

**BUFFEL (*Cenchrus ciliaris*) AND SUDAN (*Sorghum sudanense*)
GRASSES' GROWTH, YIELD AND QUALITY RESPONSES
TO NITROGEN APPLICATION IN MANDERA
COUNTY, KENYA**

By

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for the Award of Master of Science Degree in Dryland Agriculture and
Enterprise Development in the School of Agriculture and
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DECLARATION


This thesis is my original work and has neither been presented for a degree award in any other University nor submitted elsewhere for any other award.

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DEDICATION

This thesis is devoted to my family more so my lovely wife Saadia Addi, and children (Mansuur Mohamed, Munawar Mohamed, and Abdiazi Mohamed) who have been a constant source of inspiration and given me unwavering support in this process.

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LIST OF ACRONYMS AND ABBREVIATIONS

ADF	Acid Detergent Fiber
ANOVA	Analysis of Variance
AOAC	Association of Analytical Chemists
ASALs	Arid and Semiarid Lands
CAN	Calcium Ammonium Nitrate
CP	Crude Protein
CPHA	California Plant Health Association
DM	Dry Matter
ELMT	Enhanced Livelihood in Mandera Triangle
FAO	Food Agriculture Organization
GoK	Government of Kenya
KALRO	Kenya Agricultural and Livestock Research Organization
LSD	Least Significant Difference
N	Nitrogen
NDF	Neutral Detergent Fiber
RCBD	Randomized Complete Block Design
RoK	Republic of Kenya
RPLRP-K	Regional Pastoral Livelihoods Resilience Project-Kenya
SANBI	South African National Biodiversity Institute
USAID	United States Agency for International Development
WAS	Weeks After Sowing

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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 to assess 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 collection was carried out 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 grasses. 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 made 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 105 kg N ha⁻¹ rate. The study recommends the use of nitrogen fertilizer at the right time in the growth cycle of Buffel and Sudan grasses.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Livestock farming is a significant economic activity and the primary source of income for rural families in Arid and Semiarid Lands (ASALs). In Kenya, ASALs account for 88% of the total land area and are home to around 15 million people; nearly 69% of the nation's livestock production takes place in these regions, which employ over 90% of the local population (RoK, 2010, 2012). However, the sector faces various challenges, including fluctuating climatic conditions, which cause inconsistent weather patterns, resulting in reduced feed supply. Large swaths of these habitats are heavily infested with invasive wild species, resulting in poor fodder quality. Due to climate variability and shifting land-use dynamics, traditional land management practices are crumbling due to frequent droughts that are experienced in these regions (Kaplan *et al.*, 2019; Kassahun *et al.*, 2008).

Fodder production in drought-prone ASALs areas is a key limiting factor to livestock production (Pereira *et al.*, 2002; Seleiman *et al.*, 2021; Nyawade *et al.*, 2020b). 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 (Łabędzki, 2016). 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 (Lugusa, 2015; Wasonga *et al.*, 2016).

Drought has caused local pastoralist populations to pursue agriculture and irrigated farming in places like Mandera County, where it has been practiced since 1984 (Boru *et al.*, 2015). Residents here use water pumps to irrigate fodder crops to avoid severe droughts, which cause substantial livestock mortality. According to a case study conducted by the Enhanced Livelihood in Mandera Triangle (ELMT) program, fodder cultivation is a viable income-generating activity along the 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 to meet the animal feed requirements (Kisambo *et al.*, 2022; Lugusa, 2015; Omollo, 2017).

Buffel grass (*C. ciliaris*) is among the grasses commonly grown for fodder and as a cover crop in ASALs (Overman *et al.*, 1992). 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 (Overman *et al.*, 1992; Weber, 2017). 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 (Osman *et al.*, 2008). 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 the application of fertilizer, and up to 24 t ha⁻¹ with proper fertilizer use (Osman *et al.*, 2008).

Sudan grass (*S. sudanense*) is another important annual grass in ASALs with slender culms native to Southern Egypt and Sudan (Alhammad *et al.*, 2023a). This grass is a favourable forage crop especially in dry regions since it can tolerate water scarcity and has a high ability to produce more biomass yield (Ismail *et al.*, 2018). It is a suitable forage crop for cultivation under irrigation systems in not only arid but also semi-arid regions (Ibrahim *et al.*, 2016). 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 N application (Machicek, 2018; Abo-Zeid *et al.*, 2017).

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 (Massignam *et al.*, 2009; Karasu *et al.*, 2009; Heydarzadeh *et al.* 2023; Leghari *et al.*, 2016; Chepkorir *et al.*, 2023; Ochieng' *et al.*, 2021). About 78% of the nitrogen in the atmosphere is in inert form (N₂), which does not benefit the plants and, 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 (Massignam *et al.*, 2009; Nduwimana *et al.*, 2020; Ochieng', 2021).

An optimal nitrogen rate leads to increased photosynthetic processes, and a higher leaf area index, in conjunction with the total assimilation rate (Glamoclija *et al.*, 2021; Ahmad *et al.*, 2009; Raza *et al.*, 2021; Nasar *et al.*, 2021, 2022a). High leaf area per plant and above-ground biomass are key determining factors in fodder production (Beyaert *et al.*, 2005; Rafiq *et al.*, 2010). For the previous fifty years, yield in different plants has been increasing because of

nitrogen use along with improved agronomic management practices (Smil, 2004). All crops, including grasses, need nitrogen nutrition for energetic growth and development (Nasar *et al.*, 2022a; Raza *et al.*, 2023). The use of nitrogen fertilizers in a judicious way ensures maximum herbage harvest of superior quality (Leghari *et al.*, 2016). Nonetheless, its overuse should be avoided (Sairaam *et al.*, 2022). Nitrogen conveys the dark green coloration in plants and stimulates stem and leaf growth besides promoting the growth and elongation of roots (Ochieng' *et al.*, 2023). It boosts early rapid growth and increases the crude protein content of forage crops besides increasing uptake and utilization of other available nutrients such as phosphorus and potassium (Alhammad *et al.*, 2023a; Cheptoek, 2022; Mirriam *et al.*, 2023; Bloom, 2015; Nasar *et al.*, 2023).

Lack of sufficient nitrogen causes slow growth, leaf chlorosis, and restricted bud growth with the deficiency symptoms first appearing on older foliage (Bianco *et al.*, 2015; Ochieng' *et al.*, 2023; Overman *et al.*, 1992). Additionally, suboptimal nitrogen application leads to a straight decrease in crop yield (Van Der Eerden, 1998). 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. Hence, proper plant growth and development need optimal nitrogen supply. In this regard, this study sought to evaluate the optimal level of N for Buffel and Sudan grasses in dry regions.

1.2 Statement of the Problem

Even though various channels of knowledge are available, the majority of farmers don't access information on proper crop management practices to improve fodder productivity. Skills and awareness on pasture establishment, suitable varieties, crop management, and uniform sensitization of forage technologies are not sufficient in arid and semi-arid areas (Mnene, 2006). Most farmers in Mandera County do not use any fertilizer in Buffel grass and Sudan grass production, hence exploiting the inherent soil nutrients that do not meet the fodder crop's nutrition requirements leading to low forage yield of poor quality. Information and knowledge on proper management intermediations such as appropriate fodder conservation and utilization, fertilizer and manure use, weeds, and climate aspects are underutilized in dry areas, leading to challenges in the determination and enduring sustainability of fodder cultivation (Leghari *et al.*, 2016; Njarui *et al.*, 2015).

Previous research has underlined the importance of nitrogen fertilizer and the source of nitrogen fertilizer on pasture grasses. The nitrogen fertilizer source had a substantial impact on guinea grass dry matter yield, nitrogen yield, phosphorus yield, potassium yield, and protein production (Tongvinichsin, 2015). The use of a small amount of nitrogen fertilizer

could result in an adequate production of pasture grass (Madakadze *et al.*, 1999). As a result, using nitrogen fertilizer at the proper dosage and supply of nitrogen can boost plant growth and productivity. Growers should have decided on the appropriate types of nitrogen fertilizer and application rates for the most successful fertilizer use. The principle of fertilizer application is to use the appropriate fertilizers at the appropriate rates and procedures at the appropriate periods (Roberts, 2018).

Pastoral production faces a myriad of challenges including high livestock mortalities due to recurrent droughts that are common in ASALs. This condition is likely to aggravate due to climate change, hence making the traditional pastoral handling approaches ineffective, with subsequent impacts on pastoral livelihoods (Elhadi, 2014). Most dry regions have experienced overgrazing challenges due to overstocking livestock exceeding the biophysical capacity of the grasses to redevelop, resulting in inappropriate resource utilization (Msangi & Signorelli, 2016). Drought is the main frequent natural calamity in Kenya. It touches millions of people. As a result, the Kenyan government had to create a National Drought Management System, which is committed to addressing drought in ASALs (Blench and Marriage, 1999).

Fodder shortage is a recurring problem that usually reduces livestock productivity, hence damaging the relationship among the pastoral communities by aggravating conflict over grazing lands (Gok, 2015). Regular droughts lead to pasture shortage, a condition that worsens due to increasing variability in climate (Stocker *et al.*, 2014). Inadequate livestock feed has led to low livestock production even leading to massive livestock mortalities. For instance, the droughts of 2009-2011 resulted in huge mortality of livestock populations. That was a major drawback for pastoral households because it resulted in high levels of food insecurity (Gok, 2015; Joosten *et al.*, 2014).

In dry regions, adapted species have gone extinct and are being replaced by wild, annuals, shrubs, plain patches, and inedible types. Food crop farming appears to be accepted more than fodder cultivation in agro-pastoral areas, which affects the farmer's ability to produce enough livestock feed. Also, in ASALs fodder growing is diminishing with high dependence on natural pastures as livestock feed with minimum effort to improvement (Kidake *et al.*, 2016). Most ASALs have been encroached on by different land-use systems together with indiscreet rangeland activities that have dented the nutritional value of pastures (Wairore *et al.*, 2015).

1.3 Significance of the Study

Pastoralism, which is characterized by extensive livestock production and coexistence with irrigated and rain-fed agriculture, dominates the economy in ASALs (RoK, 2002). In Kenyan dry areas, the livestock sector accounts for approximately 40% of the nation's Gross Domestic Product (KALRO, 2004). Production, management, and conservation of fodder have been identified as effective interventions for relieving poverty and increasing household nutritional status (Mulwale *et al.*, 2014). Both annual and perennial cultivated fodder crops are becoming very significant animal feed resources in Kenya since they produce superior dry matter yields, which is a requirement in livestock production (Thairu and Tessema, 1995).

Food and non-food interventions are among the several interventions usually carried out to mitigate pastoral communities from risks caused by climate change such as drought (RoK, 2014; Alhammad *et al.*, 2023b; Seleiman *et al.*, 2021; Kisaka *et al.*, 2023). Some of the non-food mediations include the provision of water for livestock, supplementary feeding of livestock, and to some extent selling a portion of the livestock (Kidake *et al.*, 2016; Mogotsi *et al.*, 2011). Another progressively important non-food intervention is fodder production. This is carried out to enhance not only household resilience to drought but also increase the prices of food commodities (USAID, 2012).

Livestock production in the tropics is centered on poor grazing management, which is accountable for low yield and returns in animal production (Reis *et al.*, 2009). The productivity of fodder might be enhanced by applying fertilizer, weed control, and grazing management (McCarthy *et al.*, 2016). Fodder fertilization is crucial in the economic and biological successes of livestock systems centered on forage. Applying nitrogen fertilizer in fodder cultivation increases the forage yield and quality (Silveira *et al.*, 2014).

Nitrogen is relatively low in tropical soils (CPHA, 2002; Shao *et al.*, 2023; Mwakidoshi *et al.*, 2023; Nungula *et al.*, 2023; Otieno *et al.*, 2021). When applied to plants including grasses, N increases not only the number of leaves and tillers but also foliage surface area, thus increasing dry matter yield (Serra *et al.*, 2018). An adequate supply of nitrogen to plants leads to high photosynthetic activity, dark green colour, and vigorous vegetative growth (Gitari *et al.*, 2018; Ochieng' *et al.*, 2021). Soil nitrogen monitoring is a key aspect of quality fodder production (Tisdale *et al.*, 1993). Even though tropical forages respond highly to nitrogen fertilizer application, resulting in higher crude protein and nutritive components, the risk of leaching in the soil and high nitrate accumulation in the plant biomass due to excess nitrogen fertilization should be taken care of to prevent environmental pollution and livestock health

disorders, therefore this study was carried out to determine Mugo *et al.*, 2021; the optimal rate of nitrogen in production of Buffel grass and Sudan grass.

1.4 Conceptual Framework

The key aspects of this study include, i) The problem (Independent variables): fodder shortage, inadequate nitrogen, and low forage yield of poor nutritive content, ii) Intervening variable: nitrogen fertilizer application, and iii) Dependent variables: increased forage yield and quality, optimum nitrogen rate (Figure 1.1).

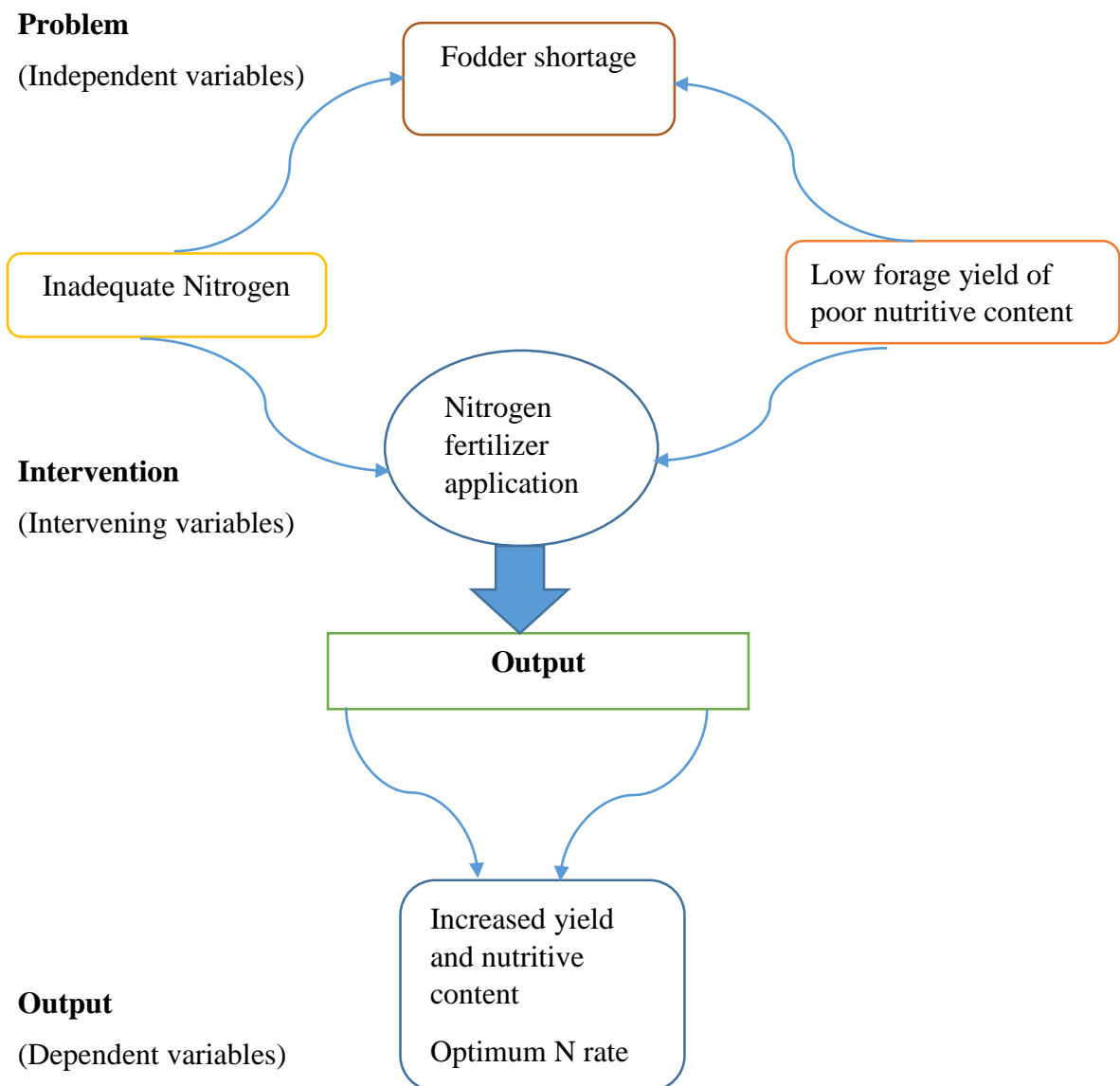


Figure 1.1: Conceptual framework Showing the interaction of dependent, independent and intervening variables (Source, Author)

1.5 Research Objectives

1.5.1 Broad objective

To optimize the production of Buffel and Sudan grasses through nitrogen fertilizer application in Mandera County.

1.5.2 Specific Objectives

Specifically, the study endeavored to:

- i. To determine the effect of nitrogen fertilizer on the growth parameters of Sudan and Buffel grasses.
- ii. To assess the influence of N fertilizer on yield parameters of Buffel and Sudan grasses.
- iii. To evaluate the herbage quality of Buffel and Sudan grasses as affected by nitrogen fertilizer application.

1.6 Research Hypotheses

- i. Nitrogen fertilizer application has significant influences on the growth of Buffel and Sudan grasses.
- ii. Nitrogen fertilizer significantly influences the yield of Buffel and Sudan grasses.
- iii. The herbage quality of Buffel and Sudan grasses is significantly influenced by nitrogen fertilizer application.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

Forage crops can be fed directly to livestock by grazing, cut, and fed fresh or processed by partial drying to form hay or pre-digested (Capstaff and Miller, 2018). Buffel grass and Sudan grass are warm-season grasses suited for cultivation in dry regions since they are less sensitive to low soil moisture and they produce more above-ground biomass that can be harvested and preserved in the form of hay and used to feed livestock during the drought period.

2.2 Buffel Grass

2.2.1 Description of Buffel grass

Buffel grass (*C. ciliaris*) is a capricious perennial grass (Cook *et al.*, 2005; Weber, 2003). The grass is deep-rooted and goes about two meters deep. Most of its varieties form rhizomes (Ecoport, 2010). It has decumbent culms, growing up to two meters in length (Weber, 2003; Cook *et al.*, 2005). In addition, the crop has a linear green to bluish foliage, which is less hairy, 4 to 35 cm long, and 5 to 10 mm in width (Clayton *et al.*, 2016). It has a spike-like panicle inflorescence, consisting of spikelets surrounded by hairy bristles (SANBI, 2010).

2.2.2 Distribution

Buffel grass originated from Africa, India, and Arabia. Exotic distribution extends to parts of the United States of America, Australia, Mexico, and South America. It was deliberately introduced for fodder in dry tropical regions during the early 1900s (Marshall *et al.*, 2012). The grass is naturally found or cultivated in vast regions and invades ASALs (Cook *et al.*, 2005; Weber, 2003). It grows well in denuded dry environments, on sandy, shallow, and rocky soils. Buffel grass thrives along the river banks and dry river beds as well as roadsides (Quattrocchi, 2006). The grass spreads by seed from plantings to other areas (Weber, 2003).

2.2.3 Adaptation

Buffel grass thrives at an altitude of about 2000 m (Mannetje *et al.*, 1992; FAO, 2010). Optimum growth conditions are a temperature range of 30°C to 35°C, with an annual rainfall range of 350 to 800 mm, well-drained and fertile soils, and a pH of between 7 and 8 (Cook *et al.*, 2005; FAO, 2010; Ochieng' *et al.*, 2023). It tolerates water shortages and

can grow in regions with a low annual rainfall of less than 100 mm. Nonetheless, in such areas, it produces the greatest yield if irrigated because of its ability to use water efficiently (Osman *et al.*, 2008). The crop is moderately tolerant to salinity but hypersensitive to manganese or aluminium toxicity (Mannetje *et al.*, 1992). Although this grass is tolerant of fire, it does not survive under waterlogged conditions for more than a week (Ecoport, 2010; Cook *et al.*, 2005). Buffel grass uses a photosynthesis type normally known as the C4 pathway that makes the grass survive in hot and dry environments (Guevara *et al.*, 2000). Long dry periods may lead to senescence of the above-ground biomass, while the root region survives and sprouts later when rains set in. Under seasonal dry periods, *C. ciliaris* responds to sufficient rainfall by flowering (Moser *et al.*, 2004).

Buffel grass desires seasonal or dry conditions. Rao *et al.* (1996) recorded average yields under rainfall ranges of 180-250 mm in a growing season. Its varieties vary substantially in terms of drought tolerance (Kharrat-Souissi *et al.*, 2012). Under high rainfall conditions, it can progressively become prone to fungal attacks (Perrott and Chakraborty, 1999). Although the grass withstands high temperatures, it is less tolerant to low temperatures of up to a freezing point (Barrera and Castellanos, 2007). It shows several characteristics for grass to exclusively suit and persist in adverse conditions in dry areas. Such attributes are its ability to accumulate carbohydrates at the stem that are slowly released when required, its deep rooting system that makes the grass get the required water, and extended seed longevity (Sharif-Zadeh and Murdoch, 2001).

2.2.4 Establishment and utilization

The grass grows well on loose soils, with a soft surface. In dry regions, seeds can be broadcasted in burnt areas. In regions receiving 600 mm rainfall or more, the seeds should be sown on prepared seedbeds. The seeds are fluffy and thus do not flow well and tend to clog seeders when sowing using conventional machinery, therefore drum seeders are more appropriate. Sowing can be done in a lightly scarified seedbed and then rolled (Robinson *et al.*, 1990). The grass should not be grazed before attaining 4 to 6 months after planting, although this depends on prevailing conditions during establishment (Cook *et al.*, 2005). Livestock is allowed to graze on the grass or cut at a height of 6 cm for it to regrow quickly and stand rotational and continuous grazing systems (FAO, 2010). Leaf to stem ratio increases rapidly with plant maturity and the highest total dry matter accumulation normally occurs between 45 to 60 days when the plant is mature therefore utilization of the grass should be around this time (Garcia and Silva, 1980).

Regular grazing increases the nutritional value of the grass. Buffel grass should be harvested at the onset of flowering when used for hay to ensure that the required nutrients are preserved. Burning the grass can also be of great benefit since it ends the old and woody grass parts while the crowns remain undamaged, the grass recuperates and new leaves of high nutrient value appear (FAO, 2010).

2.3 Sudan Grass

2.3.1 Description of Sudan grass

Sudan grass (*S. sudanense*) is an annual grass with slim culms normally 3 to 9 mm thick reaching up to 3 meters in height. It has numerous light green leaves, which are 4 to 15 cm long, and 8 to 15 mm wide. Its inflorescence consists of panicles ending in short brittle racemes. The grass has paired 6 to 7-mm long spikelets. It develops fibrous roots, with a single seed having the ability to give rise to a plant that can produce many tillers. Sudan grass has a high regrowth potential and tillers extensively (Armah-Agyeman *et al.*, 2002).

2.3.2 Distribution

Sudan grass is an outcome of the natural hybridization between *S. bicolor* and *S. arundinaceum*. It is native to Sudan and Southern Egypt. Grass was introduced into Russia and the USA in the early 1900s. It is now widespread in Australia, South Africa, South America, Northern and Central Europe (Duke, 1983). Its cultivation is also done in Thailand and the Philippines (Hacker, 1992). Many improved varieties have been developed that are tolerant to diseases, have less toxic chemical content, sweeter stems, and more leaves than the previous varieties (Armah-Agyeman *et al.*, 2002).

2.3.3 Adaptation

Sudan grass can thrive in well-drained fertile soil. It is sensitive to low pH hence liming is required if it is to be grown on acidic soils (Parecido *et al.*, 2021). For the plant to achieve its optimal production, a pH range of 6.0 to 6.5 is required (Teutsch, 2009; Cheptoek *et al.*, 2022; Haile, 2023). The crop thrives on almost every type of soil, but it performs well on loams. Porous, coarse sand or gravelly soils are usually not good for production. Generally, soils that are suitable for growing sorghum are also good for Sudan grass production. The grass is less tolerant to cold, such that during cold periods the plant remains dormant and resumes growth when conditions are favourable. It cannot tolerate frosts during the growing season (Armah-Agyeman *et al.*, 2002).

2.3.4 Establishment and utilization

The grass seeds should be sown in a firm, moist, well-prepared seedbed. Using seeds that are adapted to the area of production is paramount. It is essential to wait until the soils are warm before planting because cool soils slow germination and give the weed seeds priority over the crop. Planting is preferred when the soil temperature is at least 16°C. When using seed as a propagating material late planting is not recommended. If the grass is intended to be used for grazing, it is recommended to use at least 50 cm row spacing to give room for cattle to move in the field without stepping on the grass (Armah-Agyeman *et al.*, 2002). Since the grass is moderately tolerant to the high amount of residue or organic matter and saline soils, it is mostly grown on fields with historically low lint and cotton yields (Knowles and Ottman, 1997).

Planting depths can range from 2.5 cm to 4 cm depending on the soil type and available moisture. The seeds should be covered lightly with soil to enhance germination. In dry regions lower seeding rate is better, while higher rates are suitable for irrigated or rain-fed grass. Apply fertilizer as per the guidelines of the soil test, and amend the rate and time of application to moisture supply and optimal forage required. Applying nitrogen fertilizer in splits is recommended to minimize the likelihood of nitrate poisoning in livestock. The grass can be cut green and chopped to feed livestock and grazed before heading because dry matter intake and digestibility reduce after the heading stage (Armah-Agyeman *et al.*, 2002). Harvesting of Sudan grass from 6 to 8 weeks after planting is recommended, it can be cut every 3 to 4 weeks for hay. When grazed down quickly it takes a longer time to regrow. Livestock rotation in sections or strips promotes better regrowth, enables irrigation after grazing, and avoids uneven grazing which may result in tall unpalatable grass (Knowles and Ottman, 1997).

2.4 Influence of Nitrogen Fertilizer on Forage Yield and Nutritive Content

Plant growth and development normally require sufficient nitrogen nutrition. To improve yield and enhance forage quality it is significant to determine the amount of N fertilizer required by fodder plants (Ayub *et al.*, 2009). In a previous study by Munari-Escarela *et al.* (2017), it was indicated that nitrogen application resulted in a quadratic upsurge in shoot dry matter production, which subsequently reflected in total dry matter yield. Lack of nitrogen application greatly affected dry matter production. While working on Mombasa grass, Mello *et al.* (2008) recorded an increase in dry matter accumulation in shoots in a field trial with an increase in nitrogen fertilizer rates. Tropical grasses respond well to increased nitrogen supply thus favouring dry matter production (Castagnara *et al.*, 2011).

Nitrogen fertilizer increased plant height, enhanced biomass yield, prolonged maturity of oat plant by four to eleven days, increasing protein and cellulose content compared with the non-fertilized field (Cui *et al.*, 2016).

Nitrogen fertilizer increases fodder yield depending on the dose, a high rate of nitrogen resulted in the greatest amount of forage yield and the unfertilized plots recorded the lowest forage (Kara *et al.*, 1999; Torun and Koycu, 1996). The study was done in fodder yield while the current study was done in grass yield. According to Dasci and Comakli, (2011), nitrogen fertilizer had an impact on the percentage of crude protein of forage, whereby higher values were recorded from nitrogen application than forage from plots without fertilizer. Previous studies have indicated that an upsurge in forage yield can be possible through the application of nitrogen fertilizer (Gillen and Berg, 1998; Jacobsen *et al.*, 1996).

Quality of forage is the key standard in the production of fodder crops. Crude protein is the most essential and it is normally indicated that high crude-protein-forage is highly preferred by animals (Qureshi, 1992). According to Ullah *et al.* (2010), the crude protein percentage in elephant grass significantly increased with nitrogen application, the increase was due to the comfortable consumption of nitrogen by grasses.

Crude fiber is the portion in forage that contains insoluble cellulose and other carbohydrates. It is a crucial dietary aspect that is needed for proper metabolism and rumen functioning (Ullah *et al.*, 2015). The fiber content and crude protein in forages are not usually constant, they vary with fertilizer application (Hunt *et al.*, 1992; Knettle *et al.*, 1991). Low digestibility and poor forage intake are caused by high crude fiber content and low protein content. When fodder crops approach maturity, cell wall components and dry matter increase while the protein content reduces (Hunt *et al.*, 1992). According to Ullah *et al.* (2015), in fodder maize, nitrogen fertilizer application plays a key role in increasing crude fiber percentage. This was mainly ascribed to the plant height, and thicker stems as the rates of nitrogen increased. Proper nitrogen nutrition has a big role in increasing forage quality, whereby a balanced nitrogen supply not only stimulates the growth of fodder plants but also restricts the water stress adverse effects (Seleiman *et al.*, 2021; Wasonga *et al.*, 2016; Villar-salvador *et al.*, 2013; Nyawade *et al.*, 2020a, 2021).

Neutral detergent fiber (NDF) is an important characteristic of crude fiber in fodder crops, and so is acid detergent fiber (ADF). Acid Detergent Fiber (ADF) comprises crop constituents that are minimally digested by livestock, such as lignin and cellulose, while NDF is the structural component of the plant, that is the cell wall, and therefore they are

significant attributes of forage quality (Mut *et al.*, 2017). While working on Bermuda grass, Kering *et al.* (2011), observed that the application of nitrogen fertilizer resulted in a decrease in ADF and NDF. The study by Abdi *et al.*, 2015, revealed that urea fertilizer application led to a decrease in NDF in *Panicum maximum*, this was attributed to the enhancement of plant growth and production of new shoots and leaves, which minimized the NDF content linearly as the nitrogen rates increased.

2.5 Identified Gaps in Research on Nitrogen Fertilization in Buffel and Sudan Grasses

The growth, yield, and quality of Buffel and Sudan grasses can be significantly influenced by nitrogen fertilizer application. Nitrogen is an essential nutrient for plant growth, hence its application in adequate quantities can promote vegetative growth in both Buffel and Sudan grasses. This results in increased plant height, leaf area, and overall biomass production. Nitrogen encourages tillering, leading to the development of more shoots and leaves. This can improve ground cover and forage availability.

Buffel and Sudan grasses respond positively to nitrogen fertilization in terms of increased forage yield. Higher nitrogen levels often lead to greater biomass production, which can be valuable for livestock feed and forage production. The yield response to nitrogen varies depending on the grass species, soil type, and climate. Research is important to determine the optimal nitrogen application rates that maximize yield without excessive nitrogen loss to the environment. Nitrogen is a key component of plant proteins, and its application can increase the crude protein content in Buffel and Sudan grasses. This is especially important for livestock nutrition; as higher protein content enhances the forage's quality.

It's important to note that the effects of nitrogen fertilization on growth, yield, and quality vary depending on factors such as the initial soil nutrient status, nitrogen application timing, nitrogen source, and local environmental conditions. Therefore, it's crucial to conduct site-specific research to determine the most appropriate nitrogen fertilization practices for Buffel and Sudan grasses to achieve the desired balance between yield and quality while considering environmental sustainability.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Site Description

This study was conducted in Mandera County, located in North Eastern Kenya (Figure 3.1). The County borders Somalia towards the East and Ethiopia towards the North. The county's climate is generally dry, with limited and unreliable rainfall, which makes traditional agriculture challenging. It is located within 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. The temperature fluctuates between 24°C and 42°C. The area receives low and unpredictable rainfall with long rains being experienced from March to May whereas the short rainy season occurs between October and November. The main soil type in the region is Calcisols with a pH range of 6 to 8. 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. Mandera County is predominantly arid and semi-arid, the implementation of irrigation systems has made it possible to cultivate Sudan and buffel grasses, which are well-suited for such conditions. This agricultural practice helps support the livelihoods of the local population, particularly in terms of livestock farming.

3.2 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 an archetype 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.* (2001). The amount of phosphorus was determined using a UV-vis spectrophotometer after extraction following the Bray 1 procedures (Aura, 1978; Murphy and Riley 1962). Cations (K^+ , Na^+ , Ca^{2+} , and Mg^{2+}) were assessed by use of an Atomic Absorption Spectrophotometer (Jackson, 1967). The Walkley—Black method by Yeomans and Bremmer (1988) was used to determine soil organic carbon. In addition, the total nitrogen was determined using the Kjeldahl digestion method as described by Bremmer and Keeney (1965). The hydrometer method (as described by Gee and Bauder, 1979) was employed in the determination of the soil texture, whereas bulk density analyses were performed following the procedures provided by Doran and Mielke (1984).

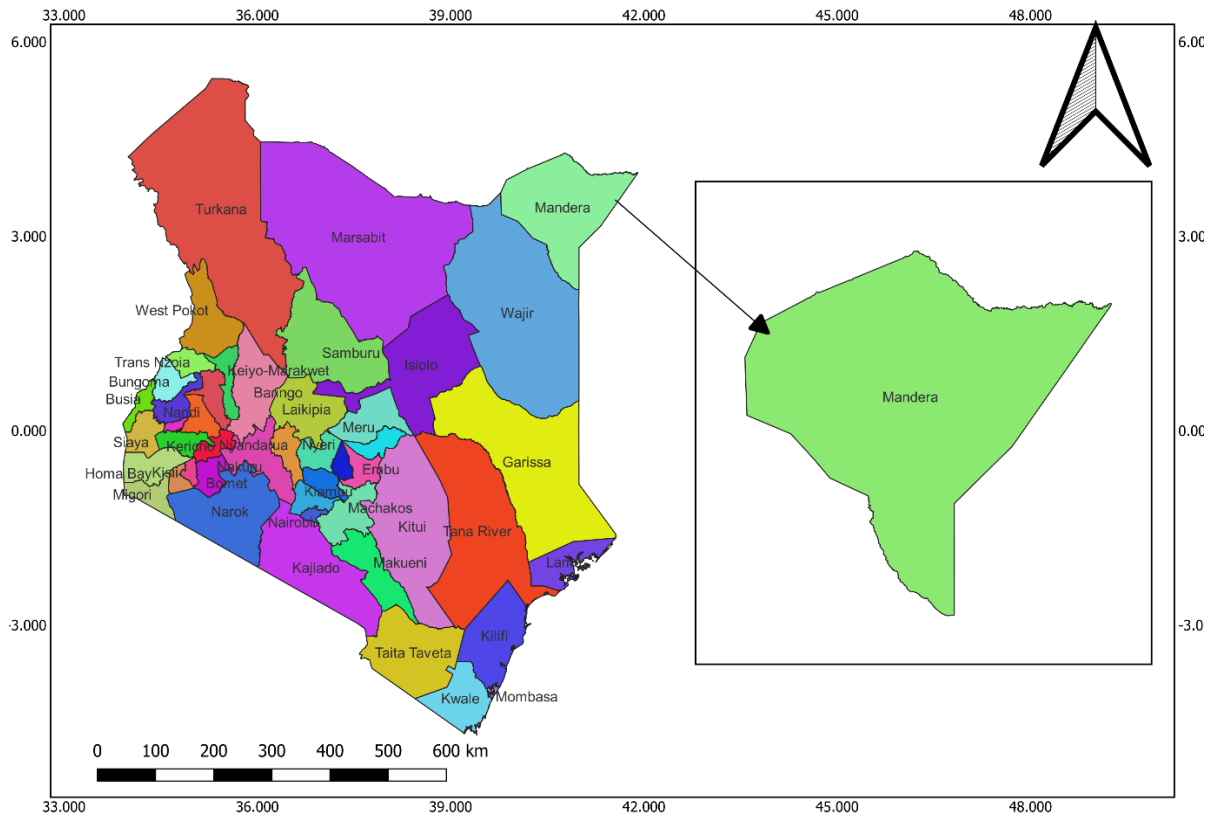




Figure 3.1: Map of Kenya showing Mander County, the study site

3.3 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 m² (5 m length × 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 3.1).

Table 3.1: Treatment combinations

Block 1	G1 × N1	G1 × N2	G1 × N3	G1 × N4	G1 × N5	G2 × N1	G2 × N2	G2 × N3	G2 × N4	G2 × N5
	Path 2.0 m									
Block 2	G1 × N2	G1 × N5	G1 × N3	G1 × N1	G1 × N4	G2 × N2	G2 × N5	G2 × N3	G2 × N1	G2 × N4
	Path 2.0 m									
Block 3	G1 × N4	G1 × N3	G1 × N1	G1 × N5	G1 × N2	G2 × N4	G2 × N3	G2 × N1	G2 × N5	G2 × N2
	Plot size: 5 x 5 m									
Main plots					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					

3.4 Field Management

The planting materials were acquired from Kenya Seed Company. Buffel grass and Sudan grass seeds were sown in a well-prepared seedbed (that had previously laid 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. Both grasses were planted on Oct 22, 2021, for the first season whereas only Sudan grass was replanted during the second season on March 25, 2021. Buffel grass being a perennial plant, regenerated upon the setting of rainfall. 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 subsurface drip irrigation (SDI) was performed using water from the Dawa River when required. This was performed uniformly on all plots at 30 mm depth per week.

3.5 Collection of Data

3.5.1 Growth and yield attributes

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, stem girth, leaf length, number of tillers, leaf width, 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 as aboveground biomass yield per hectare.

3.5.2 Herbage quality analysis

At the harvesting stage (8 WAS), 600 g samples of forage were obtained from the dried plants (Section 3.51). 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 (1995).

3.6 Analysis of Data

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.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Rainfall and Temperature Patterns during the Experimental Period

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 4.1). 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.

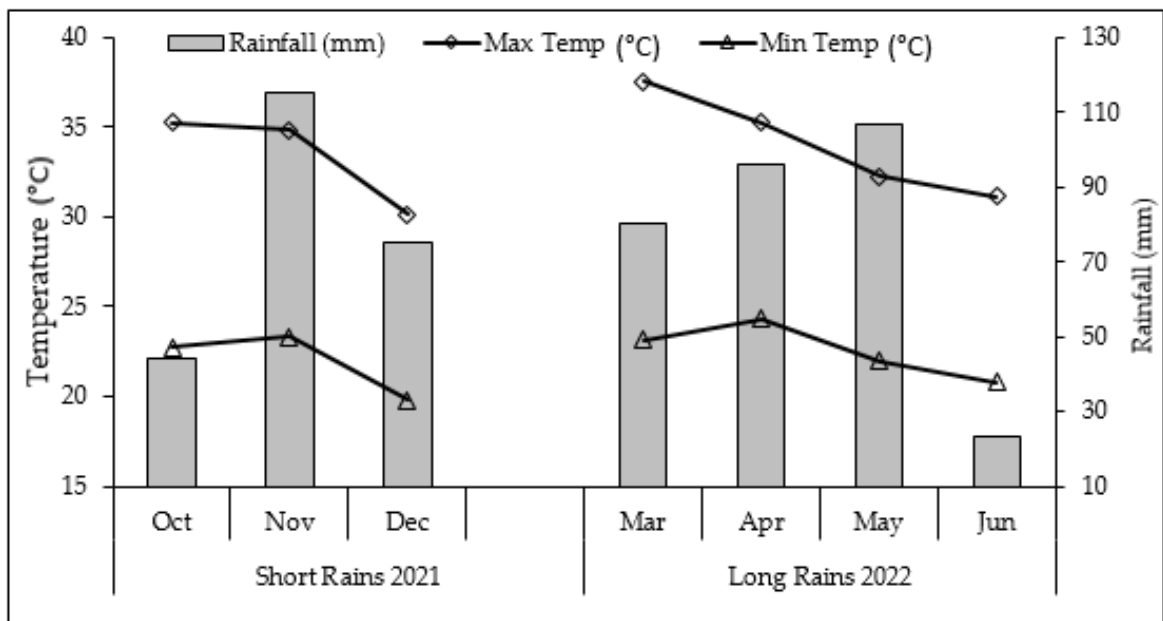


Figure 4.1: Average temperature and total monthly rainfall for the study site as recorded during the experimental period

4.2 Soil Physical and Chemical Properties of the Experimental Site

At the start of the experiment, soil analyses revealed that the site had an average bulk density of 1.04 g cm⁻³ with sand, clay, and silt of 610, 180, and 210 g kg⁻¹, respectively (Table 4.1). 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), available P

(5.8 mg kg⁻¹), and total N (0.7 g kg⁻¹). Nonetheless, it had sufficient quantities of exchangeable cations (in cmol kg⁻¹): Na (0.5) K (0.8), Ca (6.7), and Mg (1.2).

Table 4.1: 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

4.3 Effect of Nitrogen Fertilizer on the Growth Parameters of Buffel and Sudan Grasses

The growth parameters considered by the study were the plant height, leaf length, stem girth, number of leaves per plant, leaf width, and tiller number of both types of grasses.

4.3.1 Plant height

Plant height affects several processes such as growth habits, adaptability, and reproduction (Moles *et al.*, 2009). 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 4.2). 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.

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.* (2005) and Turgut *et al.* (2005). Further, Turgut *et al.* (2005) 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 plat 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 insolation amounts, hence resulting in improved growth and establishment by enhancing the competitive interaction of the grass species (Ali *et al.*, 2014; Barre *et al.*, 2015). The results in this study concur with those of Abu-Alrub *et al.* (2014), 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.* (2002), 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 (Ochieng' *et al.* 2021; Nduwimana *et al.* 2020; Mwadalu *et al.* 2022a). On the other hand, low grass growth witnessed unavailable N nutrients from the soil as nitrogen fertilizer treatment was not applied.

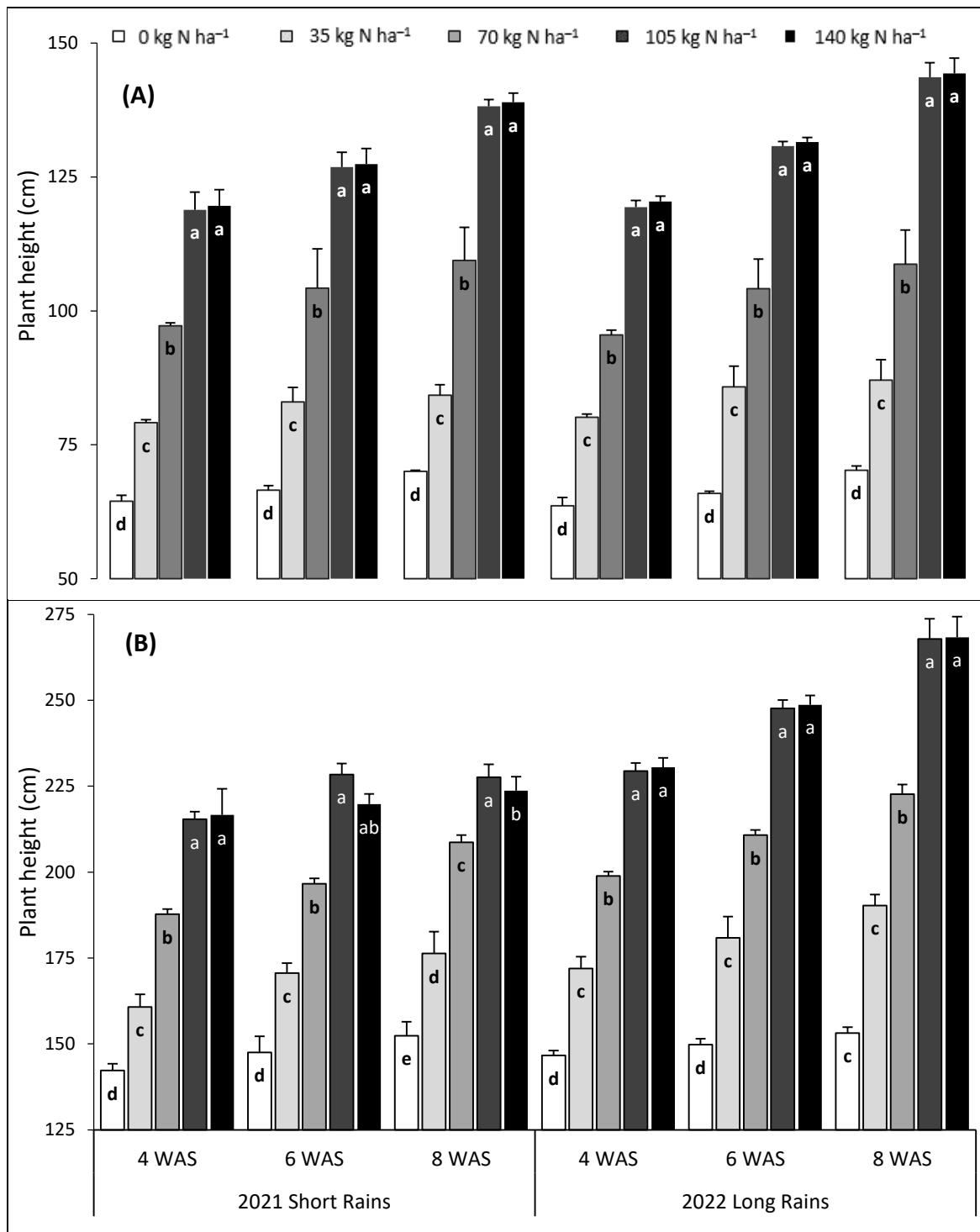


Figure 4.2: Plant height for Buffel grass (A) and Sudan grass (B) as influenced by N fertilizer application at 4, 6, and 8 weeks after sowing (WAS) during the 2021 short rains and 2022 long rains seasons in Mandera County. Bars bearing similar letters per sampling period do not vary significantly ($p \leq 0.05$).

4.3.2 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 4.3). 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 4.4). 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 4.5).

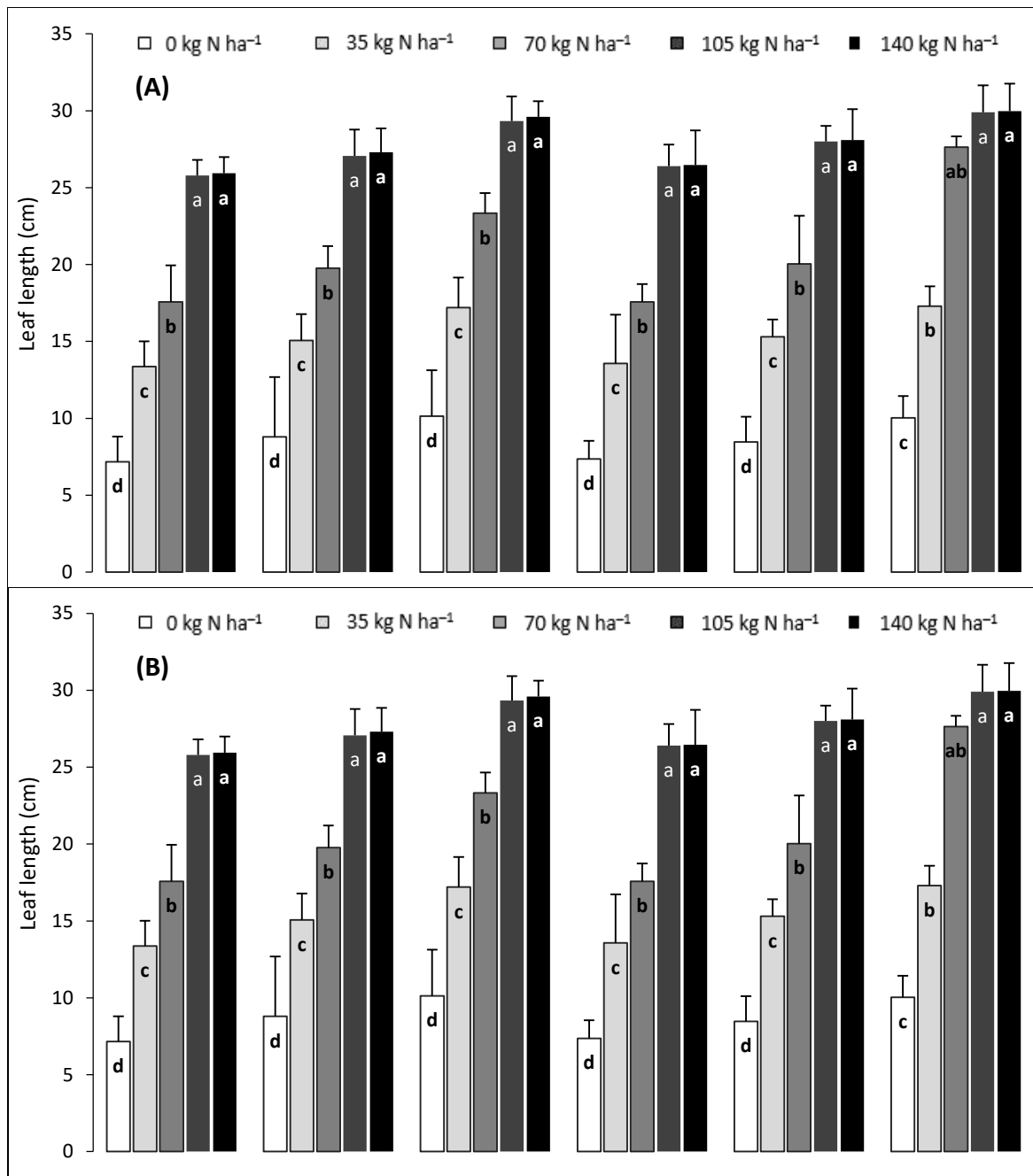


Figure 4.3: Leaf length for Buffel grass (A) and Sudan grass (B) as influenced by N fertilizer application at 4, 6, and 8 weeks after sowing (WAS) during the 2021 short rains and 2022 long rains seasons in Mandera County. Bars bearing similar letters per sampling period do not vary significantly ($p \leq 0.05$).

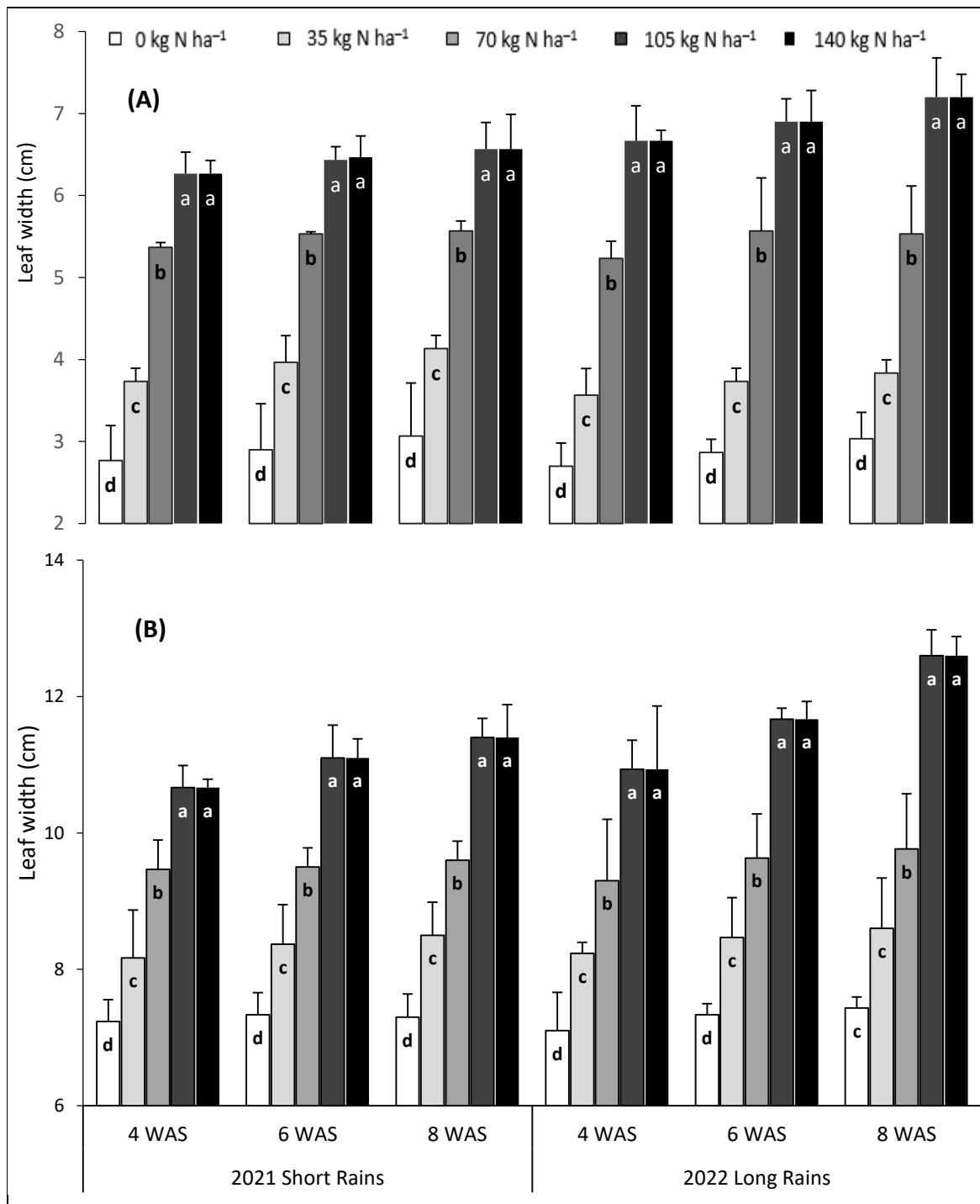


Figure 4.4: Leaf width for Buffel grass (A) and Sudan grass (B) as influenced by N fertilizer application at 4, 6, and 8 weeks after sowing (WAS) during the 2021 short rains and 2022 long rains seasons in Mandera County. Bars bearing similar letters per sampling period do not vary significantly ($p \leq 0.05$).

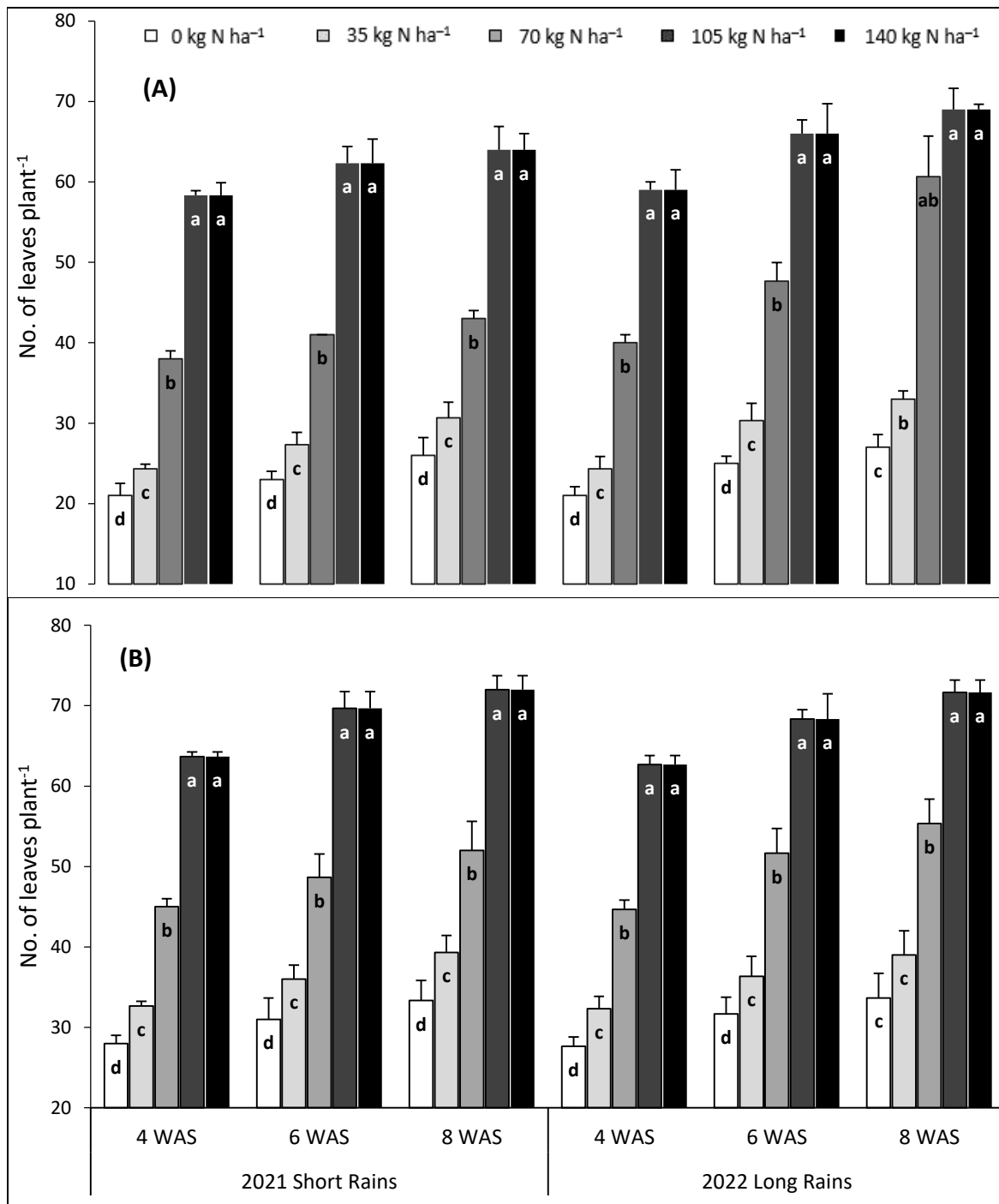


Figure 4.5: Number of leaves for Buffel grass (A) and Sudan grass (B) as influenced by N fertilizer application at 4, 6, and 8 weeks after sowing (WAS) during the 2021 short rains and 2022 long rains seasons in Mandera County. Bars bearing similar letters per sampling period do not vary significantly ($p \leq 0.05$).

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* 2016 and Moghimi and Maghsoudi (2015) who reported an increase in the number of leaves, and leaf area in sorghum cultivars

with increasing nitrogen rates. Jung *et al.* (2016) 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 increases 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 (Abo-Zeid *et al.*, 2017; Mrid, *et al.*, 2023). These results are in line with those of Nasar *et al.* (2021, 2022b) 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.

4.3.3 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 4.6). A slight growth was witnessed in the 2022 long rainy season in comparison with the first season (short rains of 2021). This is because the weather conditions during the first season did not favour maximum utilization of the nitrogen supplied. The increase in stem girth of Rhodes grass and pearl millet due to nitrogen fertilizer application was attributed to the high photosynthetic activities which created additional photosynthates hence distributing food to the active growing sites thus improving growth that resulted in thick stems (Duke, 2021)

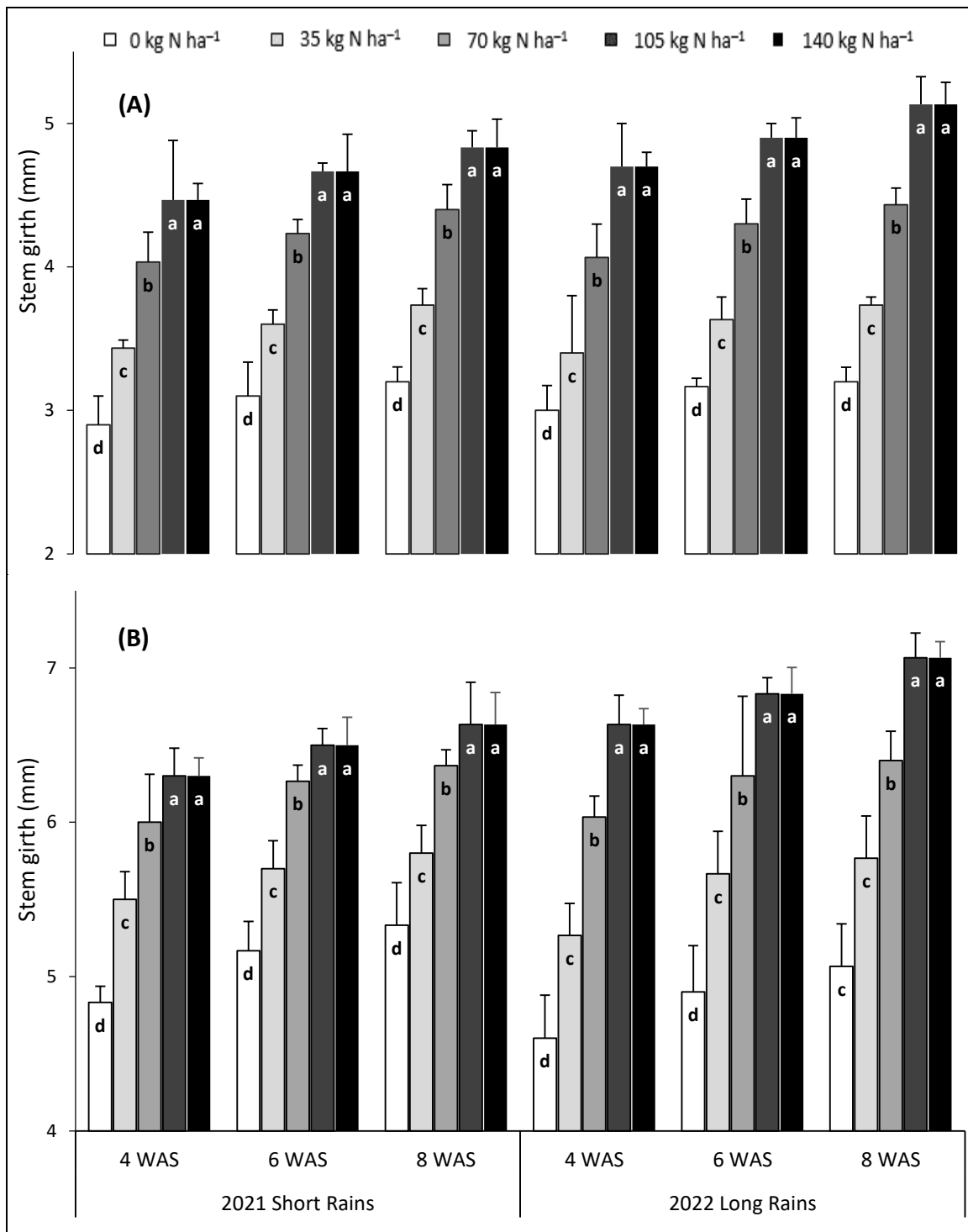
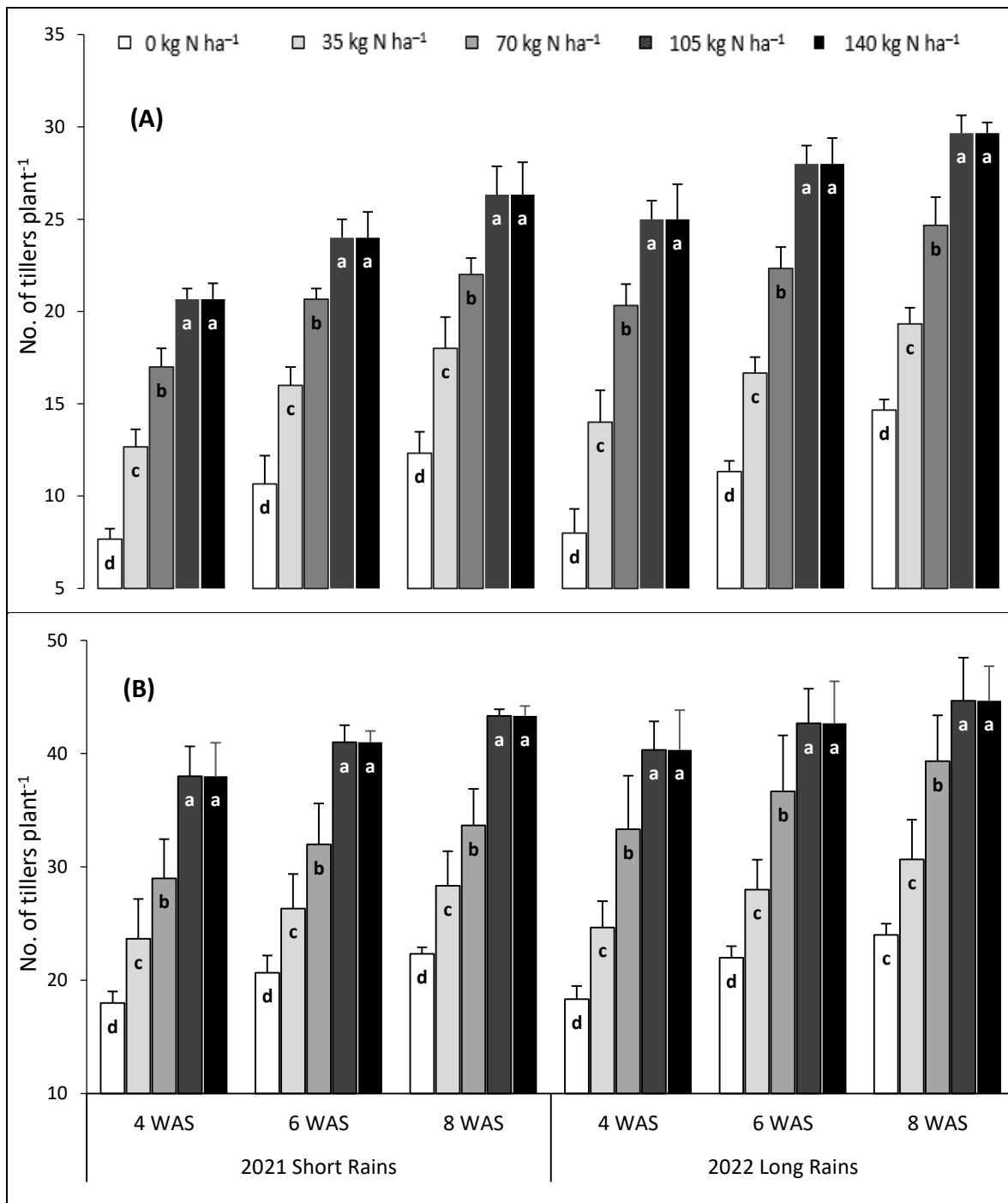


Figure 4.6: Stem girth for Buffel grass (A) and Sudan grass (B) as influenced by N fertilizer application at 4, 6, and 8 weeks after sowing (WAS) during the 2021 short rains and 2022 long rains seasons in Mandera County. Bars bearing similar letters per sampling period do not vary significantly ($p \leq 0.05$).

4.3.4 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 4.7). Beyond this N rate, the number of tillers remained constant. The higher number 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 (2002) findings, which recorded an escalation in the number of tillers with N 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 (Kisambo *et al.*, 2022).



Too wordy, kindly summarize).

4.4 Influence of Nitrogen Fertilizer on the Yield Parameters (Shoot, Root Weight, and Aboveground Biomass) of Buffel and Sudan Grasses

This study established that Buffel grass shoots weighed less than those of Sudan grass across the seasons at different N treatment levels (Figure 4.8). 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. 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 4.9). Similarly, Sudan grass roots weighed more than those of Buffel grass (Figure 4.9). 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 4.10). The higher values for Sudan grass than Buffel could be ascribed to the ability of Sudan grass to take up higher quantities of water and nutrients due to its deep rooting system (Clayton *et al.*, 2016).

Similarly, Sudan grass roots weighed more than those of Buffel grass with respective ranges of 6.7 – 7.8 and 1.6 – 2.2 g plant⁻¹ (Figure 9). Such an observation could be attributed to Sudan grass being deeply rooted with several rhizomes hence making it weigh more than the Buffel grass (Armah-Agyeman *et al.*, 2002). 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 (Goher *et al.*, 2023).

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). This is because of the greater tiller number and number of leaves produced by Sudan grass than Buffel grass. 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 (Ayub *et al.*, 2009; Kaplan *et al.*, 2019). It is also vital to note that forage yield increased with treatment level, reaching optimum at N₄ (which had 105 kg N ha⁻¹). This gave rise to a high yield implying that nitrogen fertilizer positively affects the forage yield of the two kinds of grass.

Farhadi *et al.* (2022) 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 appreciation 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.* (2019), who recounted that the green herbage yield of Sudan grass improved 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.* (2018) and Nasar *et al.* (2022), lack of nitrogen significantly decreases the leaf area, photosynthetic rate, and leaf chlorophyll content of sorghum and maize respectively, leading to lower above-ground biomass production.

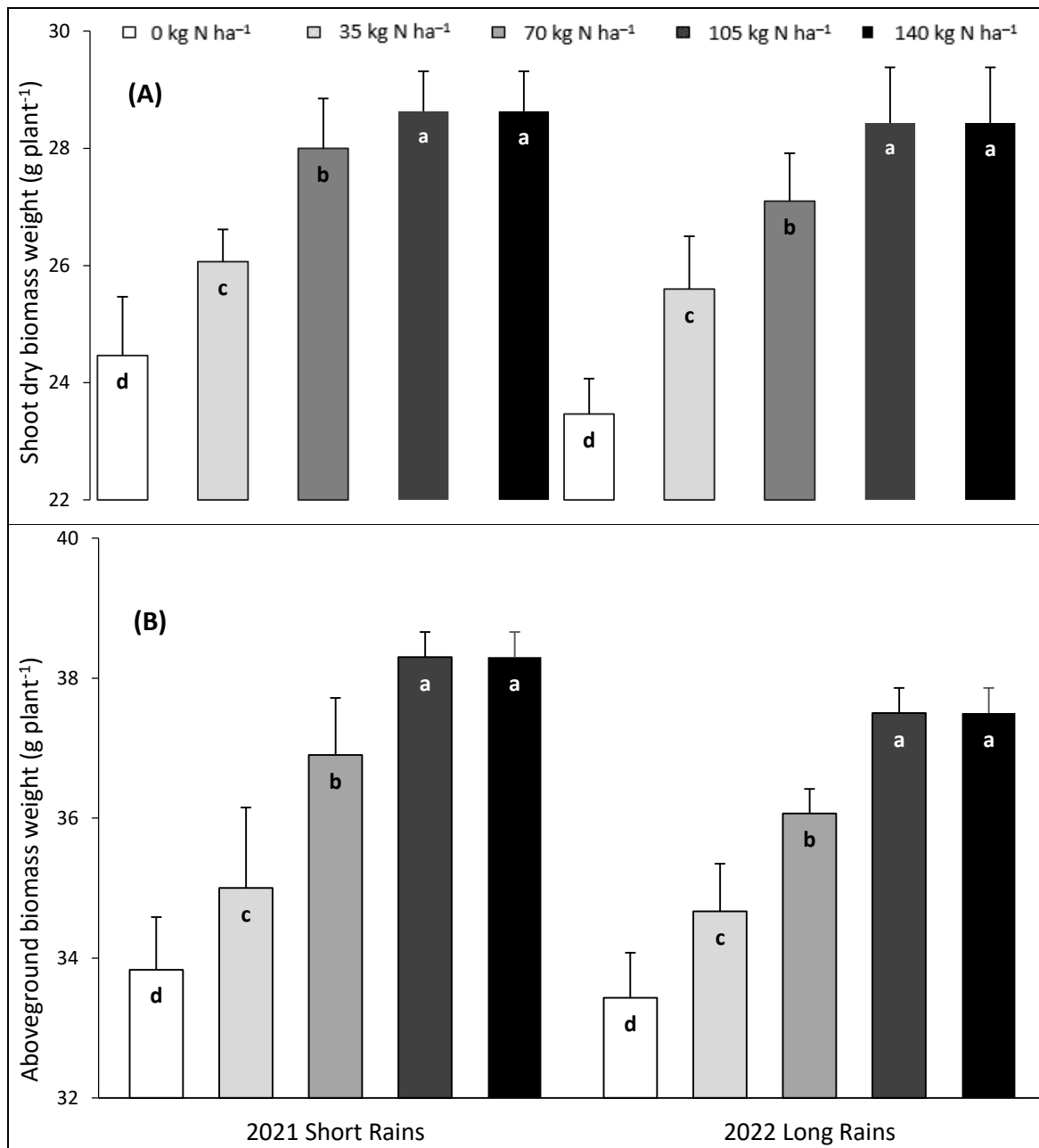


Figure 4.7: Shoot dry biomass weight for Buffel grass (A) and Sudan grass (B) as influenced by N fertilizer application during the short and long rains seasons of 2021 and 2022, respectively in Mandera County. Bars bearing similar letters per sampling period do not vary significantly ($p \leq 0.05$).

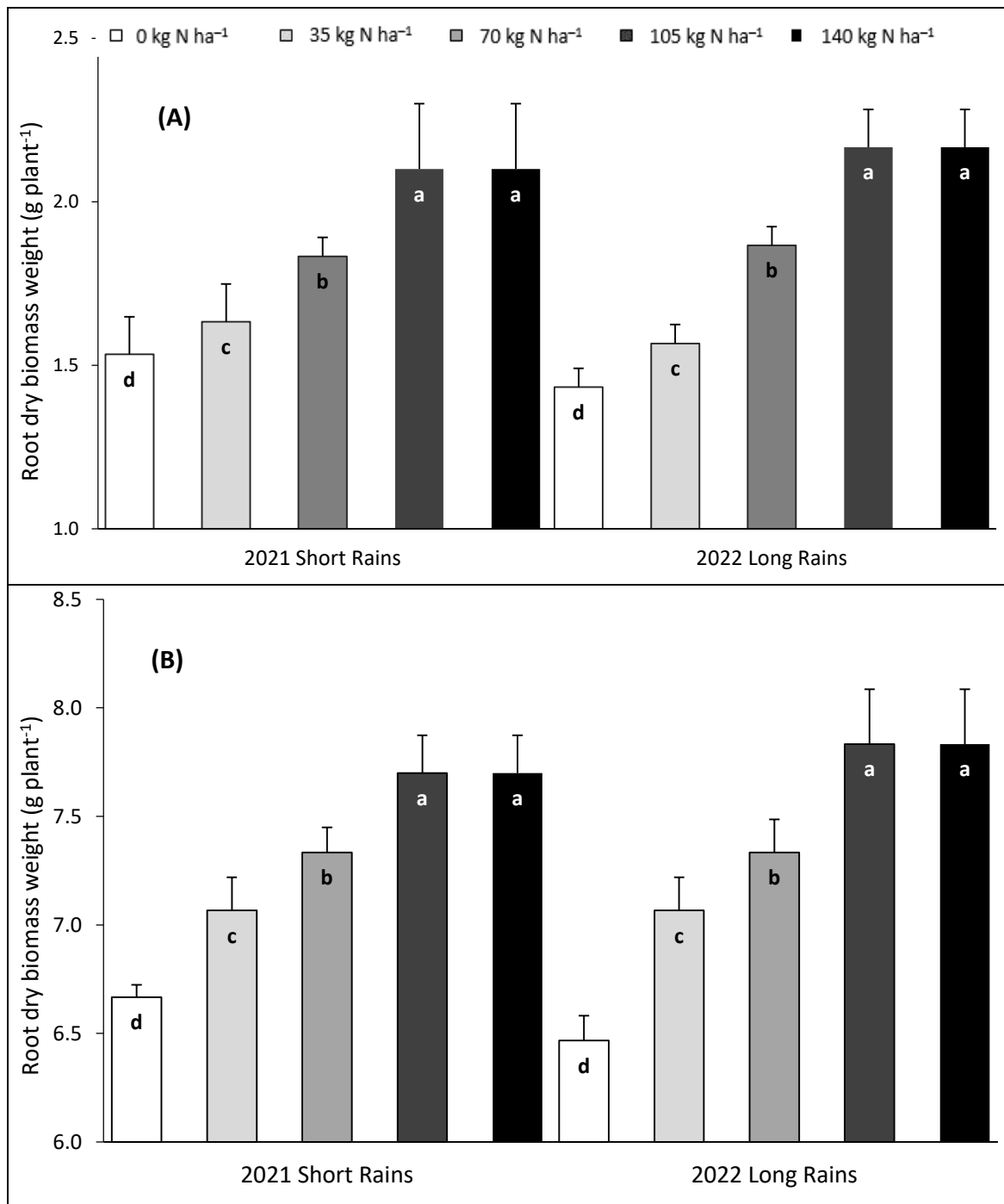


Figure 4.8: Root dry biomass weight for Buffel grass (A) and Sudan grass (B) as influenced by N fertilizer application during the short and long rains seasons of 2021 and 2022, respectively in Mandera County. Bars bearing similar letters per sampling period do not vary significantly ($p \leq 0.05$).

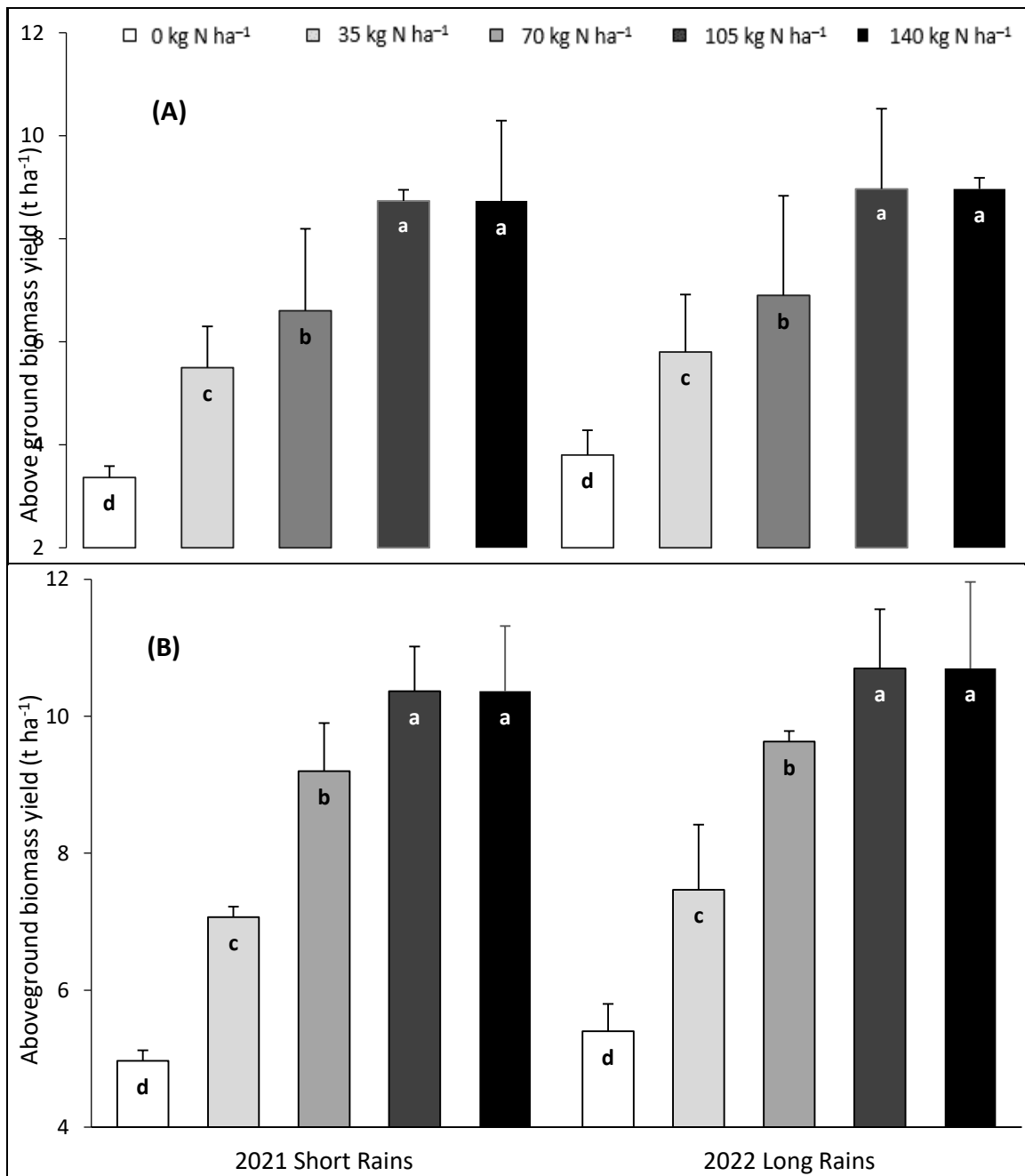


Figure 4.9: Aboveground biomass yield for Buffel grass (A) and Sudan grass (B) as influenced by N fertilizer application during the short and long rains seasons of 2021 and 2022, respectively in Mandera County. Bars bearing similar letters per sampling period do not vary significantly ($p \leq 0.05$).

4.5 Influence of Nitrogen (N) Fertilizer Application on the Herbage Quality of Buffel and Sudan Grasses

The results revealed that Sudan grass contained higher crude protein than Buffel grass at all levels of treatments (Table 4.2 and 4.3). Nitrogen fertilizer positively affects the percent 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.* (2022b) the application of sole nitrogen fertilizer led to a rise in the tissue nitrogen content of sorghum compared with the control plots. The work of Donaldson and Rootman (1977) revealed that as the rates of nitrogen fertilizer increased, there was a significant rise in forage nitrogen content. 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 N fertilizer to 140 kg N ha⁻¹. These findings confirm those of Ochieng *et al.* (2021), who noted that an upsurge in nitrogen rates increased the protein content of maize crops.

Neutral detergent fiber (NDF) and acid detergent fiber (ADF) are critical nutritional quality aspects in forages. 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. Therefore, the study revealed that Sudan grass forms better animal feeds than Buffel grass. The findings agree with those of Mut *et al.* (2017) where Sudan grass was reported to accumulate high ADF and NDF following N application. The ADF and NDF were found to vary with treatment level, confirming the findings by Mut *et al.* (2017) and Ullah *et al.* (2010), who found that these variables vary with nitrogen fertilizer application.

Table 4.2: Acid detergent fiber (ADF), crude protein (CP), and neutral detergent fiber (NDF) for Buffel grass as influenced by N fertilizer application during the short and long rains seasons of 2021 and 2022, respectively, in Mandera County

Parameter	Treatment	2021 Short Rains	2022 Long Rains
Acid detergent fiber (%)	0 kg N ha ⁻¹	25.47 ± 2.63 ^b	24.20 ± 1.10 ^d
	35 kg N ha ⁻¹	27.37 ± 4.03 ^b	26.30 ± 1.20 ^c
	70 kg N ha ⁻¹	29.53 ± 5.29 ^a	28.13 ± 1.18 ^b
	105 kg N ha ⁻¹	31.10 ± 3.25 ^a	29.67 ± 0.14 ^a
	140 kg N ha ⁻¹	30.97 ± 3.22 ^a	29.53 ± 0.12 ^a
LSD		1.98	0.79
<i>p</i> value		<.001	<.001
Crude protein (%)	0 kg N ha ⁻¹	4.07 ± 0.15 ^d	4.27 ± 0.19 ^b
	35 kg N ha ⁻¹	5.60 ± 0.16 ^c	5.80 ± 0.31 ^b
	70 kg N ha ⁻¹	6.50 ± 0.18 ^b	6.67 ± 0.55 ^a
	105 kg N ha ⁻¹	8.70 ± 0.19 ^a	8.80 ± 0.77 ^a
	140 kg N ha ⁻¹	8.63 ± 0.12 ^a	8.47 ± 0.93 ^a
LSD		0.08	1.77
<i>p</i> value		<.001	<.001
Neutral detergent fiber (%)	0 kg N ha ⁻¹	45.53 ± 3.45 ^b	44.53 ± 3.63 ^d
	35 kg N ha ⁻¹	48.07 ± 1.89 ^a	46.20 ± 2.23 ^c
	70 kg N ha ⁻¹	48.27 ± 3.35 ^a	48.90 ± 5.89 ^b
	105 kg N ha ⁻¹	49.67 ± 0.46 ^a	49.73 ± 3.95 ^a
	140 kg N ha ⁻¹	49.47 ± 1.29 ^a	49.70 ± 4.72 ^a
LSD		1.16	0.29
<i>p</i> value		<.001	<.001

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

Table 4.3: Acid detergent fiber (ADF), crude protein (CP), and neutral detergent fiber (NDF) for Sudan grass as influenced by N fertilizer application during the short and long rains seasons of 2021 and 2022, respectively in Mandera County

Parameter	Treatment	2021 Short Rains	2022 Long Rains
Acid detergent fiber (%)	0 kg N ha ⁻¹	34.93 ± 1.41 ^c	34.40 ± 2.70 ^d
	35 kg N ha ⁻¹	36.13 ± 1.43 ^{bc}	35.40 ± 1.92 ^c
	70 kg N ha ⁻¹	36.87 ± 2.18 ^{ab}	36.73 ± 2.52 ^b
	105 kg N ha ⁻¹	37.63 ± 0.96 ^a	37.53 ± 1.70 ^{ab}
	140 kg N ha ⁻¹	37.67 ± 0.92 ^a	37.47 ± 1.72 ^a
LSD		0.77	0.53
<i>p</i> value		<.001	<.001
Crude protein (%)	0 kg N ha ⁻¹	7.67 ± 0.15 ^b	7.73 ± 0.51 ^d
	35 kg N ha ⁻¹	8.43 ± 0.71 ^b	8.73 ± 0.86 ^c
	70 kg N ha ⁻¹	9.37 ± 0.31 ^a	9.40 ± 0.90 ^b
	105 kg N ha ⁻¹	10.17 ± 0.91 ^a	10.33 ± 1.06 ^a
	140 kg N ha ⁻¹	10.13 ± 1.01 ^a	10.37 ± 1.68 ^a
LSD		0.54	0.16
<i>p</i> value		<.001	<.001
Neutral detergent fiber (%)	0 kg N ha ⁻¹	61.83 ± 1.67 ^c	62.93 ± 1.62 ^d
	35 kg N ha ⁻¹	63.23 ± 3.15 ^{bc}	64.33 ± 3.80 ^c
	70 kg N ha ⁻¹	65.57 ± 1.29 ^{ab}	65.73 ± 4.01 ^b
	105 kg N ha ⁻¹	67.17 ± 2.54 ^a	67.00 ± 4.23 ^a
	140 kg N ha ⁻¹	67.17 ± 2.20 ^a	66.73 ± 1.40 ^{ab}
LSD		1.54	0.78
<i>p</i> value		0.002	<.001

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

4.6 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 4.5). 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.

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, ADF, and CP content of both Buffel and Sudan types of grasses. 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. 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.

Table 4.4: Linear regression analyses of the dependent variables (Y): aboveground biomass yield, acid detergent fiber, crude protein, and neutral 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		Acid detergent fiber		Neutral detergent fiber		Crude protein	
		R ²	Equation	R ²	Equation	R ²	Equation	R ²	Equation
Buffel grass	Plant height	0.96***	Y = 0.068x - 0.72	0.68**	Y = 0.069x + 20.69	0.71**	Y = 0.057x + 41.78	0.96***	Y = 0.059x + 0.29
	Leaf length	0.94***	Y = 0.252x + 1.08	0.70**	Y = 0.259x + 22.39	0.78 ***	Y = 0.223x + 43.01	0.92***	Y = 0.215x + 1.92
	No. of leaves	0.87***	Y = 0.104x + 1.67	0.56*	Y = 0.101x + 23.32	0.69**	Y = 0.091x + 43.58	0.95***	Y = 0.089x + 2.40
	Leaf width	0.95***	Y = 1.256x + 0.12	0.71**	Y = 1.303x + 21.36	0.76**	Y = 1.088x + 42.27	0.94***	Y = 1.081x + 1.05
	Stem girth	0.95***	Y = 2.732x - 4.91	0.75**	Y = 2.903x + 15.85	0.72**	Y = 2.302x + 38.19	0.93***	Y = 2.338x - 3.22
	No. of tillers	0.94***	Y = 0.335x - 0.73	0.64**	Y = 0.331x + 20.85	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	0.59*	Y = 0.026x + 31.12	0.75**	Y = 0.043x + 56.16	0.89***	Y = 0.024x + 4.24
	Leaf length	0.93***	Y = 0.23x + 2.28	0.68**	Y = 0.124x + 33.11	0.78 ***	Y = 0.208x + 59.51	0.96***	Y = 0.112x + 6.18
	No. of leaves	0.88***	Y = 0.122x + 1.99	0.68**	Y = 0.067x + 32.87	0.84***	Y = 0.112x + 59.15	0.91***	Y = 0.060x + 6.03
	Leaf width	0.88***	Y = 1.040x - 1.73	0.63**	Y = 0.549x + 31.03	0.80***	Y = 0.922x + 56.02	0.93***	Y = 0.509x + 4.19
	Stem girth	0.92***	Y = 3.021x - 10.18	0.69**	Y = 1.639x + 26.29	0.78***	Y = 2.608x + 48.96	0.92***	Y = 1.442x + 0.27
	No. of tillers	0.89***	Y = 0.230x + 0.422	0.77**	Y = 0.134x + 31.72	0.76**	Y = 0.198x + 58.14	0.90***	Y = 0.111x + 5.31

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

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

- Nitrogen fertilizer application significantly influenced the growth attributes of both Sudan and Buffel grass, 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.

5.2 Recommendations

- The study recommends the application of nitrogen fertilizer at the right time in the growth cycle of Buffel and Sudan grasses. Nitrogen is often most beneficial during the early stages of growth when the grasses are actively developing. Determine the appropriate dosage and rate of nitrogen fertilizer based on soil test results, grass species, and intended use (e.g., forage or pasture). Buffel and Sudan grasses have different nutrient requirements, so tailor your application accordingly.
- Particularly, the study recommends the use of 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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Appendix 1: Research Approval



KENYATTA UNIVERSITY GRADUATE SCHOOL

E-mail: dean-graduate@ku.ac.ke

P.O. Box 43844, 00100
NAIROBI, KENYA
Tel. 020-8704150

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Internal Memo

FROM: Dean, Graduate School

DATE: 20th April, 2022

TO: Mr. Mohamed Aden
C/o Department of Agricultural
Science & Technology

REF: A149/OL/GAR/32449/16

SUBJECT: APPROVAL OF RESEARCH PROPOSAL

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This is to inform you that Graduate School Board, at its meeting on 31st March, 2022, approved your Research Proposal for the M.Sc. Degree entitled, "Growth, Yield, and Nutrient Content of Buffel (*Cenchrus ciliaris*) and Sudan (*Sorghum sudanense*) Grasses Under Nitrogen Fertilizer in Mandera County, Kenya."

You may now proceed with your Data collection, subject to clearance with the Director General, National Commission for Science, Technology & Innovation.

As you embark on your data collection, please note that you will be required to submit to Graduate School completed Supervision Tracking and Progress Report Forms per semester. The forms are available at the University's Website under Graduate School webpage downloads.

Thank you.


REUBEN MURIUKI
FOR: DEAN, GRADUATE SCHOOL



CC: Chairman, Department of Agricultural Science & Technology

Supervisors:

1. Dr. Harun Gitari
C/o Department of Agricultural Science & Technology
Kenyatta University
2. Dr. Mwendu Ngie
C/o Department of Agricultural Science & Technology
Kenyatta University

Appendix 2: Research Authorization



KENYATTA UNIVERSITY GRADUATE SCHOOL

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P.O. Box 43844, 00100

NAIROBI, KENYA

Tel. 020-8704150

Our Ref: A149/OL/GAR/324492016

DATE: 20th April, 2022

Director General,
National Commission for Science, Technology
and Innovation
P.O. Box 30623-00100
NAIROBI

Dear Sir/Madam,

**RE: RESEARCH AUTHORIZATION FOR MR. MOHAMED ADEN – REG. NO.
A149/OL/GAR/32449/16**

I write to introduce Mr. Mohamed Aden who is a Postgraduate Student of this University. He is registered for M.Sc. degree programme in the **Department of Agricultural Science & Technology**.

Mr. Mohamed Aden intends to conduct research for a M.Sc. thesis Proposal entitled, “Growth, Yield, and Nutrient Content of Buffel (*Cenchrus ciliaris*) and Sudan (*Sorghum sudanense*) Grasses Under Nitrogen Fertilizer in Mandera County, Kenya.”

Any assistance given will be highly appreciated.

Yours faithfully,


PROF. ELISHIBA KIMANI
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