site as recorded during the experimental period.

2.2. Soil Sampling and Analysis

Soil sampling was carried out using the soil auger 28 days before setting the field trial. In this case, 20 cores were taken from the site in a zigzag pattern (0–20 cm depth). The soil from the cores was thoroughly mixed in a bucket, and a representative sample was drawn for chemical and physical analysis. The composite sample was air-dried for three days and passed through a 2 mm sieve. Soil pH was measured in 1:2.5 *v/v* (soil: water solution) using the pH meter as described by Ryan et al. [29]. The amount of phosphorus was determined using a UV-vis spectrophotometer after extraction following the Bray 1 procedures [30,31]. Cations (K^+ , Na^+ , Ca^{2+} , and Mg^{2+}) were determined using an atomic absorption spectrophotometer [32]. The Walkley–Black method by Yeomans and Bremner [33] was used to determine soil organic carbon. Total nitrogen was determined using the Kjeldahl digestion method as it is described by Bremner and Keeney [34]. The hydrometer method (as described by Gee and Bauder, [35]) was employed in the determination of the soil texture, whereas bulk density analyses were performed following the procedures provided by Doran and Mielke [36].

Soil Physical and Chemical Properties

The soils in the region are mainly Calcisols. At the start of the experiment, soil analyses revealed that the site had a mean bulk density of 1.04 g cm^{-3} with sand, clay, and silt of 610, 180, and 210 g kg^{-1} , respectively (Table 1). Hence, the soil could be classified as having a sandy loam texture. In addition, the soil was slightly alkaline (pH of 7.05) with an electrical conductivity of 0.3 mS cm^{-1} . The soil was characterized by low levels of organic carbon (OC) (1.5 g kg^{-1}), total N (0.7 g kg^{-1}), and available P (5.8 mg kg^{-1}). Nonetheless, it had sufficient quantities of exchangeable cations: Na (0.5 cmol kg^{-1}), K (0.8 cmol kg^{-1}), Ca (6.7 cmol kg^{-1}), and Mg (1.2 cmol kg^{-1}).

Table 1. Soil physical and chemical properties for the upper 0.20 m depth at the study site.

Physical Property	Value	Chemical Property	Value
Clay (g kg^{-1})	180	pH (water) 1:2.5	7.05
Sand (g kg^{-1})	610	Electrical conductivity (mS cm^{-1})	0.3
Silt (g kg^{-1})	210	Exchangeable Na (cmol kg^{-1})	0.5
Textural class	Sandy loam	Exchangeable K (cmol kg^{-1})	0.8
Bulk density (g cm^{-3})	1.04	Exchangeable Ca (cmol kg^{-1})	6.7
		Exchangeable Mg (cmol kg^{-1})	1.2
		Organic carbon (g kg^{-1})	1.5
		Total N (g kg^{-1})	0.7
		Available P (mg kg^{-1})	5.8

2.3. Experimental Treatment and Design

The experiment was designed as a split plot in a randomized complete block design and replicated thrice. The main plots included Buffel grass and Sudan grasses, while the subplots contained five nitrogen rates (0, 35, 70, 105, and 140 kg N ha^{-1}). The area of the individual plot measured 25 m^2 (5 m length $\times$ 5 m width), with a 1.5 m space being left between the plots and a footpath of 2 m between the blocks, one block contained 10 treatments (Table 2).

Table 2. Treatment combinations.

Block 1	G1 $\times$ N1	G1 $\times$ N2	G1 $\times$ N3	G1 $\times$ N4	G1 $\times$ N5	G2 $\times$ N1	G2 $\times$ N2	G2 $\times$ N3	G2 $\times$ N4	G2 $\times$ N5
Block 2	G1 $\times$ N2	G1 $\times$ N5	G1 $\times$ N3	G1 $\times$ N1	G1 $\times$ N4	G2 $\times$ N2	G2 $\times$ N5	G2 $\times$ N3	G2 $\times$ N1	G2 $\times$ N4
Block 3	G1 $\times$ N4	G1 $\times$ N3	G1 $\times$ N1	G1 $\times$ N5	G1 $\times$ N2	G2 $\times$ N4	G2 $\times$ N3	G2 $\times$ N1	G2 $\times$ N5	G2 $\times$ N2

Table 2. Cont.

Main Plots (Grasses)		Subplots (N Levels)
	G1—Buffel grass	N1—0 kg N ha ^{−1}
	G2—Sudan grass	N2—35 kg N ha ^{−1}
		N3—70 kg N ha ^{−1}
		N4—105 kg N ha ^{−1}
		N5—140 kg N ha ^{−1}

2.4. Field Management

Buffel grass and Sudan grass seeds were sown in a well-prepared seedbed (that had previously lied fallow for three years) at a seed rate of 5 kg ha^{−1} using a hand drill in rows that were set 25 cm apart. Single superphosphate (SSP) fertilizer application was made at a rate of 50 kg P ha^{−1} during seedbed preparation to promote root development. The grasses were top dressed using nitrogen fertilizer (calcium ammonium nitrate—CAN) 14 days after emergence. Weeding was performed manually as necessary, while irrigation was performed using water from the Dawa River when required. This was performed uniformly on all plots at 30 mm depth per week.

2.5. Data Collection and Analysis

Ten plants were indiscriminately selected and marked for the collection of data on growth parameters. Data collection was performed thrice at two-week intervals beginning from the fourth week after sowing (WAS). The parameters considered were plant height, the number of leaves per plant, leaf width, stem girth, leaf length, number of tillers, and shoot and root dry weights. Plant height was measured from the base soil level to the tallest tiller using a tape measure, whereas leaves and tillers were physically counted. A vernier caliper was useful and it was used to measure stem girth. Destructive sampling of the plants from central 1 m² from each plot was performed at 8 WAS to determine the yield parameters (shoot and root dry weight per plant, and aboveground biomass yield per hectare) of Buffel and Sudan grasses. The harvested plants were dried in an oven at 60 °C for two days. This was followed by weighing on an electronic weighing scale per plant to determine the average shoot and root dry weight per plant. Afterward, the shoot dry weight data from each plot were expressed in aboveground biomass yield per hectare. At the harvesting stage (8 WAS), 600 g samples of forage were obtained from the dried plants. The dried samples were ground using a miller in the laboratory and thereafter analyzed for acid detergent fiber, crude protein content, and neutral detergent fiber using procedures of AOAC [37].

2.6. Statistical Analysis

The collected data were tabulated and managed in Microsoft Excel, after which analysis of variance (ANOVA) was performed using Genstat 15th edition statistical software. Separation of treatment means was then carried out using Fisher's least significance difference (LSD) test at a 5% level of probability.

3. Results

3.1. Effect of Nitrogen Fertilizer on the Growth Parameters

3.1.1. Plant Height

There was a high response of the two types of grasses to the application of nitrogen fertilizer at different treatment levels. Nitrogen fertilizer application heightened plants' height with pick values (110 cm for Buffel grass and 209 cm for Sudan grass) being noted at 8 weeks after sowing (WAS) (Figure 2). Notably, the growth was optimum at the treatment that received 105 kg N ha^{−1} for both kinds of grass. Across the seasons, plant height

progressively increased as N rates increased, up to a maximum of 141 and 246 cm for Buffel grass and Sudan grass, respectively, which were associated with a 105 kg N ha⁻¹ rate. Nonetheless, there was no noteworthy enhancement in plant height (142 and 246 cm) with an additional upsurge in N fertilizer rate to 140 kg N ha⁻¹ relative to the one of 105 kg N ha⁻¹.

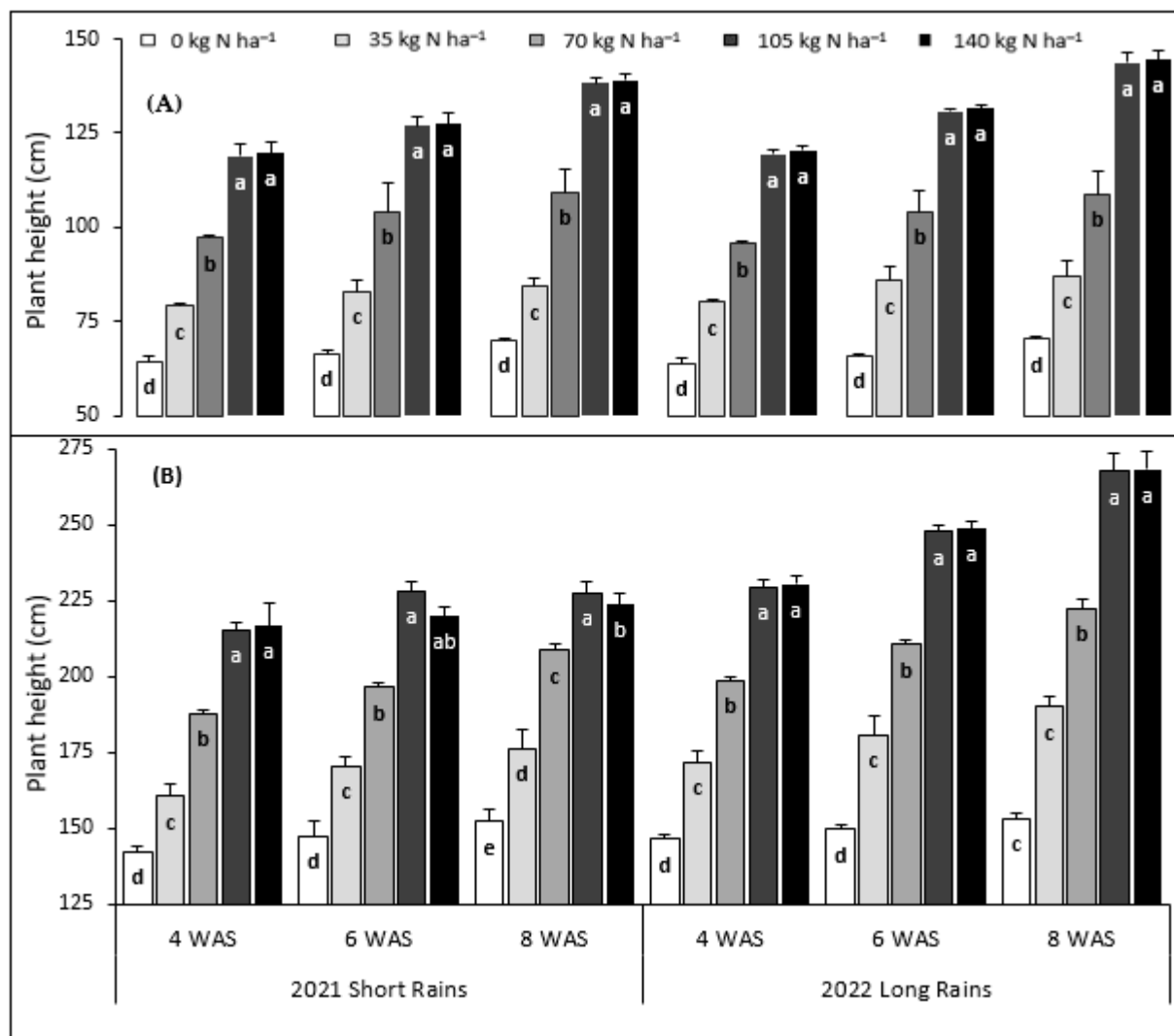


Figure 2. Plant height for Buffel grass (A) and Sudan grass (B) as influenced by N fertilizer application at 4, 6, and 8 weeks after sowing (WAS) during the 2021 short rains and 2022 long rains seasons in Mandera County. Bars bearing similar letters per sampling period do not vary significantly ($p \leq 0.05$).

3.1.2. Leaf Length, Width, and Number of Leaves per Plant

This study established that Sudan grass had longer and wider leaves at all treatment levels than the Buffel grass. Plant height, leaf width, length, and the number of leaves per plant increased with increasing N level up to the rate of 105 kg N ha⁻¹. For instance, across the seasons, irrespective of the grass type, control plots had the lowermost leaf lengths with an aggregate mean of 12 cm (Figure 3). The height then increased gradually to a plateau that was noted at the rate of 105 kg N ha⁻¹ (33 cm). A comparable trend was detected for leaf width with increased N fertilizer levels to 105 kg N ha⁻¹, which had a mean length of 30 cm and 36 cm for Buffel grass and Sudan grass, respectively (Figure 4). The trend was upheld with regard to the number of leaves per plant with the respective highest No. of leaves being recorded at 105 kg N ha⁻¹ (Figure 5).

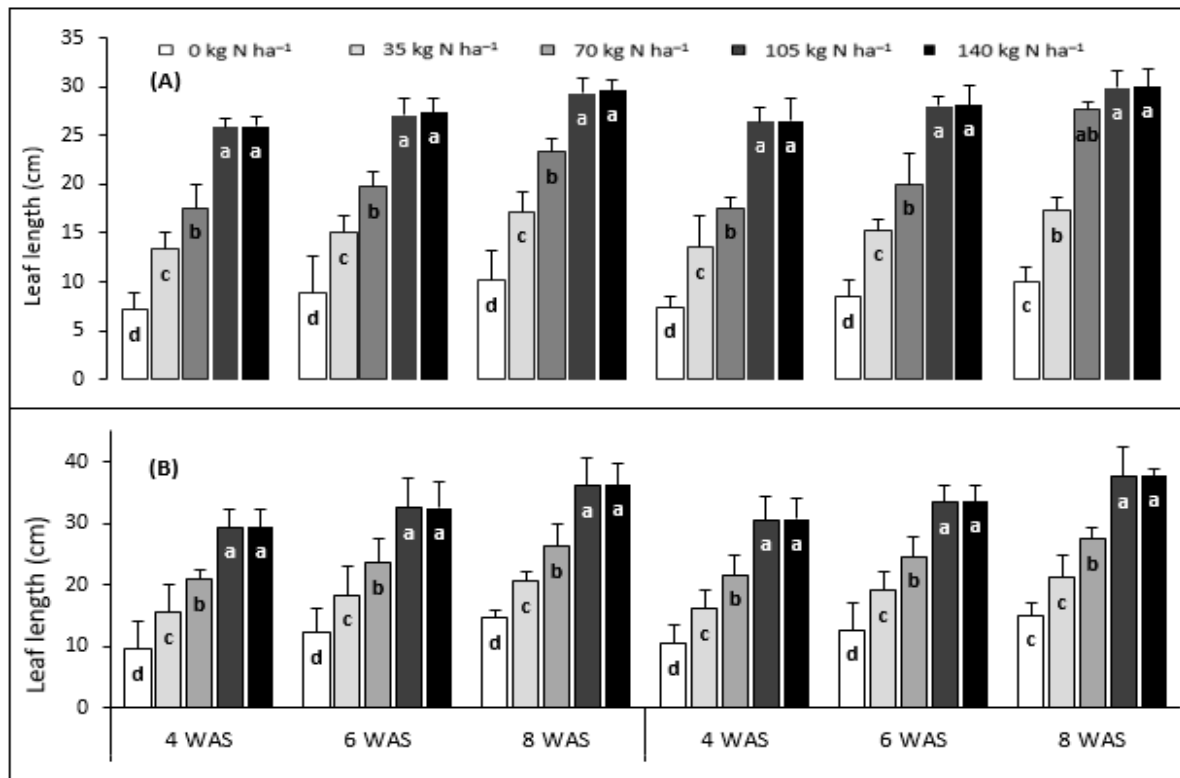


Figure 3. Leaf length for Buffel grass (A) and Sudan grass (B) as influenced by N fertilizer application at 4, 6, and 8 weeks after sowing (WAS) during the 2021 short rains and 2022 long rains seasons in Mandera County. Bars bearing similar letters per sampling period do not vary significantly ($p \leq 0.05$).

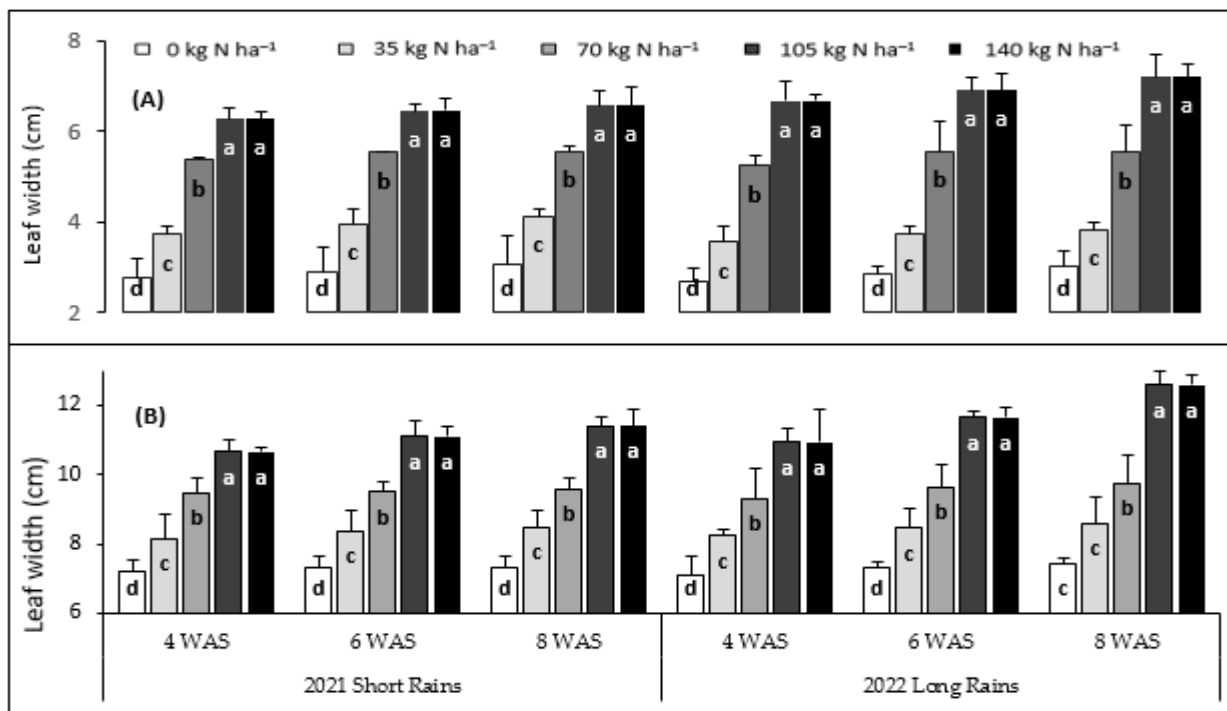


Figure 4. Leaf width for Buffel grass (A) and Sudan grass (B) as influenced by N fertilizer application at 4, 6, and 8 weeks after sowing (WAS) during the 2021 short rains and 2022 long rains seasons in Mandera County. Bars bearing similar letters per sampling period do not vary significantly ($p \leq 0.05$).

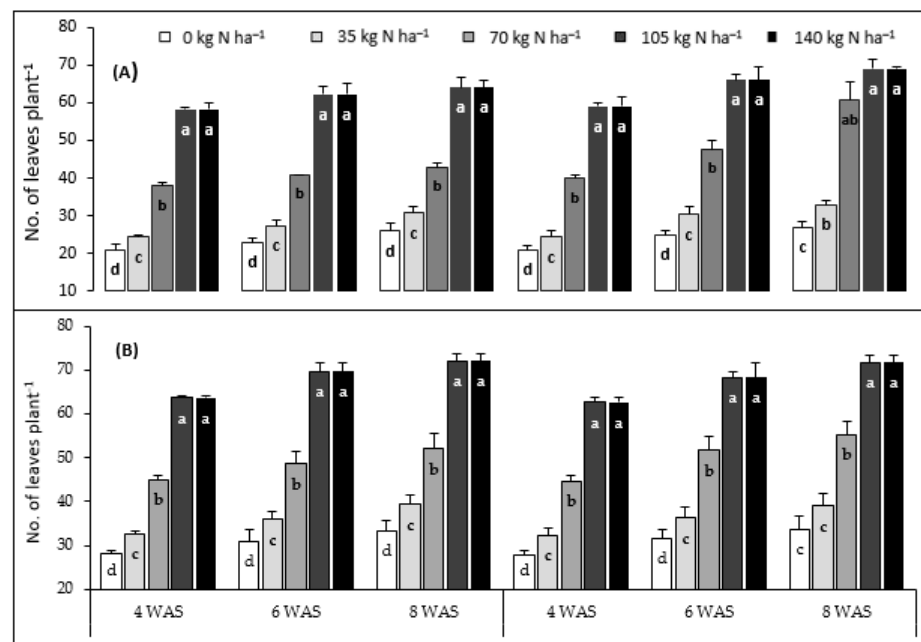


Figure 5. Number of leaves for Buffel grass (A) and Sudan grass (B) as influenced by N fertilizer application at 4, 6, and 8 weeks after sowing (WAS) during the 2021 short rains and 2022 long rains seasons in Mandera County. Bars bearing similar letters per sampling period do not vary significantly ($p \leq 0.05$).

3.1.3. Stem Girth

This study established that stem girth for both types of grass increased with increasing N rate, though at a marginal rate compared with other growth parameters such as stem height, leaf breadth, and length. Nevertheless, optimum stem girth was noted in the treatment that had received 105 kg of N ha⁻¹ (Figure 6). A slight growth was witnessed in the second season in comparison with the first season. This is because the weather conditions during the first season did not favor maximum utilization of the nitrogen supplied.

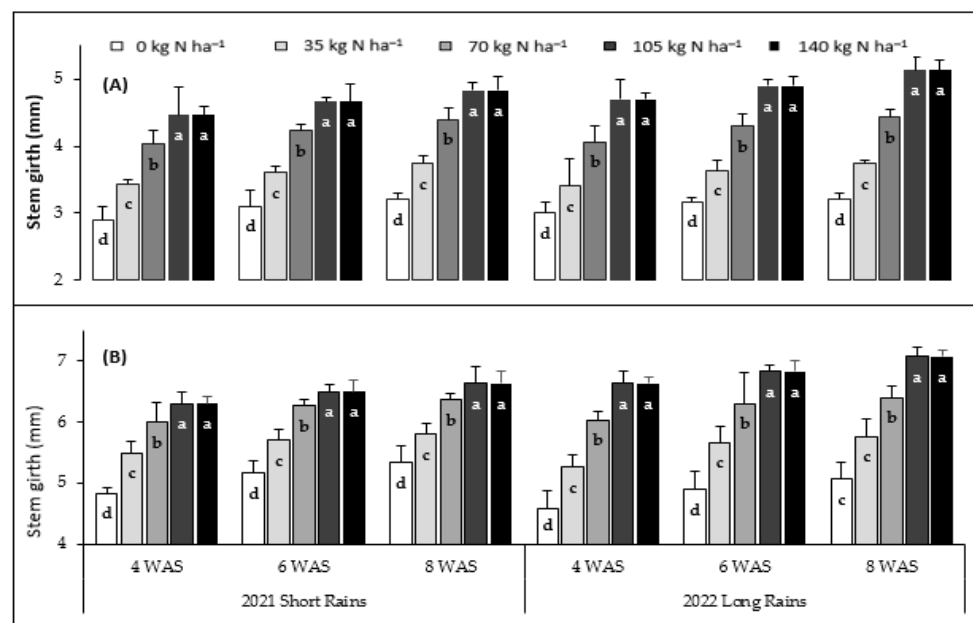


Figure 6. Stem girth for Buffel grass (A) and Sudan grass (B) as influenced by N fertilizer application at 4, 6, and 8 weeks after sowing (WAS) during the 2021 short rains and 2022 long rains seasons in Mandera County. Bars bearing similar letters per sampling period do not vary significantly ($p \leq 0.05$).

3.1.4. Number of Tillers

This study further established that Sudan grass had more tillers than Buffel grass. The number of tillers was found to increase with the treatment level and reached optimum at N4, which received an application of 105 kg N ha⁻¹ (Figure 7). Beyond this N rate, the number of tillers remained constant.

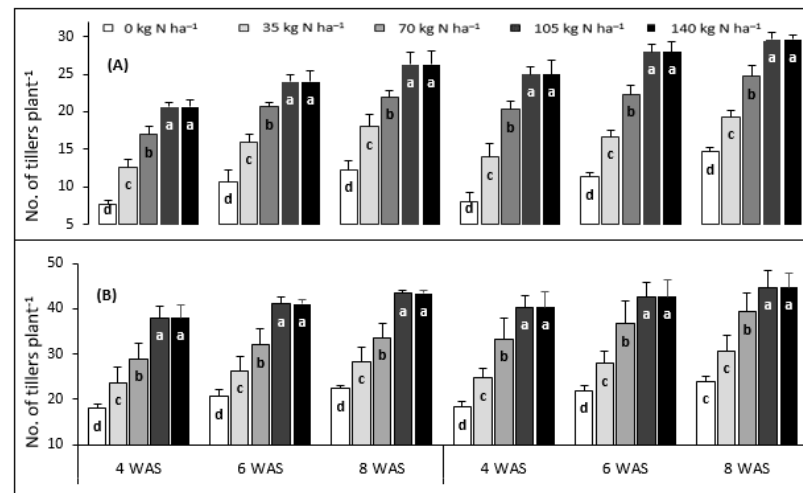


Figure 7. Number of tillers for Buffel grass (A) and Sudan grass (B) as influenced by N fertilizer application at 4, 6, and 8 weeks after sowing (WAS) during the 2021 short rains and 2022 long rains seasons in Mandera County. Bars bearing similar letters per sampling period do not vary significantly ($p \leq 0.05$).

3.2. Influence of Nitrogen Fertilizer on the Yield Parameters (Shoot, Root Weight, and Aboveground Biomass)

This study established that Buffel grass shoots weighed less than those of Sudan grass across the seasons at different N treatment levels (Figure 8). For instance, Sudan grass weighed from 33.6 g plant⁻¹ for control to 38.8 g plant⁻¹ for treatment that received 105 kg N ha⁻¹. On the other hand, lower values with a range of 24.3–29.9 g plant⁻¹ were noted for Buffel grass. On the other hand, lower values with a range of 24.3–29.9 g plant⁻¹ were noted for Buffel grass with respective ranges of 6.7–7.8 and 1.6–2.2 g plant⁻¹ (Figure 9). Similarly, Sudan grass roots weighed more than those of Buffel grass (Figure 9). Consequently, Sudan grass yielded more forage of up to 10 t ha⁻¹ compared to Buffel grass, which achieved only a maximum yield of 8 t ha⁻¹ at the optimal N application of 105 kg N ha⁻¹ (Figure 10).

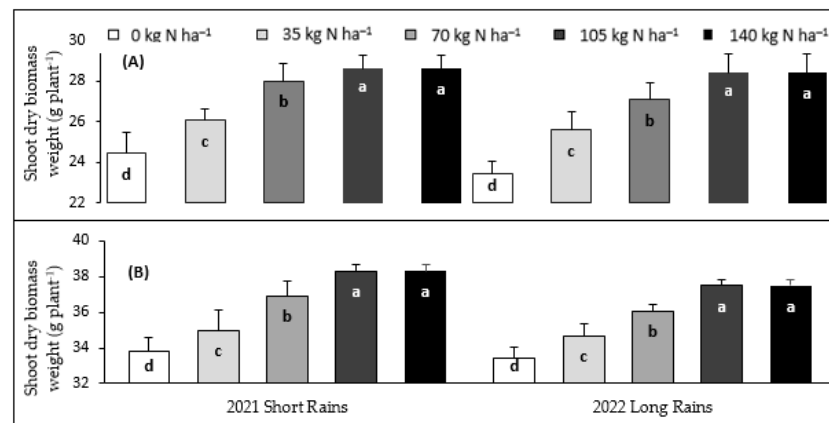


Figure 8. Shoot aboveground biomass weight for Buffel grass (A) and Sudan grass (B) as influenced by N fertilizer application during the short and long rains seasons of 2021 and 2022, respectively, in Mandera County. Bars bearing similar letters per sampling period do not vary significantly ($p \leq 0.05$).

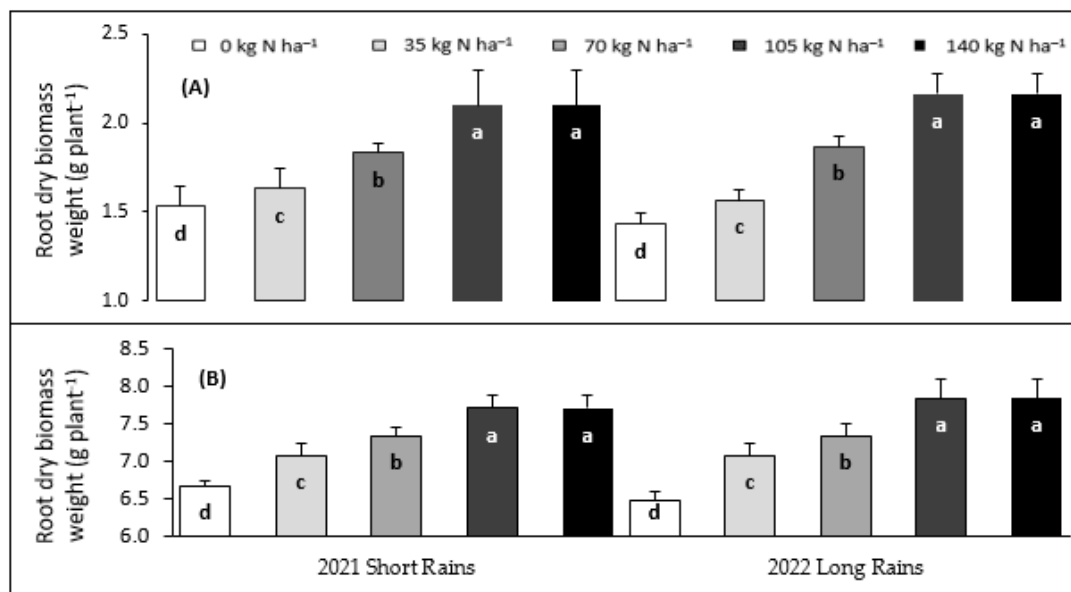


Figure 9. Root dry biomass weight for Buffel grass (A) and Sudan grass (B) as influenced by N fertilizer application during the short and long rains seasons of 2021 and 2022, respectively, in Mandera County. Bars bearing similar letters per sampling period do not vary significantly ($p \leq 0.05$).

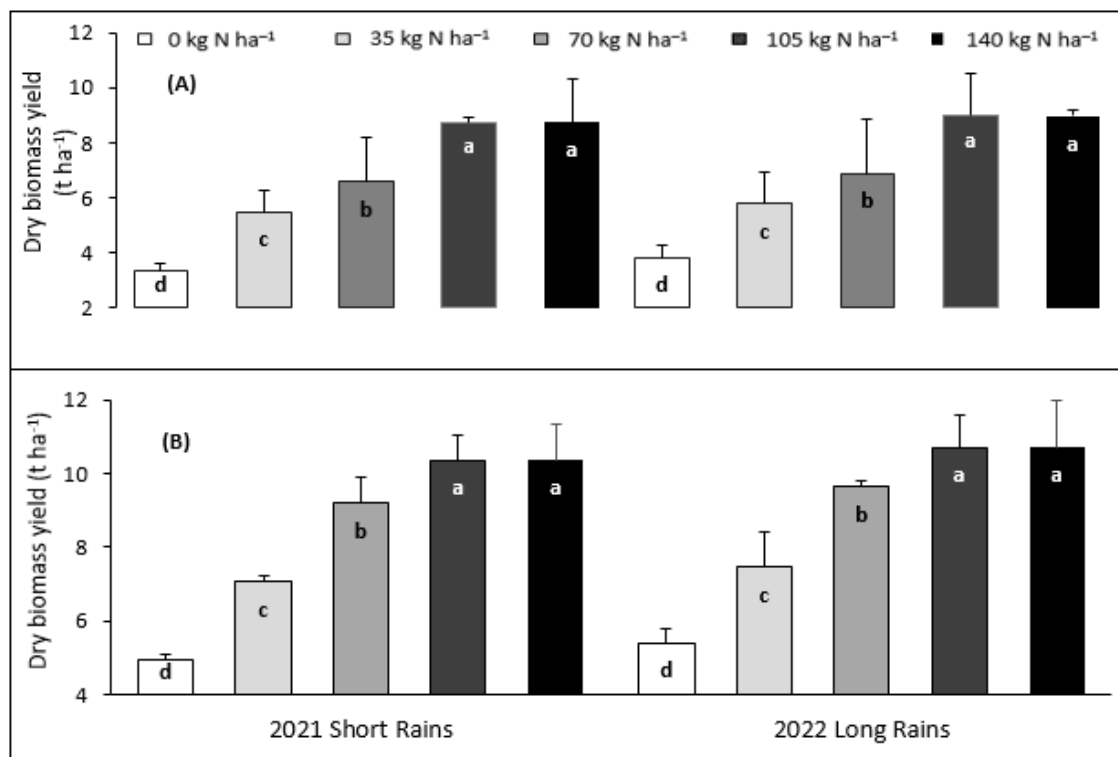


Figure 10. Aboveground biomass for Buffel grass (A) and Sudan grass (B) as influenced by N fertilizer application during the short and long rains seasons of 2021 and 2022, respectively, in Mandera County. Bars bearing similar letters per sampling period do not vary significantly ($p \leq 0.05$).

3.3. Influence of Nitrogen (N) Fertilizer Application on Grass Quality

The results revealed that Sudan grass contained higher crude protein than Buffel grass at all levels of treatments (Tables 3 and 4). Crude protein content was found to increase with treatment level and reached optimum at N4 (105 kg N ha⁻¹), and thereafter remained constant despite the addition of nitrogen fertilizer to 140 kg N ha⁻¹. The study results

established that the NDF content was higher than the ADF for both grass types. However, Sudan grass had a higher content of both ADF and NDF than Buffel grass.

Table 3. Crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF) for Buffel grass as influenced by N fertilizer application during the short and long rains seasons of 2021 and 2022, respectively, in Mandera County.

Season	Treatment	Crude Protein (%)	Neutral Detergent Fiber (%)	Acid Detergent Fiber (%)
2021 Short rains	0 kg N ha ^{−1}	4.07 ± 0.15 ^d	45.53 ± 3.45 ^b	25.47 ± 2.63 ^b
	35 kg N ha ^{−1}	5.60 ± 0.16 ^c	48.07 ± 1.89 ^a	27.37 ± 4.03 ^b
	70 kg N ha ^{−1}	6.50 ± 0.18 ^b	48.27 ± 3.35 ^a	29.53 ± 5.29 ^a
	105 kg N ha ^{−1}	8.70 ± 0.19 ^a	49.67 ± 0.46 ^a	31.10 ± 3.25 ^a
	140 kg N ha ^{−1}	8.63 ± 0.12 ^a	49.47 ± 1.29 ^a	30.97 ± 3.22 ^a
	LSD	0.06	1.16	1.28
<i>p</i> value		<0.001	<0.001	<0.001
2022 Long rains	0 kg N ha ^{−1}	4.27 ± 0.19 ^b	44.53 ± 3.63 ^d	24.20 ± 1.10 ^d
	35 kg N ha ^{−1}	5.80 ± 0.31 ^b	46.20 ± 2.23 ^c	26.30 ± 1.20 ^c
	70 kg N ha ^{−1}	6.67 ± 0.55 ^a	48.90 ± 5.89 ^b	28.13 ± 1.18 ^b
	105 kg N ha ^{−1}	8.80 ± 0.77 ^a	49.73 ± 3.95 ^a	29.67 ± 0.14 ^a
	140 kg N ha ^{−1}	8.47 ± 0.93 ^a	49.70 ± 4.72 ^a	29.53 ± 0.12 ^a
	LSD	1.77	0.29	0.79
<i>p</i> value		<0.001	<0.001	<0.001

Down the column and per season, different letters denote means that vary significantly at $p \leq 0.05$.

Table 4. Crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF) for Sudan grass as influenced by N fertilizer application during the short and long rains seasons of 2021 and 2022, respectively, in Mandera County.

Season	Treatment	Crude Protein (%)	Neutral Detergent Fiber (%)	Acid Detergent Fiber (%)
2021 Short rains	0 kg N ha ^{−1}	7.67 ± 0.15 ^b	61.83 ± 1.67 ^c	34.93 ± 1.41 ^c
	35 kg N ha ^{−1}	8.43 ± 0.71 ^b	63.23 ± 3.15 ^{bc}	36.13 ± 1.43 ^{bc}
	70 kg N ha ^{−1}	9.37 ± 0.31 ^a	65.57 ± 1.29 ^{ab}	36.87 ± 2.18 ^{ab}
	105 kg N ha ^{−1}	10.17 ± 0.91 ^a	67.17 ± 2.54 ^a	37.63 ± 0.96 ^a
	140 kg N ha ^{−1}	10.13 ± 1.01 ^a	67.17 ± 2.20 ^a	37.67 ± 0.92 ^a
	LSD	0.54	1.54	0.77
<i>p</i> value		<0.001	0.002	0.003
2022 Long rains	0 kg N ha ^{−1}	7.73 ± 0.51 ^d	62.93 ± 1.62 ^d	34.40 ± 2.70 ^d
	35 kg N ha ^{−1}	8.73 ± 0.86 ^c	64.33 ± 3.80 ^c	35.40 ± 1.92 ^c
	70 kg N ha ^{−1}	9.40 ± 0.90 ^b	65.73 ± 4.01 ^b	36.73 ± 2.52 ^b
	105 kg N ha ^{−1}	10.33 ± 1.06 ^a	67.00 ± 4.23 ^a	37.53 ± 1.70 ^{ab}
	140 kg N ha ^{−1}	10.37 ± 1.68 ^a	66.73 ± 1.40 ^{ab}	37.47 ± 1.72 ^a
	LSD	0.16	0.78	0.53
<i>p</i> value		<0.001	<0.001	<0.001

Down the column and per season, different letters denote means that vary significantly at $p \leq 0.05$.

3.4. Relationship Associations among the Assessed Variables

There were great associations between the dependent variables (aboveground biomass yield—DBY, neutral detergent fiber—NDF, acid detergent fiber—ADF, and crude protein—CP) and independent variables (plant height, No. of leaves, leaf length, leaf width, stem girth, and No. of tillers) with the coefficient of regression ranging from 0.56 to 0.96 for Buffel grass and 0.59 to 0.96 for Sudan grass (Table 5). The associations were not only high ($R^2 \geq 0.56$), but also significant ($p \leq 0.05$). Regression of DBY and CP against the growth parameters yielded greater coefficients with ranges of 0.87–0.96 and 0.89–0.96, respectively,

whereas the respective ranges recorded with regression of ADF and NDF were 0.56–0.77 and 0.70–0.84.

Table 5. Linear regression analyses of the dependent variables (Y): aboveground biomass yield, crude protein, neutral detergent fiber, and acid detergent fiber against the independent variables (x): plant height, leaf length, No. of leaves, leaf width, stem girth, and No. of tillers.

Grass Species	Independent Variable (x)	Aboveground Biomass Yield		Crude Protein		Neutral Detergent Fiber		Acid Detergent Fiber	
		R ²	Equation	R ²	Equation	R ²	Equation	R ²	Equation
Buffel grass	Plant height	0.96 ***	Y = 0.068x − 0.72	0.96 ***	Y = 0.059x + 0.29	0.71 **	Y = 0.057x + 41.78	0.96 ***	Y = 0.059x + 0.29
	Leaf length	0.94 ***	Y = 0.252x + 1.08	0.92 ***	Y = 0.215x + 1.92	0.78 ***	Y = 0.223x + 43.01	0.92 ***	Y = 0.215x + 1.92
	No. of leaves	0.87 ***	Y = 0.104x + 1.67	0.95 ***	Y = 0.089x + 2.40	0.69 **	Y = 0.091x + 43.58	0.95 ***	Y = 0.089x + 2.40
	Leaf width	0.95 ***	Y = 1.256x + 0.12	0.94 ***	Y = 1.081x + 1.05	0.76 **	Y = 1.088x + 42.27	0.94 ***	Y = 1.081x + 1.05
	Stem girth	0.95 ***	Y = 2.732x − 4.91	0.93 ***	Y = 2.338x − 3.22	0.72 **	Y = 2.302x + 38.19	0.93 ***	Y = 2.338x − 3.22
	No. of tillers	0.94 ***	Y = 0.335x − 0.73	0.91 ***	Y = 0.286x + 0.37	0.70 **	Y = 0.280x + 41.76	0.91 ***	Y = 0.286x + 0.37
Sudan grass	Plant height	0.88 ***	Y = 0.05x − 1.86	0.89 ***	Y = 0.024x + 4.24	0.75 **	Y = 0.043x + 56.16	0.89 ***	Y = 0.024x + 4.24
	Leaf length	0.93 ***	Y = 0.23x + 2.28	0.96 ***	Y = 0.112x + 6.18	0.78 ***	Y = 0.208x + 59.51	0.96 ***	Y = 0.112x + 6.18
	No. of leaves	0.88 ***	Y = 0.122x + 1.99	0.91 ***	Y = 0.060x + 6.03	0.84 ***	Y = 0.112x + 59.15	0.91 ***	Y = 0.060x + 6.03
	Leaf width	0.88 ***	Y = 1.040x − 1.73	0.93 ***	Y = 0.509x + 4.19	0.80 ***	Y = 0.922x + 56.02	0.93 ***	Y = 0.509x + 4.19
	Stem girth	0.92 ***	Y = 3.021x − 10.18	0.92 ***	Y = 1.442x + 0.27	0.78 ***	Y = 2.608x + 48.96	0.92 ***	Y = 1.442x + 0.27
	No. of tillers	0.89 ***	Y = 0.230x + 0.422	0.90 ***	Y = 0.111x + 5.31	0.76 **	Y = 0.198x + 58.14	0.90 ***	Y = 0.111x + 5.31

Significant at $p < 0.01$ (**), and $p < 0.001$ (***).

4. Discussion

Plant height is an important growth measure that indicates the progress of the plant in response to the supplied nutrients. This is because the grasses were readily able to take up the nitrogen fertilizer in time in a well-aerated soil, enhancing the height growth, as opined by Cook et al. [38] and Turgut et al. [39]. Further, Turgut et al. [39] observed that there were taller sorghum plants in the plots fertilized with nitrogen since nitrogen boosted vegetative growth, hence leading to vigorous plant growth. At zero treatment level, Sudan grass was almost twice as tall as Buffel grass. A similar trend was repeated at all treatment levels. This is mainly linked to Sudan grass' morphological nature that enabled it to have a faster take-up of the nitrogen fertilizer than the Buffel grass. The low plant heights recorded at 35 and 70 kg N ha^{−1} rates could have been due to low liberation of the available nitrogen into the soil for a swift take-up by the grasses.

Taller and quicker-growing grasses have an advantage since they possess high insulation amounts, hence resulting in improved growth and establishment by enhancing the competitive interaction of the grass species [40]. The finding in this study concurs with those of Abu-Alrub et al. [41], where nitrogen fertilizer was noted to significantly increase Buffel grass height relative to control, without a further increase at higher N rates. Further, the outcomes corroborate with those of Armah-Agyeman et al. [42], who recounted a low growth at lower N rates. Timely nitrogen fertilizer uptake by the grass promotes grass growth and increases the internodes and length, thereby increasing the height [11,17,43]. On the other hand, low grass growth witnessed in the absence of nitrogen fertilizer treatment could be due to unavailable N nutrients from the soil to stimulate growth [15,19].

The longer and wider leaf witnessed with the Sudan grass was due to faster uptake of the nitrogen that was supplied through fertilizer, which facilitated the growth of the leaves. The findings are in agreement with the ones of Sher et al. [44] and Moghimi and Maghsoudi [45], who reported an increase in the number of leaves, and leaf area in sorghum cultivars with increasing nitrogen rates. Jung et al. [46] reported that nitrogen application resulted in a significant upsurge in the average leaf width of sorghum and Sudan grass hybrids. The growth during season two was enormous and it was revealed that leaf length attributes of both kinds of grass were higher than in season one. This can be attributed to higher precipitation received during this period, which led to maximum utilization of the fertilizer applied.

Further, this study established that the number of leaves per plant increase with increasing nitrogen rates, with Sudan grass having more leaves than Buffel grass. This implies that nitrogen fertilizer treatment for both types of grass ensured more leaves for making foliage for animal feeds [14]. These results agree with those of Mrid et al. [20]

and Wang et al. [47], who reported that photosynthetic activities, leaf chlorophyll content, and other leaf attributes of maize crops improve under nitrogen fertilization. Nitrogen fertilizer has been found to stimulate the growth of leaves and their enlargement, which subsequently forms nutritious animal feed.

The higher number of tillers associated with Buffel grass could be ascribed to its deep rooting system and a high potential for regrowth due to the space provided during planting and easy uptake of nitrogen fertilizer during the second season. The results agree with Iptas and Brohi's [48] findings, which recorded an escalation in the number of tillers with nitrogen application in Sudan grass. From the aforementioned growth parameters, it is clear that nitrogen fertilizer application positively and significantly affects the growth of both kinds of grass [5].

Shoots of Sudan grass weighed more than those of Buffel grass; this phenomenon could be ascribed to the ability of Sudan grass to take up higher quantities of water and nutrients due to its deep rooting system [19,49]. Similarly, Sudan grass roots weighed more than Buffel grass, an observation that could be attributed to Sudan grass being deeply rooted with several rhizomes, hence making it weigh more than the Buffel grass [50]. Such characteristics enable it to survive in drier environments than the Buffel grass because of its ability to obtain water deep from deep soil horizons and utilize it for maximum production. Such mechanisms enable plants to adapt to harsh conditions in dry lands [51].

Sudan grass produced more forage yield compared to Buffel grass, this is because of the greater tiller number and number of leaves produced by Sudan grass than Buffel grass [1,14]. Moreover, the higher forage yield observed in Sudan grass was also attributed to the fact that the dry matter in the shoot was more than that in Buffel, making Sudan grass a better feed for animals due to its higher quality [52,53]. It is also imperative to note that forage yield increased with treatment level, reaching optimum at N_4 (which had 105 kg N ha^{-1}). This gave rise to a high forage yield, implying that nitrogen fertilizer positively affects the forage yield of the two kinds of grass. Farhadi et al. [54] recorded increased values of water use efficiency, green herbage yield, and dry organic matter in forage sorghum as the rates of nitrogen supplied increased. Nonetheless, there was no significant increase in yield with a further upsurge of N rate to 140 kg N ha^{-1} , an implication that the additional nitrogen was consumed luxuriously. These findings corroborate those of Kaplan et al. [53], who reported that the green herbage yield of Sudan grass increased with an increase in nitrogen doses. The unfertilized plots were found to have a low forage yield for both Sudan and Buffel grasses. According to Tommasino et al. [55], lack of nitrogen significantly decreases the leaf area, photosynthetic rate, and leaf chlorophyll content of sorghum, leading to lower above-ground biomass production.

Nitrogen fertilizer positively affects the percentage of crude protein of the two forage kinds of grass at every level of nitrogen application. More so, crude protein content was found to be higher in plots where N application was performed than in the control plots. According to Mwadalu et al. [56], the application of sole nitrogen fertilizer resulted in an increase in the tissue nitrogen content of sorghum compared with the plots treated with nitrogen fertilizer. The work of Donaldson and Rootman [57] revealed that, as the rates of nitrogen fertilizer increased, there was a significant rise in forage nitrogen content. These findings confirm those of Ochieng et al. [18], who noted that an upsurge in nitrogen rates increased the protein content of maize crops. The ADF and NDF were found to vary with treatment level, confirming the findings by Mut et al. [58] and Wang et al. [47], who found that these variables vary with nitrogen fertilizer application.

The observed high associations between the dependent and independent variables implied that growth parameters had great roles in determining not only the yield, but also the ADF, ADE, and CP content of both Buffel and Sudan grasses [5,19,55]. For instance, for Buffel grass, with all factors being held constant, a unit increase in plant height, leaf length, No. of leaves per plant, leaf width, stem girth, and No. of tillers per plant would have resulted in yield increases of 68, 251, 100, 1256, 2730, and 330 kg, respectively [59,60]. On the other hand, under favorable conditions, with other factors fixed, it required an upward

adjustment in plant height by 20 cm, leaf length by 4.4 cm, leaf width by 0.9 cm, stem girth by 0.3 cm, No. of leaves per plant by 8.1 units, and No. of tillers per plant by 4.3 units to achieve a unit increase in Sudan grass yield.

5. Conclusions

Nitrogen fertilizer application significantly influenced the growth attributes of both Sudan and Buffel grasses, where optimal growth parameter values were obtained at the rate of 105 kg N ha⁻¹. Herbage yield and yield components were significantly influenced by nitrogen rates, with the highest yield being observed at the rate of 140 kg N ha⁻¹, though it did not vary significantly from the 105 kg N ha⁻¹ rate for both kinds of grass. The herbage quality parameters (acid detergent fiber, crude protein, and neutral detergent fiber) were positively influenced by nitrogen fertilizer application, whereby they increased as the rates of nitrogen increased. The indices were greatest at the rates of 105 and 140 kg N ha⁻¹. Farmers ought to use nitrogen fertilizer in the production of Sudan and Buffel grasses for increased growth and tillering (herbage). Particularly, this study recommends the use of CAN fertilizer for both Buffel and Sudan grasses cultivation at the rate of 105 kg N ha⁻¹ for optimum herbage yield of high nutritional quality.

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