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SCHOOL OF ANIMAL SCIENCE AND VETERINARY MEDICINE

DEPARTMENT OF ANIMAL SCIENCE

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By

Azanu Fitalew Yenehun

December, 2023

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SUBMITTED IN THE PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER SCIENCES (MSc.) IN FEEDS AND ANIMAL NUTRITION

Advisor: Fentahun Mehret (Assistant professor)

December, 2023

Bahir Dar, Ethiopia

THESIS APPROVAL SHEET

As members of the board of examiners, we examined this thesis entitled "**Effect of Fertilizer Level and Harvesting Age on Morphological Characteristics, Dry Matter Yield and Chemical Composition of Sudan Grass (*sourghum Sudanese*) Grown under Irrigation, in the northern Amhara Region, Ethiopia** "prepared by **Azanu Fitalew Yenehun**. We here by certify that the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Sciences (MSc.) in **Feeds and Animal Nutrition**.

Board of Examiners

External examiner name	Signature	Date
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DECLARATION

This is to certify that the thesis entitled "**Effect of Fertilizer Level and Harvesting Age on Morphological Characteristics, Dry Matter Yield and Chemical Composition of Sudan Grass (*sourghum Sudanese)* Grown under Irrigation, in the northern Amhara Region, Ethiopia**" was submitted in partial fulfillment of the requirements for the degree of Master of Science in **Feeds and Animal Nutrition** to the graduate program of college of agriculture and environmental sciences Bahir Dar University, is a record of original work carried out by **Azanu Fitalew Yenehun (ID No. BDU1300494PR**) and has never been submitted to this or any other institution to get any other degree or certificates.

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Name of advisors	Signature	Date

ACKNOWLEDGMENTS

Firstly, my thanks to the gigantic “GOD” and St. “Mary” who helped me for this dissertation.my thank appreciation to my advisor **Fentahun Meheret** for their valuable suggestion, continuous inspiration, constructive comments .first special thanks goes to Bahir Dar University College of Agriculture and Environmental Sciences School of Animal Science and Veterinary Medicine department of Animal science for enabling me in joining MSc program and Animal Nutrition Laboratory for timely analysis of forage samples.

Secondly thanks go to Tegedie worda agriculture office for allowing me to the program and use the experiment site. Finally thanks go to Gondar Agriculture Research Center for sharing Sudan grass cultivar seed and other field area material. Personally first special thanks go to Endalkachew Birilie, Adebabay Adane, Tenaw Temsgen and Tesfa Getachew for their valuable suggestion, immense help starting from research title selection, experimental procedure, data collection and final thesis write up.

Very special thanks go to my husband Yirga Ayelghe and our children, Soliyana and KebronYirga, for their continual love, support, understanding, sacrifice and resilience during my studies.

ABBREVIATIONS AND ACRONYMS

ADF	Acid Detergent Fiber
ADL	Acid Detergent Lignin
AOAC	Association of Official Analytical Chemists
CP	Crude Protein
CPY	Crude Protein Yield
CSA	Central statistical Agency
DDM	Digestible Dry Matter
DM	Dry Matter
DMY	Dry Matter Yield
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agricultural Organization of the United Nations
FTC	Farmer Training Center
GLM	General Linear Model
IVDMD	In Vitro Dry Matter Digestibility
LL	Leaf Length
LMM	Livestock and Meat Marketing Program
LSR	Leaf to Stem Ratio
MRDP	Matelile Rural Development Project
NDF	Neutral Detergent Fiber
NLPP	Number of Leaves Per Plant
NTPP	Number of Tiller Per Plant
PH	Plant Height
RCBD	Randomized Complete Block Design
SAS	Statistical Analysis System
SPS	Sanitary and Phytosanitary Standards
USAID	United States Agency for International Development

Abstract

Effect of Fertilizer Level and Harvesting Age on Morphological Characteristics, Dry Matter Yield and Chemical Composition of Sudan Grass (*sourghum Sudanese*) Grown under Irrigation, in the northern Amhara Region, Ethiopia

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The experiment was conducted to evaluate the effect of fertilizer level and harvesting age on morphological characteristics, dry matter yield and chemical composition of Sudan Grass (sourghum Sudanese) grown under irrigation condition at Soroka farmer training center (FTC), in northern Amhara Region, Ethiopia. A factorial arrangement in a random complete block design (RCBD) with four level of fertilizer (0, 50, 75 and 100kg/ha) and three harvesting ages (30, 50 and 70) with 3 replications in 3m×3m (9 m^2) plot size area were used. Data on morphological characteristics, dry matter yield and chemical composition of the grass were recorded. In addition, harvesting age significantly affected the morphological characteristics and DMY of Sudan grass except number of leaves per plant (NLPP). Plant height (PH), dry matter yield (DMY), leaf length (LL), number of root per plant (NRPP), root length (RL), and dry matter yield (DMY) which were increased with increasing harvesting age, while number of tillers per plant (NTPP) and leaf to stem ratio (LSR) were showed a decreasing trend. The CP content declined as the harvesting age increased, while NDF, ADF and ADL content increased. The highest ash content (13.48%) was recorded at middle (50) harvesting age. The Level of fertilizer application significantly affected plant height (PH), tillers per plant (NTPP), and number of leaf per plant (NLPP) but no other agronomic parameters of Sudan grass (cultivar Michello). Application of Fertilizer levels and harvesting ages had an interaction effect was significant on all chemical composition parameters, but not for on crud protein yield. The lowest NDF (67.87%) and the highest ash (13.38%) content were recorded from 50 kg fertilizer per hectare. From the result of the present study, it is concluded that Sudan grass can be harvested at 50 days of age and use 50 kg/ha level of fertilizer for good quality forage, higher dry matter and crude protein yield with minimum fertilizer cost. At last, to fully utilize the potential of Sudan grass, further studies on agronomic performances, and chemicals composition, under various agro-ecology and animal feeding trial evaluations are recommended.

***Keywords**: Dry Matter Yield, Fertilizer level, Forage Characteristics, Harvesting Age*

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1. INTRODUCTION

1.1. Background and Justification

Ethiopia is a country that owns huge livestock population in African. The total livestock population for the country is estimated to be about 70.29 million cattle, 42.91 million sheep, 52.46 million goats, 2.15 million Hors, 10.79 million donkeys,0.38 million mules, 8.15 million camels and 56.99 million poultry (CSA, 2021). Ethiopian farmers rely heavily on the sale of their livestock as a source of revenue and a means of subsistence (Dereje Duressa *et al*., 2014). In addition, because they are a "near-cash" capital asset, livestock products and by-products are essential for supplying export commodities and a certain degree of stability during periods of crop failure (CSA, 2021). However, the demand for livestock products and food with animal origin is being severely pressured by the constantly expanding population, urbanization, and economic expansion (Getnet Assefa *et al*., 2017). However, the productivity of livestock in Ethiopia is below the African average due to inadequate supply of feed and poor feeding practices are the pioneer limiting factors, among others. (Shapiro *et al*., 2015; Gelayenew *et al*., 2016). Moreover, poor animal nutrition and productivity arising from inadequate supply and low-quality feed are among the major constraints facing livestock production in developing countries (Alemayehu Mengistu *et al*., 2017).

In Ethiopia, green fodder (grazing) accounts for around 54.54 percent of all feed resources, followed by crop residue at 31.13 percent, hay at 7.35 percent, improved feed at 0.57 percent, by-products and another source of feed were also used as animal feeds that comprise about 2.03 and 4.37 percent, respectively (CSA, 2021). However, indigenous forage species from grazing lands in Ethiopia have low in quality, poor productivity and inadequate nutrients to maintain animals, especially during the dry season (Alemayehu Mengistu *et al*., 2017). So, it is time to act on improving the existing grazing land through the introduction of improved grasses by studying their agronomic performance and chemical composition (FAO, 2012). The problem of feed shortage can be addressed through the identification, evaluation and promotion of forage species with better forage yield and nutritive value, which are also adapted to drought and low soil fertility (Ghimire *et al*., 2015).

Sudan grass(*sourghum sudanese*) is a promising forage crop essentially in arid and semiarid regions as it is less sensitive to water shortage and produces large amounts of biomass (Ismail *et al*., 2018). The green foliage of Sudan grass is succulent, very palatable, and nutritious feed for dairy cattle. It represents an ideal bulky forage crop due to its dense vegetative growth and high dry yield. The study conducted by Brock *et al*., (2019) shows that Sudan grass is harvested throughout a 30-day, 45-day, and 90-day period, with the 30-day harvest yielding the greatest crude protein percentages of 11.0%, 5.8%, and 4.4%, respectively. Even though forage dry mater (DM) production was maximized over 90 harvest days, Sudan grass should be harvested at shorter intervals of time to maximize its nutritional value and yield. Alemu Tarekegn *et al*., (2021) stated that Sudan grass cultivated in midland area on 40, 50, and 60 days of harvesting interval, the dry biomass yield (5.04, 6.31, 7.49) and crude protein yield (0.59, 0.67, 0.73) ton per hectare were produced respectively. Therefore the harvesting interval of Sudan grass increases, it gives better output in dry biomass and crude protein yield. Afzal *et al*., (2012) show that delayed cutting might increase the yield, yet the overall quality of Sudan grass may fall and they show that on 49 days of harvesting CP content is 12.8% and on 56 days of harvesting CP content is 12.77% in the semi-arid area. In this context, improving the growth, forage yield, and quality of Sudan grass requires the adoption of suitable agronomic practices among which cutting age and fertilization are important (Nahrawy *et al*., 2011 and uranira, *et al*., 2015). However, there is limited information on agronomic practices, dry matter yield and feed quality values of different forage cultivars (DRLME, Mezrut cv., Wichello cv., Michello cv., Aden cv.) of Sudan grass in Ethiopia.

1.2. Statement of the Problem

The availability and nutritional quality of feed resources are the most important factors that determine livestock productivity. In Ethiopian, the productivity of livestock is below the African average due to inadequate supply of feed and poor feeding practice (Shapiro *et al*., 2015, Gelayenew *et al.*, 2016). In Ethiopia, natural pasture is the major animal feed source. However, the biomass yield and chemical composition of natural pasture is low and even the nutrient requirement of the animals has not satisfied. The role of natural pasture is diminishing from time to time due to shrinking grazing land size and the use of native hay is limited in coverage (Yayneshet Tesfay, 2010). Crop residues and natural pasture hay are poor in nutritive values, their crude protein, minerals and vitamins are generally low, below the minimum requirement for animal production (Ulfina Galmessa *et al.*, 2013).

Consequently, technological interventions must be developed quickly and distributed to the user population in order to guarantee an adequate availability and quality of feed supplies. Therefore, Sudan grass is one of the potential forage grasses for assuring the availability and quality of feed resources, among others. Even though, morphological characteristics, nutritive value and forage yield of fodder grass is affected by plant species, fertilizer application, environmental factors (rainfall, temperature, altitude and soil type) (Cook *et al*., 2005). Simple and affordable management techniques, such as the right fertilizer dosage and application technique, harvesting age, cutting height, planting area, and routine weeding, will significantly increase Sudan grass productivity. However, there is a knowledge gap on Sudan grass agronomic management practices. So, the purpose of the study was to evaluate the effect of fertilizer level and harvesting age on dry matter yield and chemical composition of Sudan grass grown under irrigation condition.

1.3. Objectives

1.3.1. General objective

- The general objective of this research was evaluation of fertilizer application level and harvesting age on morphological characteristics, dry matter yield and chemical composition for utilization of Sudan grass as alternative feed resources in the agro-ecology of Tegedie district, Central Gondar, Amhara Region, Northwest Ethiopia.

1.3.2. Specific objectives

- To evaluate the effect of fertilizer level and harvesting age on morphological characteristics and dry matter yield of Sudan grass.
- To determine the effect of fertilizer and harvesting age on chemical composition of Sudan grass.
- To determine the effect of fertilizer and harvesting age on Economic feasibility of Sudan grass.

2. LITERATURE REVIEW

2.1. Overview of Feed Resource in Ethiopia

In Ethiopia, natural grazing land is a predominant feed source and animal feed sources are classified as green fodder (grazing), crop residue, improved feed, hay, industrial by-products, and none conventional feed (CSA 2021). According to Adugna Tolera *et al*., (2012) animal feed resources are classified into the natural pasture, crop residue, improved forage and pasture crops, agro-industrial by-products and non-conventional feed resources. Green fodder is simply pasture grasses; crop residue includes harvested by-products (straw and chaff of cereals and pulses, etc.); improved feed is like alfalfa; hay includes any type of grass, clover etc. cut and dried as fodder; and finally industrial byproducts are like oil cake (rapeseed cake, nueg cake, sunflower cake, etc.), bran, and brewery residue (CSA, 2021)

Table2. 1: Proportion of Animal Feed Resources in Ethiopia

S/N.	Feed resources	Percentage
1	Green fodder	54.54 %
2	Crop residue	31.13 %
3	Improved fodder or pasture	0.57 %
4	Hay	7.35 %
5	Agro-industrial by-products	2.03 %
6	Others feed/concentrate feeds	4.37 %

(Source: CSA, 2021)

2.1.1. Natural pasture

Natural pasture supplies the bulk of livestock feed which is composed of indigenous forage species and is subjected to overgrazing. Natural pasture is an important sources of ruminant livestock feed in developing countries (CSA, 2021). According to Dereje Duressa *et al*. (2014), grazing of natural pasture constitutes the main source of animal feed throughout the year with maximum availability during crop growing season (June to December). However, the quality and productivity of natural pastures are very poor to meet the nutrient requirement of animals (Malede Birhan and Takele Adugna, 2014) particularly in the dry season, due to poor management and their inherent low productivity and poor quality. Additionally, the size of natural grazing land resource faced to high level of degradation and decreasing grazing land size.

Alemayehu Mengistu *et al*., (2017), the reason for the decrease in natural pasture contribution from time to time may be due to the increase in human population and increasing demand for food, grazing lands are shifted in to crop land and topographic, edaphic and climatic limitations.

2.1.2. Crop residues

Crop residues are the fibrous by-products which result from the cultivation of cereals, pulses, oil plants, roots and tubers are represent an important feed resource (Yayneshet Tesfay, 2010). Feeding of crop residues is practiced throughout the year its contribution is decreases from June to October because of decreasing availability (Addisu Endalew *et al*., 2016). In Ethiopia, crop residue is one of the main feeds resources for animal production, especially that area which practice livestock and crop production. In addition to being a source of animal feed, residues are also utilized as fuel, sold as a source of money, and used to build houses, used for plastering walls and thatching roofs. Some farmers additionally mulch their fields with crop residues to improve the fertility of the soil (Dereje Duressa *et al*., 2014). Crop residues are characterized by high fiber content and low digestibility and feed intake (Zewdie Wondatir *et al*., 2011). The basic limitation of crop residue with crude protein contents around the border line of 6 to 7% (Solomon Bogale and Alemu Yami, 2009). Hence, there is a need to look for other alternative feed resources as complementary feeds to crop residues.

Table2. 2: Chemical composition of common feed resources in Ethiopia

Feed resource	DM	CP	ASH	NDF	ADF	ADL	IVDMD	Source
Maize stover	85.7	3.94	6.2	79.96	40.55	10.43	51.1	Mengistu Lemma *et al.*, (2016)
Barley straw	94	4.48	19.7	75.06	49.46	9.79	57.51	Solomon Bogale, (2004)
Wheat straw	94.2	4.14	8.22	78.62	47.58	10.23	53.92	Solomon Bogale, (2004)
Natural pasture	93.9	9.64	10.22	73.58	42.21	5.12	66.83	Solomon Bogale, (2004)
Stubble	94.5	3.47	8.57	79.7	55.34	11.24	45.63	Solomon Bogale, (2004)
Rice straw	88.9	4.5	17.6	62.4	38.8	-	45.63	Solomon Bogale, (2004)

(Cited by Negasu Yiberkew *et al*., 2020)

2.1.3. Agro-industrial by products

Agro-industrial by-products have special value in feeding livestock mainly in urban and peri urban livestock production system, as well as in situations where the productive potential of the animals is relatively high and require a high nutrient supply (Andualem Tonamo, 2016). Natural pasture and crop residues are naturally of low quality and do not fulfill the nutrient requirement of animals. Hence, high producing animals such as dairy cattle and fattening animals should be supplemented with high energy and protein concentrates (Beyadglign Hunegnaw, 2019). The major agro-industrial by products commonly used are obtained from flour milling industries (wheat bran, wheat short, wheat middling and rice bran), edible oil extracting plants (noug cake, cottonseed cake, peanut cake, linseed cake, sesame cake, sunflower cake etc.), breweries and sugar factories (Molasses). However, the contribution of these by-products is proportionally low and mainly used for dairy, fattening and commercial poultry production and the scope for their wider use by smallholder producers is low due to availability and price (Yoseph Mekasha *et al.*, 2010).

2.1.4. Improved Forages

Improved fodder species generally have higher herbage yield potential than natural pasture. Getnet Assefa *et al*., (2016), about 13, 8 and 10.5 t/ha DM yield for grasses, herbaceous legumes and browse trees, respectively, while the average herbage DM yield obtained from seasonally rested pasture and continuously grazed pasture was 4 and 1 t/ha, respectively. The overall average production of the improved fodder crops per unit area has been determined to be roughly three and ten times greater than the productivity of seasonally rested and continuously grazed natural pastures, respectively (Fekede Feyissa *et al*., 2015). Utilizing improved forage varieties, according to Etsubdink Tekalign (2014), have several benefits, including enhancing animal nutrition leading to higher-producing livestock and aiding livestock producers in storing forage for the dry season. In addition, it supports crop production by maintaining soil fertility through nitrogen fixation. Furthermore, when included in natural resource management plans, improved fodder crops, particularly legumes, can support crop output by preserving soil fertility through fixing and accumulating nitrogen. They can also assist in preventing soil erosion and replenishing degraded land (Getnet Assefa *et al*., 2016). They also have a long growing season and help to extend the green feed period so as to provide useful nutrients mainly in rural areas where availability and accessibility of agro-industrial by products is limited.

2.1.5. Other feed resources

Livestock feed resources are classified as conventional and non-conventional (Alemayehu Mengistu, 2003). Non-conventional feed resources generally refer to all those feeds that have not been traditionally used for feeding livestock and are not commercially used in the production of livestock feeds (Amata, 2014). Non-conventional feeds such as vegetable refusals, sugarcane leaves, Enset leaves, fish offal, left over Enjera and Porridge, home waste, local brewery by products etc. are used as animal feed in the different parts of Ethiopia (Endale Yadessa *et al*., 2016). Non-conventional feeds like abish (Trigonela foenum gracium), tobacco, and mineral soils were used for feeding animals in south west Shewa zone (Zelalem Yilma *et al*., 2009). However, in the country non-conventional feeds are not available at large and its contribution to livestock feed is about 4.37(CSA 2021).

2.2. General Description and Benefits of Sudan grass (*Cultivar Michello*)

Sudan grass as a forage grass has many reliable characters that include high yielding potential, drought, heat tolerance, very good water use efficiency, high response to N fertilization, less susceptibility to forage grass disease, and most importantly the crop's ability to provide more than 2-3 cuts per growing season (Machicek, 2018). In Egypt Sudan grass (Sorghum sudanense (Piper) Stapf.) stands as an important short-term annual and summer season forage crop widely grown to balance the desperate demands of the livestock industry (A. M. Ibrahim, *et al*., 2016). It is recognized among the most satisfactory summer forage resources cultivated under irrigation system in many of the arid and semiarid parts of Egypt (Ibrahim, A. M, *et al.*, 2016). The area cultivated with Sudan grass reached about 3500 ha producing 190913 tons, with an average production of around 9.2 tons/ha (M. Afzal, *et al.*, 2012). The green foliage of Sudan grass is succulent, very palatable, and nutritious feed for dairy cattle. With good agronomic practices, Sudan grass represents an ideal bulky feed grass due to its dense vegetative growth and high dry yield. In this context, improving the growth, forage yield, and quality of Sudan grass requires the adoption of suitable agronomic practices among which cutting time and N fertilization are important (Nahrawy *et al*., 2011 and uranira, *et al*., 2015).

2.3. Effect of Fertilizer and Harvesting Age on Morphological Characteristics

2.3.1. Plant height

Plant height is the shortest distance between the upper boundary of the main photosynthetic tissues (excluding inflorescences) on a plant and the ground level, expressed in length. Plant height is an important parameter contributing to biomass yield in forage crops. According to (Biniyam Mihret et al., 2018) the application of chemical fertilizer and manure were significantly affected on growth of plant than without fertilizer application. This implies nitrogen response for the growth of plant. The increase in the plant height of grasses through fertilization depends on the availability of soil nitrogen. Fertilizer application and growing legumes in association with grasses also increases the level of soil nitrogen. According to Prakasha et al. (2018) exhibited that different level of NPK fertilizer application increased the plant height of finger millet as increase level of fertilizer. According to Jeong, *et al.*, (2016) plant height was significantly affected by N application rates. Plants attained maximum height before the end of the vegetative phase of growth. According to Wubetie Adnew *et al*., (2019), there is a significant effect on mean plant heights for the *Brachiaria* grasses generally increased and were significantly different ($P<0.05$) throughout the growth period. Mean plant height was low in early stage of growth, but for harvesting after 120-days, enhanced growth was observed in Desho grass (Bimrew Asmare *et al*., 2017).

2.3.2. Number of tillers per plant

Tillers are new grass shoots, made up of successive segments (phytomers), which are composed of a growing point of stem, leaves, roots nodes, and latent buds all of which can rise from crown tissue buds, rhizomes, stolon's or above ground nodes (aerial tillers). The number of tillers per plant is an important yield contributing character that may affect the forage yield of Sudan grass (Ziki *et al*., 2019). Nitrogen fertilization is a very essential nutrient to increase productivity and feed values of forage material. Tillers are very important to understanding grass growth and re-growth (Forage Information System, 2018). Bimrew Asmare *et al*, (2017) harvesting age had significant effects on tiller numbers. Mean tiller number per plant is increased from 36.4 at 75 days growth to 106.4 at 135 days ($P<0.01$) in Desho grass.

2.3.3. Number and length of leaves per plant

Leaf length in grasses plays an essential role in shaping the physical structure of the grass canopy and consequently in competition for light within the sward (Wubetie *et al.*, 2019). According to Negasu *et al.*, (2020) fertilizer application had a significant effect on LLPP of Brachiaria hybrid Mulato II grass. Ghiwot Wanania (2019), the length of leaf per plant (43.96 cm) observed at 60 days of harvesting was significantly lower as compared with 120 days in Buffel Grass (Cenchrus ciliaris linn). According to Genet *et al*, (2017) Leaf number per plant, which, in part, determines the photosynthetic capacity of the plants, was significantly affected by harvesting age. The number of leaves increased with an increase in harvesting days, and fewer total leaves per plant were produced from short harvesting intervals of grass due to cutting at the younger stage of growth, while leaf length per plant was highest at reduced harvesting intervals (Butt *et al*., 1993).

2.3.4. Leaf to Stem Ratio

Leaf to stem ratio is used as an index of quality, the quality of herbage depends on the proportions of stem and leaf in the particular plant species (Van Soest, 1982). Leaf to stem ratio (LSR) was significantly affected by fertilizer type. According to (Ball *et al*., 2001) leaves are higher in quality than stems, as the plant mature forage quality decrease. Leaf stem ratio was influenced by the application of varied levels of fertilizers (Venlayudham *et al*., 2011). Leaf to stem ratio of grass is affected by days of harvesting. The influence of late harvesting intervals progressively increased stem-to-leaf proportion and reduced the leaf yield as well as quality (Van Soest, 1982). The highest leaf to stem ratio in Napier grass was obtained in the short harvesting intervals (Taye Bayble, 2004).

2.4. Effect of Fertilizer and Harvesting Age on Yield and Nutritional Quality of Forage

2.4.1. Dry matter content and dry matter yield

The dry matter (DM) content is the proportion of total components like fibers, proteins, ash, water-soluble carbohydrates and lipids etc. remaining after the water has been removed. Dry mater content increases with the harvesting stage increases. Grasses which yield the highest DM should be the most sought since they can supply the highest amount of forage to livestock. According the finding by Ziki *et al.,* (2019), the maximum obtained dry yield (t/ha) values were recorded on late cutting compared to early cutting of Sudan grass in both seasons. Alemu

Tarekegn *et al*., (2021) report, Sudan grass cultivated in midland area on 40, 50, and 60 days of harvesting interval, the dry biomass yield (5.04, 6.31, 7.49) and the authors conclude that the harvesting interval of Sudan grass increasing, it gives the better output in dry biomass. Wubetie Adnew *et al*., (2019), the harvesting stage can affect the forage DM yield and nutritive values of Brachiaria grasses.

Dry matter content of Desho grass increased with an increase in the growth and development status of the plants, and with advancement in harvesting dates (Bimrew Asmare, 2016). Harvesting day can influence the quality and quantity of forages, which in turn influences their composition and feeding value. Moreover, the maturity stage at harvest is the most important factor determining forage quality. Also, the maturity of forage crops influences forage digestibility and consumption by animals (Atis *et al*., 2012). According to Yossif and Ibrahim (2013), the applications of fertilizer increased the forage dry matter yield of natural pasture. The dry matter yield of fertilized plots of natural pasture is 9.47 t/ha as compared to unfertilized plots 5.67 t/ha at 90 days of harvests (Adane Kitabe, 2003). This was due to N fertilizer fastening the growth of grass to be competitive over legume. According by Ziki *et al*., (2019), dry matter yield was significantly and steadily increased with the increasing N levels from 35 up to 105 kg N/ha/cut. Sharajabian and Soleymani (2017) obtained the highest total dry matter of forage sorghum (Sorghum bicolor L.) by addition of the top N level (240 kg N/ha).Also, Abo-Zeid et al. (2017) reported a significant increase in Sudan grass dry forage yield as N rates were increased from 50 to 75 and then to 100 kg N/ha. NPS fertilizer and manure application increased the dry matter content and dry matter yield of Desho grass.

2.4.2. Ash content

Ash is the inorganic residue remaining after the water and organic matter have been removed by heating in the presence of oxidizing agents, which provides a measure of the total amount of minerals within forage. The quantity of ash in any feed is a positive indicator of the inorganic or minerals content. Generally, most forage has ash content ranging from 3% to 12% (Linn and Martin, 1999). According to Wubetie *et al*., (2019), the majority of the six studied *Brachiaria* grasses in different location had high mineral content at early harvesting. The report by Biniyam Mihret et al., (2018) indicated that fertilizer application was increased with an increase in the ash concentration of desho grass. According to (Fekadu Nemera et al., 2017) report applications of organic and inorganic fertilizer increased the ash content of natural pasture. Although Ahmad et al. (2011) who reported that ash content increased the application of inorganic, organic and mixed types of fertilizer than without fertilizer forage of oat (Avena Sativa L.) respectively.

2.4.3. Crude protein content

Crude protein (CP) content is an important constituent in forages and essential for the maintenance and production of new tissues and an indicator of good quality fodder (Bama *et al.* 2013). The CP content is one of the major nutrients in forage for determination of nutritional quality, since DM intake and rumen microbial growth increase with increasing levels of CP in a feed (Bizelew Gelayenew *et al*., 2019). Crude protein (CP) and digestible dry matter (DDM) are the most important components of a feed. The CP content declines with the increasing age of forages. This could be attributed mainly to dilution of the CP contents of the forage crops by the rapid accumulation of cell wall carbohydrates at the later stages of growth (Van Soest, 1994). Crude protein of Desho grass (*Pennisetum pedicellatum*) decreased with an increase in harvest days Bimrew Asmare, 2016). Crude protein (CP) concentration was significantly affected by harvesting age, declining from 10.9% at 75 days to 9.3% at 135 days (Genet Tilahun *et al*., 2017). According to the report by Biniyam Mihret *et al*., (2018) that application of NPS fertilizer and manure were significantly different from the crude protein of desho grass. The same author, plant spacing was significantly difference in CP concentration of desho grass. Crude protein was affected significantly by different source of fertilizers so statistically the maximum crude protein (10.76 %) inorganic fertilizer application on forage oat (Ahmad *et al*., 2011).

2.4.4. Crude protein yield

The crude protein yield (CPY) is affected by stage of forage maturity. Aschalew et al. (1996), grasses harvested at 4, 6 and 8 weeks produced 2.86, 2.89 and 2.35 t/ha CPY. Ansah *et al*., (2010), The CPY showed a decreasing trend with increase in harvesting days. According to Ashagire Abate (2008) reported that the quantity and quality of natural pasture were improved with the application of fertilizer coupled with stage of harvesting. The effect of fertilizer application indicated an increasing trend in CPY with biomass yield. Abedi Hassen, (2015) indicated that the application of N fertilizer improved both quantity and quality of forages.

2.4.5. Neutral detergent fiber content

Tropical grasses are characterized by low nutritive value due to the higher lignin content and less degradable materials in their cell wall due to the rapid rate of achieving maturity (Minson, 1980). Generally, fiber concentration of the forage crops increases while quality and digestibility decrease as aging prolongs (Atis *et al*., 2012). The increase in cell wall constitutes (NDF) is a very important limiting factor of the nutritive value of feeds (Van Soset and Roberston, 1985). Neutral detergent fiber (NDF) is good indicators of fiber contents but does not measure how digestible that fiber is, but NDF is a good indicator of "bulk" and thus feed intake. Increasing trend of NDF content was observed with extended days of harvesting (Seyoum *et al*., 1998; Adane, 2003). Neutral detergent fiber content varied from 58% to 63% in Napier grass harvested at 68 days to 114 days (Tessema *et al*., 2002). The NDF content of desho grass was highest (77.68%) from late harvesting (150 d after planting) while it was comparatively lower for earlier harvesting periods (72.78% at 90 day and 73.96% at 120 day) (Bimrew Asmare, 2017). Neutral detergent fiber concentration in desho grass increased significantly as the harvesting age extended (Genet Tilahun *et al*., 2017). The NDF concentration of grass decreases with increase fertilizer application. This may be elucidated that the urea fertilizer improves the plant growth and raise new leaves and shoots, which minimizes the NDF content as the urea fertilizer level increases (Van Nieker *et al*., 1993; González *et al*., 1998; Rethman *et al*., 2002) in Panicum maximum and Cenchrus ciliaris grass. Other authors revealed that the application of NPS and manure affect NDF concentration of desho grass.

2.4.6. Acid detergent fiber content

Acid detergent fiber (ADF) is the portion of the forage that remains after treatment with a detergent under acid conditions. It includes the cellulose, lignin and silica. Acid detergent fiber is a good indicator of digestibility and thus energy intake (Van Soest, 1994). ADF is important because it is negatively correlated with how digestible forage may be when fed. As the ADF increases, the forage becomes less digestible (Schroeder, 2004). ADF concentration increased significantly with an increase in harvesting in desho grass (Genet Tilahun *et al*., 2017). According to Taye Bayble, *et al*. 2007, recorded increase in ADF when Napier grass was harvested at 60, 90 and 120 days and should be expected with increasing grass maturity. ADF content of Panicum maximum was significantly influenced by nitrogen fertilization and increased nitrogen fertilization significantly decreased ADF content (Magani *et al*., 2010). According to Abedi Hasen *et al*., (2015) ADF content of grass is decreases as the level of fertilizer increase in panicum maximum forage. Acid detergent fiber concentration is significantly influenced by nitrogen fertilization and increased nitrogen fertilization significantly decreased ADF content.

2.4.7. Acid detergent lignin content

Lignin is the non-carbohydrate component of the forage cell wall and is identified as limiting fiber digestibility. Lignin is the prime factor influencing the digestibility of plant cell wall material. As concentrations of lignin increase, digestibility, intake and animal performance usually decreases (Chamberlain *et al.*, 2016). Lignin limits cell wall (fiber) digestion by providing a physical barrier to microbial attack and the concentration of both fiber and lignin increases as plants mature (Van Soest *et al*., 1991). Ruminants can digest the cellulose and hemicelluloses components of fiber but the lignin inhibits the rate and extent of digestion especially when the proportion of lignin in fiber begins to increase. According to Abedi Hasen *et al.*, (2015) ADL content of grass is decreases as level of fertilizer increase in panicum maximum forage. Acid detergent lignin (ADL) content of Napier grass increased from 4.58 to 6.25% as the days of harvesting increased from 60 to 120 (Taye Bayble, 2004).

3. MATERIAL AND METHODS

3.1. Description of the Study Area

a) Location

The study was conducted in the farmer training center (FTC) at Soroka kebele site in Tegedie district, Central Gondar zone, Amhara region, Northwest Ethiopia. It is located at 360 to 37070′ E longitude and at 130 0 ′0″ to 130 30 ′N latitudes and 295km far from Bahir Dar, the capital city of Amhara regional state and 835 km far from Addis Ababa, the capital city of Ethiopia. The district has an area of 167,420.26 ha. The borders of the district are in North, wolkayt Tegedie (Humera zone), in South, Tach Armachiho district, in East, Debate and debark district and in West, west Armachiho.

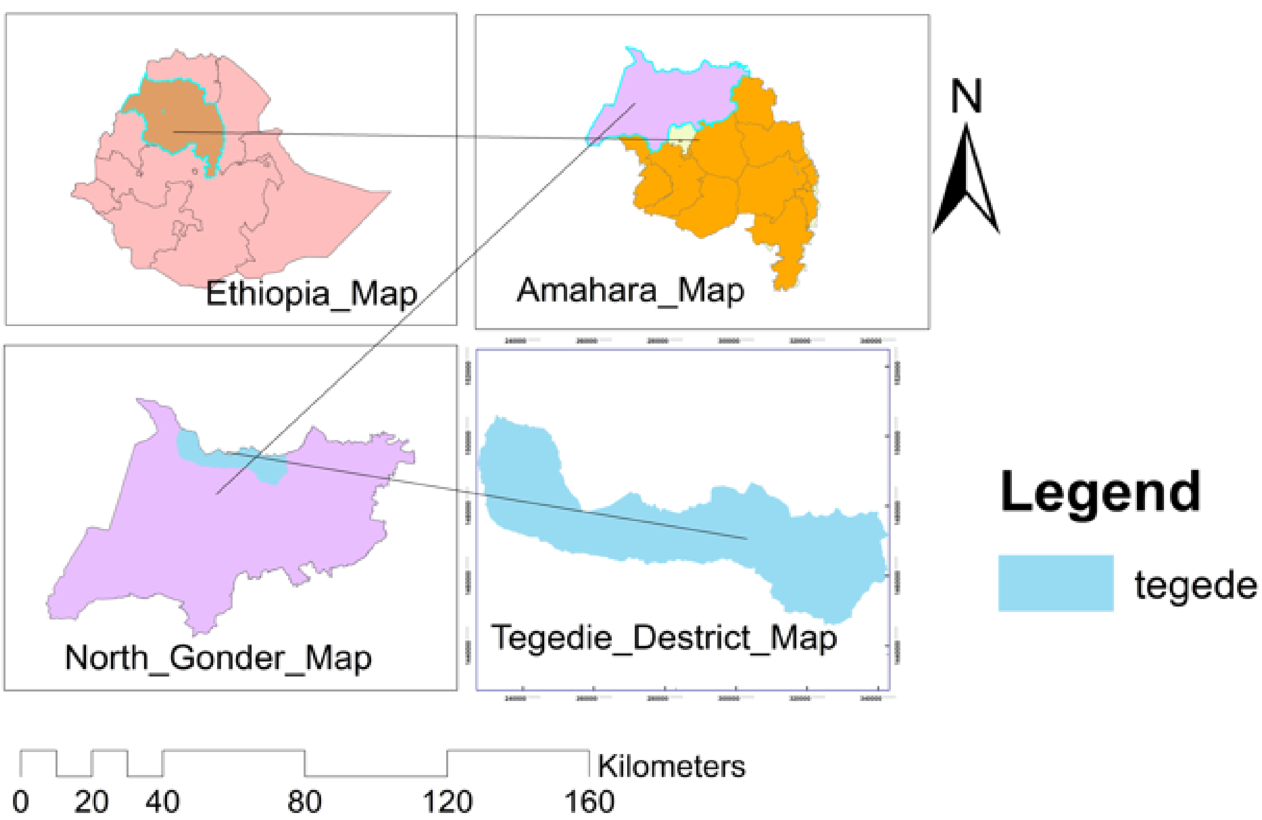

Figure 3. 1:Map of the study area

b) Climate

According to the agricultural office Tegedie district report 2017, the district is characterized by about 5% highland, 25% midland and 70% lowland. The district is majorly covered with lowland and has an annual rain fall amount of 700mm to 1800mm and a mean annual temperature range from 13^{o}c -37^{o}c.

c) Geographical setting and land use type

The district ranges from 500m to 2850 meters above sea level and the physiographic setting of the study area is characterized by 50% (83,710.5ha) plain, 16% (2,677.36 ha) mountainous, 21% (35,158.4ha) hills and 13% (21,764ha) valley. The district also has 47.7% (79,725.7ha) farming land, 17.3% (28,900ha) Grazing land, 13.8% (23,115.56ha) Forest land, 13% (21,764ha) River and gorge land, 1.2% (2,047) Construction and building land and 7% (11,868ha) others land use type.

d) Livestock production and feeding system of the study area

The number of livestock in Tegedie district is 350,191 cattle, 195,283 sheep and goat, 18,392 equine and 54,688 poultry. The livestock production system is classified as traditional production system, and also, the feeding system is more dependent on free grazing and in some extant crop residue and oil byproducts used as sources of supplement feed during the dry season.

3.2. Experimental Layout, Design and Treatments

The experiment design used in the present study was 3x4 factorial arrangements in a random complete block design (RCBD) with 3 replications. Each block contains 12 plots and a total of 36 plots. The experiment consist two factors, the first is fertilizer level (FL) which had four levels of fertilizer (FL_0 = without fertilizer, FL_1 = with 50kg/ha; FL_2 = with 75kg/ha and FL_3=100kg/ha fertilizer level) and the second factor was harvesting age (HA) that had three harvesting age (HA_1 = at 30, HA_2 = at 50 and HA_3 = at 70 days of age after sowing). The total experimental area was 13 m×44 m (572 m^2) with a net plot size 3m×3m (9 m^2). The space between blocks and plots was 1m and 0.5m, respectively. The spacing between plants and rows were 10 cm and 30 cm, respectively.

Sudan grass seed was obtained from Gondar Agricultural Research Center and the type of fertilizer used was NPSB (N (nitrogen) = 18.9%, P (phosphorus) =37.7%, S (sulfur) 6.95% and

B (boron) = 0.1%). Before planting, the experiment site was plugging and harrowing with oxen to be crushed and leveled out to maintain a well prepared seedbed for the establishment of plant materials following the land preparation of the grass per recommendation (Khelil *et al.,* 2005). The experimental blocks and plots were prepared by hand before sowing. A total of 7 kg/ha seed Sudan grass was used for this experiment, and seeds were planted at a depth of 1 inch in clay loam soil (Brian Lang, 2001). The fertilizer was applied during the sowing time. The study was done during the dry season, so the supply of water was done three times a week scheduling with furrow irrigation system to enable the establishment of seedlings and the growth of Sudan grass.

Table3. 1: The treatment combinations used in the experiment

Fertilizer Levels (FL)	Harvesting Age (HA)		
	HA_1	HA_2	HA_3
FL_0= without fertilizer (T_1)	FL_0 x HA_1	FL_0 x HA_2	FL_0 x HA_3
FL_1= 50 kg/ha fertilizer (T_2)	FL_1 x HA_1	FL_1 x HA_2	FL_1 x HA_3
FL_2=75kg/ha fertilizer (T_3)	FL_2 x HA_1	FL_2 x HA_2	FL_2 x HA_3
FL3=100kg/ha fertilizer (T_4)	FL_3 x HA_1	FL_3 x HA_2	FL_3 x HA_3

3.3. Data Collection and Analytical Procedure

3.3.1. Morphological characteristics and dry mater yield

The morphological data was recorded from ten randomly selected plants from the middle rows of each plot at 30, 50 and 70 days after sowing the seeds of Sudan grass *(cultivar Michello)* from ground level to the tip of the apical meristems on plant height (PH) and leaf length (LL) and root length (RL) in centimeter, number of tillers per plant (NTPP), number of leaves per Plant (NLPP) and number of root (NR) was computed by counting. Leave to stem ratio (LSR) and dry matter yield parameter thought out the experimental period. The height of the forage was measured by using a steel tape from the ground level to the base of the top. It was done by hand using a sickle, leaving a stubble height of 5 cm above the ground. Samples of each treatment (plot) were subjected to chemical analysis for the determination of organic matter (OM) following the methods of (AOAC, 2004), at Bahir Dar University, Animal Nutrition Laboratory.

Fresh weight of the forage was determined by harvesting 7.2m^2 areas from each plot at each harvesting age by leaving the border rows. Then about 500gm sub-samples were taken from the harvested samples and subjected drying to measure the dry weight of the samples. The leaf to stem ratio (LSR) was estimated by dividing leaf dry weight to stem dry weight, then the mean of each was calculated. Leaf and stem dry weight divided by leaf and stem fresh weight and multiplied by 100 to determine DM % for each sample. Based on the basis of these DM % and fresh biomass yield from the sample area of each plot were used to calculate total dry matter yields for each plot and, thereafter, converted to tons per hectare. After determining the DMY the samples were used for chemical analysis.

3.3.2. Chemical composition analysis

Dried forage samples were grounded to pass through a 1 mm sieve screen (Willy mill) for analysis of chemical composition. The ground samples were stored in an airtight plastic bag. The chemical analyses of the samples were conducted at Bahir Dar University, Animal Nutrition Laboratory. The grass samples were dried at 65^{o}c for 72 hours and ground to pass through a 1mm sieve. Ash/Organic matter (OM), Dry mater (DM), Crude protein and total ash were determined according to (AOAC, 2004). The neutral detergent fibers (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were determined according to Van Soest and Robertson (1985).

3.3.3. Economic feasibility of fertilizer application

Economic feasibility was done from production cost and revenue from sells of dry matter of Sudan Grass. The net return of experimental Sudan grass at different level of fertilizer was computed as total gross return from grass subtracted from total variable costs (NR=TGR-TVC) the amount of gross return is direct sell of dried grass and also total variable cost of experimental Sudan grass was computed NPS cost pluses seed of sudan grass and labour cost.

3.4. Statistical Analysis

The collected data was managed, organized with MS-Excel 2019 and subjected to analysis of variance (ANOVA) using SAS package version 9.0 (SAS, 2004). The mean of the treatments was compared using Duncan's Multiple Range Test (DMRT) at $p < 0.05$. The differences were considered statistically significant at a 0.05% significance level. The effect of different level of fertilizer, harvesting age and their interaction on morphological characteristics, dry matter yield and chemical composition were determined using the following model;

$$Yijk=\mu+B_i+F_j+H_k+ (F*H)_{jk}+\varepsilon_{ijk}$$

Where:

Y_{ijk} = the response variables

μ = overall mean

B_i = Effects of i^{th} block

F_j = Effect of j^{th} fertilizer

H_k = Effects of k^{th} harvesting age

$F*H_{jk}$ = Interaction between fertilizer and harvesting age

ε_{ijk} = random error

4. RESULTS AND DISCUSSION

4.1. Effect of Fertilizer Level and Harvesting Age on Morphological Characteristic Performance of Sudan grass

All the obtained results from the effect of fertilizer level and harvesting age on morphological characteristic performance of Sudan grass is presented in (Table 4.1). Overall, there was no significant interaction effect (P>0.05) between the fertilizer level and harvesting age.

4.1.1. Plant height

Plant height of Sudan grass had significantly affected (P < 0.001) by harvesting age and fertilizer levels, but not interaction effects (Table 4.1). From the present result, plant height has increased progressively as harvesting age increased i.e., 66.58cm, 185.62 and 216.98cm plant height were recorded at 30, 50 and 70 harvesting age respectively. This growth change might be due to the massive root development and efficient nutrient uptake which leads to continue height growth. The present result agrees with Abdirahman Muhumed (2018), who reported that the plant height of Sudan grass has increased significantly with the advanced age at harvest (plant height 115.8, 186.4 and 205.17 was recorded at 60, 90 and 120 harvesting stage, respectively). From the observation of the effect of fertilizer level,, 143.93, 156.48, 160.48 and 164.67 cm of plant height were recorded from 0, 50, 75 and 100 kg/ha, respectively. The highest plant height (164.67 cm) was recorded at 100kg/ha fertilizer level and the lower plant height (143.93 cm) was recorded at the control treatment. The effect of fertilizer level treatments had no statistical (P > 0.05) but numerical difference in plant height. The current observation agrees with Arvind Chahal *et al*. (2021) who reported that when fertilizer levels increased, plant height had significantly increased. Awoke Kefyalew *et al*. (2020) shows that plant height of desho (*Pennisetum pedicellatum*) grass increased from a lower level of 37.19 cm at 90 days of age to a significantly higher value of 45.43 cm at the age of 150 days. According to Wubetie Adnew *et al*., (2019) study there is a significant effect on mean plant heights for the Brachiaria grasses generally increased and were significantly different (P<0.05) throughout the growth period. Mean plant height was low in the early stage of growth, but for harvesting after 120 days, enhanced growth was observed in Desho grass (Bimrew Asmare *et al*, 2017).

4.1.2. Number of tillers per plant

The number of tillers per plant is an important yield contributing character that may affect the forage yield of Sudan grass. The current finding showed that harvesting age was highly significant effect (P < 0.001) on number of tillers per plant (Table 4.1). There was a statistical difference between the 1st and the rest two harvesting ages. The maximum number of tiller numbers was observed at the earlier harvesting age, followed by middle and late harvesting age. i.e. 21.08, 17.50 and 15.75 number of tillers was recorded from 30, 50 and 70 days of harvest age, respectively. This might be due to the shattering of dried shots increased as the harvesting age increased. Similar finding by Ziki *et al*., (2019), the highest number of shoots per plant (1.911, 1.637, and 1.581) was recorded at the 1st late cutting (56 days) and 2nd and 1st early cutting (35 days after 1st cut and 49 days) in the first season. These authors conclude that the early cutting date was in favor of obtaining a higher number of shoots per plant compared to late cutting in both seasons and suggests that the earlier cutting date of Sudan grass coincides with higher tillering, which may stimulate more shoots per plant, respectively. The tiller number of Sudan grass had significantly affected by fertilizer level. Mean tiller numbers 15.44, 18.44, 18.89 and 19.67 were counted at fertilizer levels 0, 50, 75 and 100 kg/ha respectively. The tiller number per plant recorded from the control (0 kg/ha fertilizer level) treatment was significantly lower than the number per plant obtained from the nitrogen fertilizer level (50, 75 and 100 kg/ha fertilizer level). However, there is no statistical difference between fertilizer levels regarding tiller numbers. The current finding disagreed with Ziki *et al.,* (2019), the tiller number was significantly increased as the fertilizer level was increased from 35 up to 105 kg N/ha/cut. Contrary to this study, the finding by Ates *et al*. (2019) on two sorghum-Sudan grass hybrid cultivars under different nitrogen doses, the result shows that the tiller number was not affected by fertilizer level. This could be due to environmental conditions, soil fertility and management of the study. But, contrary to Ertan Ates *et al*., (2019), the effects of N fertilizer dose on the number of tillers per plant were not significant.

4.1.3. Number of leaf per plant

Harvesting age and interactions between treatments did not significant effect on number of leaf of Sudan grass. Fertilizer application had significant effect (P<0.05) on number of leaf per plant of Sudan grass while harvesting age and their interactions did not significant effect (Table 4.1).

The effect of fertilizer application was significantly different on leaf number than the control. The highest leaf number (112.22) was observed at 75kg/ha fertilizer level and the lowest (89.56) were recorded from the control. But not a significant effect ($p > 0.05$) difference between 50, 75 and 100 kg/ha level of fertilizer on leaf number. The present result agreed with Ertan Ates *et al*. (2019) finding on number of leaves per plant of sorghum-Sudan grass cultivars (*Cv.)* was significantly affected by different nitrogen doses.

4.1.4. Leaf length

Leaf length of Sudan grass had highly significantly affected ($P<0.001$) by harvesting age, but not statistically affected by fertilizer level and their interaction (Table 4.1). The recorded mean leaf length was 38.42, 42.08 and 46.08 cm at harvesting age of 30, 50, and 70 days, respectively. From the present study, leaf length increased with increasing harvesting age. This could be age of plants increases there is enhanced or encourage the elongation of leaf of Sudan grass (*cultivar Michello*). Moreover, the longest leaf length per plant increased with maturity of the grass (Rambau *et al.*, 2016). A similar study by Awoke Kefyalew *et al*. (2020) that obtained leaf length of desho (*Pennisetum pedicellatum*) grass increased from a lower level of 37.19 cm at 90 days of age to a significantly higher value of 45.43 cm at the age of 150 days. Moreover, the variation between the harvest stages may be due to the growth of additional tiller, leaf formation, leaf elongation and stem development (Onyeonagu and Asiegbu, 2013; Amole *et al.*, 2015). Also, depending on Ghiwot (2019) report, the length of leaf per plant (43.96 cm) observed at 60 days of harvesting was significantly lower as compare with 120 day in Buffel Grass (Cenchrus ciliaris linn).

4.1.5. Leaf to Stem Ratio

The effect of harvesting age, fertilizer level and their interaction on leaf to stem ratio of Sudan grass were presented in(Table 4.1). Leaf to stem ratio was not significantly affected ($P>0.05$) by fertilizer application and interactions between treatments, while it was significantly affected ($P<0.001$) by harvesting age. The highest leaf to stem ratio was observed at early (30 day) than mid (50 days) and late (70 days) harvesting age (2.34, 0.43, 0.23) respectively. These results indicated that leaf to stem ratio (LSR) decreased when the harvesting age increased. This might be due to the plant maturity leading to the accumulation of structural carbohydrate and lignin in the plant tissues and defoliation of old leaves. Simili *et al.* (2013) investigated growth rate of sorghum x Sudan grass hybrid during fall and reported a leaf/stem ratio of 0.5. Similar result to the current observation has reported by Awoke Kefyalew *et al*. (2020), leaf to stem ratios of Desho (*Pennisetum pedicellatum*) grass were significantly (p<0.01) affected by harvesting age. From the current observation, leaf to stem ration was not affected by fertilizer level. The present result disagreed with Ertan Ates *et al*. (2019) who compared different sorghum-Sudan grass cultivars (Cv) under different dose of nitrogen fertilizer, the result shows that leaf to stem ratio of sorghum-Sudan grass cultivars (Cv) were significantly affected by different nitrogen doses. Also Arvind Chahal *et al*., (2021) reported leaf stem ratio of sorghum Sudan grass hybrid increased with increasing fertilizer levels.

4.1.6. Number of roots per plant

The effect of harvesting age, fertilizer level and their interaction on number of roots per plant of Sudan grass were presented in (Table 4.1). Sudan grass was significantly affected (P<0.001) by harvesting age. But, number of roots per plant of Sudan grass did not statistically affect (P>0.05) by fertilizer level and their interaction. The present result shows that number of roots per plant increased with increasing age of harvesting. Roots numbers 49.08, 74.58 and 87.50 were recorded at 30, 50 and 70 age of harvest respectively. This might be due to the growth of plant absorbing the water and nutrients from the soil to the upper part of the plant this tends to the overall structural development of each plant part. The current study is in agreement with Mimila *et al.*, (2020) indicated that the highest number of Para Grass (*Brachairia mutica stapf*) root was recorded from the late harvesting age (120 days).

4.1.7. Root length

Harvesting age had a significant (P < 0.01) effect on root length. However, fertilizer level and their interactions did not statistically significant (P > 0.05) effect on the root length of Sudan grass (Table 4.1). The longest root length per plant was observed at the late harvesting age followed by middle and early harvesting age (18.04cm, 16.48cm and 15.59cm at 70, 50 and 30 age of harvest, respectively). In similar studies by Mimila Zemene *et al.,* (2020), roots length of Para Grass (*Brachiaria mutica stapf*) increased with increasing harvesting age. Whenever, the age of plants increases there is enhanced development of roots for searching for water and nutrients. Root elongation and branching are iterative processes in root development (Atkinson *et al.,* 2014).

4.1.8. Dry matter yield (t/ha)

Harvesting age had highly significant ($P < 0.001$) effect on dry matter yield (ton/ha) of Sudan grass (Table 4.1). The higher dry matter yield was recorded from late harvesting age (70) as compared as the intermediate (50) and early (30) harvesting age. The recorded DM yield was 5.62t/ha at 30day, 8.16t/ha at 50day and 11.76 t/ha at 70day harvesting age. From the current result DMY increased as the harvesting age increased. This might be due to the maturity of grass and an increment of structural carbohydrate concentration in the plant tissues that increases the dry matter yield. The current result in agreement with Ziki *et al.*, (2019), the maximum obtained dry yield (ton/ha) values were recorded on late cutting compared to early cutting of Sudan grass in both seasons. Alemu Tarekegn *et al*. (2021) stated that Sudan grass cultivated in midland area on 40, 50, and 60 days of harvesting interval, the dry biomass yield (5.04, 6.31, 7.49) and the authors concluded that the harvesting interval of Sudan grass increasing, it gives the better output in dry biomass. Result from current finding show that DM yield (t/ha) of Sudan grass was not statistically affected by fertilizer level. Maximum DM yield (9.30 t/ha) recorded at a higher rate of fertilizer level (100 kg/ha). DM yield of 7.90, 8.27, 8.59 and 9.30 t/ha have recorded at 0, 50, 70 and 100 kg/ha of fertilizer level, respectively. This result shows that DM yield has numerically increased with fertilizer level increased, but not statistical difference among different level of fertilizer. The obtained result from the current study has disagreed with different research reports. Abo-Zeid *et al*. (2017) confirmed that dry matter yield responded well due to fertilizer application which implies a positive effect with increasing levels of Nitrogen application. Dry matter yield significantly and steadily increased with the increasing N levels from 35 up to 105 kg N/ha/cut (Ziki *et al*., (2019). Sharajabian and Soleymani (2017) obtained the highest total dry matter of forage sorghum (Sorghum bicolor L.) by the addition of the top N level (240 kg N/ha).Also, Abo-Zeid *et al*. (2017) reported a significant increase in Sudan grass dry forage yield as N rates were increased from 50 to 75 and then to 100 kg N/ha. Findings by Hazary *et al*., (2015), N fertilizer application had a significant ($P<0.01$) effect on DM yield of Jumbo grass (Sorghum Grass × Sudan Grass) up to the dose N 1 (40 kg/ha). But further increase N (80, 120 & 160 kg N/ha) did not show any significant improvement of DM yield. Dry matter accumulation of sorghum Sudan grass hybrid increased with increasing fertilizer levels (Arvind Chahal *et al*., 2021). This difference might be due to soil fertility, management practice, and the environmental condition of the study area.

Table 4. 1: Effect of harvesting age and fertilizer level on morphological characteristics and DMY of Sudan grass (cultivar Michello)

Parameters	Factors													
	Harvesting Age (HG)					Fertilizer Level (FL)						Inter. (HA*FL) Sig.	SEM	CV%
	30	50	70	Mean	Sig.	0	50	75	100	Mean	Sig.			
PH (cm)	66.58^{c}	185.62^{b}	216.98^{a}	156.39	***	143.93^{b}	156.48^{a}	160.48^{a}	164.67^{a}	156.39	***	NS	19.68	5.27
NTPP (count)	21.08^{a}	17.50^{b}	15.75^{b}	18.11	***	15.44^{b}	18.44^{a}	18.89^{a}	19.67^{a}	18.11	**	NS	0.93	12.82
NLPP (count)	106.58^{a}	105.67^{a}	99.75^{a}	104.00	NS	89.56^{b}	104.33^{a}	112.22^{a}	109.89^{a}	104.00	*	NS	3.60	14.36
LL(cm)	38.42^{c}	42.08^{b}	46.08^{a}	42.19	***	41.44^{a}	43.33^{a}	41.33^{a}	42.67^{a}	42.19	NS	NS	1.07	7.77
LSR	2.34^{a}	0.43^{b}	0.23^{b}	1.00	***	0.93^{a}	0.98^{a}	0.98^{a}	1.10^{a}	1.00	NS	NS	5.11	34.90
NRPP (count)	49.08^{c}	74.58^{b}	87.50^{a}	70.39	***	61.78^{a}	72.67^{a}	73.44^{a}	73.67^{a}	70.39	NS	NS	0.41	16.62
RL (cm)	15.59^{b}	16.48^{b}	18.04^{a}	16.70	**	16.89^{a}	17.70^{a}	16.41^{a}	15.81^{a}	16.70	NS	NS	0.29	10.40
DMY (t/ha)	5.62^{c}	8.16^{b}	11.76^{a}	8.51	***	7.90^{a}	8.27^{a}	8.59^{a}	9.30^{a}	8.51	NS	NS	0.99	27.33

** = significant at p<0.05; ** = significant at p<0.01, *** = significant at p<0. 001; NS=Non-Significant; means within a row followed by the same letters are not significantly different, HA= harvesting age;, FL= fertilizer level, SEM= standard error of the mea;, PH=plant height; NTPP=number of tillers per plant; NLPP = number of leaf per plant; LLPP=leaf length per plant; LSR=Leaf to Stem Ratio; NRPP=Number of root per plan; RLPP=Root length per plant and DMY=dry matter yield.*

4.2. Chemical Composition of Sudan Grass as Affected by Fertilizer Applications and Harvesting Age

The effect of fertilizer level and harvesting age on the chemical composition and protein yield of Sudan grass is shown in (Table 4.2). There were significant interactions ($P< 0.05$) between the main factors (harvesting age and fertilizer level), but not for protein yield.

4.2.1. Dry matter content **(%)**

Harvesting age, Fertilizer level, and their interactions had significant ($P < 0.01$) effects on dry matter (DM) percentage of Sudan grass. A higher dry matter percentage was observed from the late harvesting age as the compared as intermediate and early harvesting age.

Dry matter content of 92.62%, 94.00% and 94.46% were recorded at 30, 50 and 70 days of harvesting age. The result indicated that the dry matter content increased with increasing age of harvesting. This might be due to an increment of structural carbohydrates i.e., cellulose, pectin, and hemicellulose in the plant tissues and also, when the grass become more matured loss of moister continents in plant tissues. The current result agrees with Salma Mamoun (2007), the dry matter content of Sweet Sorghum increased by increasing time of harvest range (93.82%-92.90%). Moreover, the dry matter content of Sudan grass was statistically affected by fertilizer level. Dry matter content 93.44, 93.98, 93.98 and 93.37 has been recorded at 0, 50, 75 and 100 kg/ha fertilizer levels, respectively. The highest dry matter content (93.98 %) was resulting at fertilizer level 50 and 75kg/ha. No significant difference between the control treatment (0 kg/ha N) and the maximum fertilizer level (100 kg/ha).

4.2.2. Ash content (%)

Harvesting age, fertilizer level, and their interactions had significant effect ($P < 0.01$) on ash content of Sudan grass (Table 4.2). Higher ash content was resulted from the intermediates harvesting age as compared to the early and later harvesting age. Ash content 13.02 at 30, 13.48 at 50day and 12.64 at 70 day of harvesting age were recorded. From the result lower ash content was recorded at late harvesting age. Similarly, the current result is agreement with Abdirahman Muhumed (2018) that the ash content of Sudan grass; significantly decreased with advancing dates of harvesting stages. This might be due to the natural dilution and translocation of nutrients during the growth and development of plant tissue. Moreover, the decline in ash content with increasing maturity could be due to a natural dilution process as dry matter accumulation outstrips mineral uptake as the forages mature (Amole *et al*. 2015). The ash content of Sudan grass was significantly affected ($P<0.01$) by fertilizer level. Ash content 13.04, 13.38, 12.91, and 12.86 were recorded from 0, 50, 75 and 100 kg/ha fertilizer application. From the result, the higher result of ash content has been recorded from the 50 kg/ha fertilizer level. The current observation is in line with Glamoclija *et al*. (2011), the ash content of Sudan grass, fodder sorghum, and their hybrid were affected by different level of fertilizer. Also, a similar result has reported by Hazary *et al*. (2015), ash content of Jumbo grass (*Sorghum Grass* × *Sudan Grass*) was significantly affected by nitrogen fertilizer level.

4.2.3. Crude protein content (%)

Harvesting age, fertilizer level and their interactions were significantly affected ($P < 0.01$) crude protein content of Sudan grass. The highest crude protein content was result at early harvesting age, and then followed by intermediate and late harvesting ages. Crude protein content of 16.35, 8.87 and 5.58% was recorded from 30, 50 and 70 days of harvesting age respectively. The current study shows that crude protein content decreases in advance of plant maturity. This might be due to an increment of structural carbohydrate and lignin content of forage materials and reducing leaf to stem ratio (Ghiwot Wanania, 2019). Moreover, rapid accumulation of cell wall carbohydrates that attributed to the dilution of the CP contents. The current finding agreed with Glamoclija *et al*., (2011), the crude protein content in the tested samples depended on mowing time. Hay with a higher content of total and digestible proteins was obtained by earlier mowing (intense stem elongation phase). The study conducted by (Brock C. *et al.*, 2019) shows that the yield of Sudan grass harvested in 30, 45 and 90 days and the 30 days harvesting Sudan grass gives better crude protein percentages i.e. 11.0%, 5.8% , 4.4% respectively. Finally, the authors recommended that although the 90 harvest days maximized forage DM production, to achieve nutritional value and yield of Sudan grass short day interval of harvesting is recommended. The present results are contrary to the study report by Ziki *et al.* (2019), who reported no cutting time has not significant effects on the crude protein content of Sudan grass. This could be due to variances in management, agro climatic conditions and soil fertility. The current study shows that increasing fertilizer level has significantly affected ($P < 0.01$) crude protein content of Sudan grass. Form the result, 9.45, 9.95, 10.15 and 11.52 percent of crude protein were recorded from 0, 50, 75 and 100kg/ha fertilizer application. This result is in agreement with Ziki *et al.* (2019) increasing the fertilizer level from the lowest level up to the highest level caused a significant increase in the crud protein content of Sudan grass. According to (Abedi Hassen, 2015), the application of fertilizer improved both the quantity and quality of forages.

4.2.4. Crude protein yield (t/ha)

The interaction between fertilizer level and harvesting age had no significant (P>0.05) effect on the total crude protein yield. In this study, the crude protein yield of Sudan grass was significantly affected by harvesting age (P< 0.001). Crud protein yield 0.52, 0.80 and 1.11t/ha obtained from 30, 50 and 70 harvesting age, respectively. The current result shows that crude protein yield increased as harvesting age increased. The present finding is in keeping with Alemu Tarekegn *et al*. (2021) who stated that Sudan grass cultivated in midland area and harvested at 40, 50, and 60 days of age, 0.59, 0.67, 0.73 tons of crude protein per hectare was produced, respectively. Therefore, a better crude protein yield of Sudan grass was obtained at late harvesting age. The current result has in contrary to Ziki *et al*. (2019), cutting dates did not significantly affect crude protein yield of Sudan grass.

In the current study, the crude protein yield of Sudan grass (cultivar Michello) has significantly affected by nitrogen fertilizer level. Crud proteins yields of 0.68, 0.71, 0.83 and 1.02 t/ha were recorded from fertilizer levels 0, 50, 75, and 100kg/ha respectively. The highest crude protein yield was recorded from a higher (100kg/ha) nitrogen fertilizer level and was statistically different from other treatments. This might be due to its tremendous response of nitrogen fertilizer on crud protein yield. The current study is in line with Ziki et al. (2019), increasing the level of N fertilizer was in favor of increasing the protein yield (kg/ha) in Sudan grass under the present investigation. The application of increased levels of Nitrogen fertilizer presumably increased the availability of soil N which might have enhanced quality forage yield. According to (Abedi Hassen, 2015), the application of nitrogen fertilizer improved both the quantity and quality of forages. The current finding is similar to Hazary et al. (2015) report, increasing the level of N fertilizer resulted in a significant (P<0.01) increase in the total CP yield of Jumbo grass (Sorghum Grass × Sudan Grass) up to 80 kg/ha but further increase of N (120 and 160 kg

N/ha) fertilizer did not show any significant improvement of CP yield when compare with control and 40kg N/ha..

4.2.5. Neutral detergent fiber content (%)

Harvesting age, Fertilizer level, and their interactions had highly significant effect ($P < 0.001$) on neutral detergent fiber content of Sudan grass. The neutral detergent fiber content (NDF %) of Sudan grass were progressively increased with harvesting age increased. i.e. 61.63%, 72.18% and 73.43% at 30, 50 and 70 days of harvesting age, respectively. The NDF contents increased with delay in harvesting (Amole *et al*, 2015). This might be due to higher proportion of structural parts of the plant increased with age of harvest delayed. Neutral detergent fiber represents the total cell wall contents of the forage i.e., hemi-cellulose, cellulose, lignin and silica (Bama *et al*. 2013). According to Ates, (2016), NDF increase as the plant matures causing a decline in the quality of the forage. The current finding in agreement with Abdirahman Muhumed (2018), NDF content was highly significantly ($P<0.01$) influenced by different harvesting stages (60, 90 and 120 days of harvesting age, 58.91, 66.35 and 72.11 % NDF recorded, respectively) of Sudan grass (*Sorghum sudanense l.*). The present study shows that neutral detergent fiber content (% NDF) was significantly affected by fertilizer level. From the result, recorded NDF proportion have been 70.05, 67.87, 70.35, 68.05 from fertilizer levels 0, 50, 75 and 100kg/ha, respectively. A similar finding was reported by Ertan *et al.* (2019), the different N doses affected the NDF contents of Sorghum-Sudan grass hybrid cultivars. The current finding is contrary to Hazary *et al.* (2015) who did not find any significant effect on the NDF content in Jumbo grass (*Sorghum Grass* × *Sudan Grass*) with the increasing level of N fertilizer. Gulumser *et al.*, (2016), NDF of Sudan grass and sorghum x Sudan grass hybrid varieties was not affected by fertilizer rates. This could be management, environmental conditions and soil fertility.

4.2.6. Acid detergent fiber content (%)

Harvesting age and interactions between main treatments (fertilizer and harvesting ages) were significantly affecting ($P < 0.01$) acid detergent fiber content (ADF %) of Sudan grass (*cultivar Michello*). From the current observation ADF content was progressively increased (43.55, 49.48, and 50.56%) with advanced harvesting age (30, 50 and 70 days) respectively. This might be due to the increment of structural carbohydrates. This might be due to cellulose and lignin proportion increasing with plant maturity. The present result agrees with Abdirahman Muhumed (2018) report, proportion of ADF content of Sudan grass (*Sorghum sudanense l.*) was increased with harvesting age increased (60, 90 and 120 days of harvesting age, 33.75, 37.94 and 44.24 % ADF were recorded, respectively). ADF increase as the plant matures causing a decline in the quality of the forage (Ates 2016). Depending on the current study, NDF content had not affected by fertilizer level (Table 5). In line with the current study, Hazary *et al.* (2015) on Jumbo grass (*Sorghum Grass* × *Sudan Grass*) and Gulumser *et al.* (2016) on Sudan grass and sorghum x Sudan grass hybrid varieties reported that ADF content was not affected by fertilizer rates. Contrary to the present observation Ertan *et al*. (2019), the different N doses affected the ADF contents of Sorghum-Sudan grass hybrid cultivars. This difference could be agro-climatic condition, management practice, etc.

4.2.7. Acid detergent lignin content (%)

Harvesting age and interactions between treatments (fertilizer level and harvesting ages) were significantly affected ($P < 0.01$) acid detergent lignin content of Sudan grass. The ADL content of Sudan grass progressively increased with harvesting age increased. ADL content 8.55, 10.03 and 10.99 percent was recorded at 30, 50 and 70days of harvesting age. This study shows, the concentration of acid detergent lignin increased with the advance of plant maturity increased. This study in line with Abdirahman Muhumed (2018) report that ADL content of Sudan grass (Sorghum sudanense) increased by 7.94, 9.98 and 12.09 % ADL at 60 to 90 and 120 days of harvesting age, respectively. Also, the present finding is supported by the findings of (Baba, et al., 2013; Amole et al., 2015), who reported that this is due to rapid lignification to occur in late harvesting stages. Lignin is the non-carbohydrate component of the forage cell wall and is identified as limiting fiber digestibility.

Table 4. 2: Effect of Fertilizer Level and Harvesting Age on Chemical Composition of Sudan Grass (Cultivar Michello)

Parameters	Factors: Harvesting Age (HD)					Fertilizer Level (FL)						Inter. (HA*FL) Sig.	SE	CV%
	30	50	70	Mean	Sig.	0	50	75	100	Mean	Sig.			
DM (%)	92.62^{c}	94.00^{b}	94.46^{a}	93.69	***	93.44^{b}	93.98^{a}	93.98^{a}	93.37^{b}	93.69	**	***	0.29	0.49
Ash (%)	13.02^{b}	13.48^{a}	12.64^{c}	13.05	***	13.04^{ab}	13.38^{a}	12.91^{b}	12.86^{b}	13.05	*	***	0.20	3.03
CP (%)	16.35^{a}	8.87^{b}	5.58^{c}	10.27	***	9.45^{c}	9.95^{b}	10.15^{b}	11.52^{a}	10.27	***	***	1.39	3.89
CPY (t/ha)	0.52^{c}	0.80^{b}	1.11^{a}	0.81	***	0.68^{b}	0.71^{ab}	0.83^{ab}	1.02^{a}	0.81	*	NS	0.10	38.09
NDF (%)	61.63^{c}	72.18^{b}	73.43^{a}	69.08	***	70.05^{a}	67.87^{b}	70.35^{a}	68.05^{b}	69.08	***	***	1.71	1.20
ADF (%)	43.55^{c}	49.48^{b}	50.56^{a}	47.86	***	48.18^{a}	47.92^{a}	47.85^{a}	47.50^{a}	47.86	NS	***	0.96	1.61
ADL (%)	8.55^{c}	10.03^{b}	10.99^{a}	9.86	***	10.11^{a}	9.65^{a}	9.96^{a}	9.72^{a}	9.86	NS	***	0.38	5.59

** = significant at p<0.05; ** = significant at p<0.01, *** = significant at p<0. 001; NS=Non-Significant; means within a row followed by the same letters are not significantly different; SEM = standard error of the mean; HA= Harvesting Ag;, FL= Fertilizer Level; DM = Dry Matter%; Ash = Ash%; CP = Crude Protein%; CPY = crude protein yield; NDF = Neutral Detergent Fiber %; ADF = Acid Detergent Fiber % and ADL= Acid Detergent Lignin%.*

4.3. Correlation among morphological characteristics, Chemical Compositions, CP Yield and DM Yield of Sudan Grass

Simple linear bivariate correlation among agronomical morphological characteristics and chemical compositions, of Sudan Grass are presented in Table 4.3. Plant height was positively correlated ($P<0.05$) with dry matter yield, crude protein yield, root number per plant , root length per plant, neutral detergent fiber, acid detergent fiber, and acid detergent lignin while negatively correlated with tiller numbers, leaf number, leaf to stem ratio and crude protein content. Leaf length was positively correlated with crude protein yield, root number per plant, root length per plant, neutral detergent fiber, acid detergent fiber, acid detergent lignin while negatively correlated with a number of leaf per plant, leaf to stem ratio, crude protein content, crude protein yield, dry matter yield and ash content. Dry matter yield is positively correlated ($P<0.001$) with plant height, leaf length per plant, root length per plant, crude protein yield, neutral detergent fiber, acid detergent fiber and acid detergent lignin, but negatively correlated with number of tiller per plant, leaf to steam ratio and crude protein content. Crude protein content was positively correlated ($P<0.001$) with number of leaf per plant and leaf to steam ratio, but negatively correlated with dry matter content, neutral detergent fiber, acid detergent fiber and acid detergent lignin. Crude protein yield was positively correlated with plant height, leaf length per plant, root number per plant root length per plant, dry matter content neutral detergent fiber, acid detergent fiber and acid detergent lignin, while negatively correlated ($P<0.001$) with leaf to steam ratio, number of tillers, ash and crude protein content.

Neutral detergent fiber was positively correlated ($P<0.05$) with plant height, acid detergent fiber acid detergent lignin, dry matter content and dry matter yield, while negatively correlated ($P<0.001$) with the number of tiller per plant, number of leaf per plant, crud protein and ash content. Acid detergent fiber was positively correlated ($P<0.05$) with plant height, number of root per plant, root length per plant neutral detergent fiber, acid detergent lignin, while negatively correlated ($P<0.001$) with number of tiller per plant and leaf stem ratio. Acid detergent lignin was positively correlated ($P<0.05$) with neutral detergent fiber, acid detergent fiber, plant height, leaf number per plant, number of root per plant, root length per plant, while negatively correlated with number of tiller per plant, leaf to stem ratio and ash content.

Table 4. 3: Correlation coefficients among morphological parameters, chemical composition and yield of Sudan grass

	PH	NTPP	NLPP	LLPP	NRPP	RLPP	LSR	DMY	DM	Ash	NDF	ADF	ADL	CP	CPY
PH	1	-0.54***	- 0.05	0.09	0.83***	0.43**	-0.93***	0.73***	0.76***	-0.08	0.90***	0.91***	0.74***	-0.93***	0.60***
NTPP		1	0.56***	0.27	-0.28	-0.37*	0.59***	-0.37*	-0.36*	0.15	-0.58***	- 0.64***	0.64***	0.66***	-0.28
NLPP			1	-0.38*	0.10	-0.20	0.091	0.03	0.05	0.12	-0.08***	- 0.18	0.70***	0.20	0.02
LLPP				1	0.10	0.15	-0.02	-0.35*	0.05	-0.38*	0.11	0.09	0.11	-0.26	-0.27
NRPP					1	0.50**	-0.75***	0.78***	0.64***	-0.08	0.73***	0.75***	0.37*	-0.76***	0.56***
RLPP						1	-0.43**	0.43**	-0.53***	-0.13	0.38*	0.48**	0.33*	-0.48**	0.12*
LSR							1	-0.63***	0.71***	0.02	-0.90***	-0.91***	-0.75***	0.91***	-0.54***
DMY								1	0.56***	-0.27	0.61***	0.64***	0.57***	-0.70***	0.38*
DM									1	-0.07	0.71***	0.77***	0.69***	-0.75***	0.45**
Ash										1	-0.06	0.08	-0.78***	0.09	-0.13
NDF											1	0.84***	0.85***	- 0.91***	0.51**
ADF												1	0.90***	- 0.93***	0.55***
ADL													1	- 0.72***	0.44**
CP														1	- 0.54***
CPY															1

*Level of significance: *** = P<0.001, ** = P<0.01; * = P<0.05, PH=plant height, NTPP=number of tillers per plant, NLPP = number of leaf per plant, LLPP=leaf length per plant, LSR=Leaf to Stem Ratio, NRPP=Number of root per plant, RLPP=Root length per plant, NLPP=number of leaves per plant and DMY=dry matter yield, DM=Dry Matter%; Ash=Ash%; OM=Organic Matter%, NDF=Neutral Detergent Fiber%; ADF=Acid Detergent Fiber%, ADL=Acid Detergent Lignin% and CP=Crude Protein%, CPY= crude protein yield*

4.4. Partial budget analysis of Fertilizer Application

Partial budget analysis was done from production cost and revenue from sells of dry matter of Sudan Grass (sorghum Sudanese) as shown below in Table 4.4. The net benefit of experimental Sudan grass at different level of fertilizer was computed as total return from Sudan Grass subtracted from total variable costs. The net benefits among fertilizer level were quite different. This is due to production potential of dry matter yield differences among experimental *Sudan* grass cultivar at both fertilizer levels. The highest net benefit was obtained from *Sudan* grass (sorghum Sudanese) (68,716.67birr) at 100Kg NPSB fertilizer. The intermediate net benefit was recorded from Sudan grass (62669.67, 60522.67 birr) at75 Kg, 50Kg NPSB fertilizer respectively. While the lowest net benefit was recorded from Sudan grass (58,928.67 birr) at without fertilizer.

Table 4. 4: Partial Budget analysis for dry matter yield of Sudan Grass at different level of fertilizer applications

Trt.	Fertilizer level (Kg/ha)	DMY (ton/ha)	NPS Cost (ETB/ha)	Seed Cost (ETB/ha)	Labour Cost (ETB/ha)	TVC (ETB/ha)	Return From Sudan Grass sell (ETB/ha)	GR (ETB/ha)	NR (ETB/ha)
1	0	7.9	-	400.00	19,671.33	20,071.33	79,000.00	79,000.00	58,928.67
2	50	8.27	2,106.00	400.00	19,671.33	22,177.33	82,700.00	82,700.00	60,522.67
3	75	8.59	3,159.00	400.00	19,671.33	23,230.33	85,900.00	85,900.00	62,669.67
4	100	9.3	4,212.00	400.00	19,671.33	24,283.33	93,000.00	93,000.00	68,716.67

DMY= dry matter yield; TVC= total variable cost; GR= gross Return; NR= net return
Selling price was estimated by the market price (10ETB/1kg) of Sudan grass.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The result of the present study showed that morphological characteristics, dry matter yield and chemical composition of Sudan grass (sorghum Sudanese) were affected by harvesting age and fertilizer level, but not by their interaction effect except some parameters of chemical composition. It indicated that performances of morphological characteristics, and dry matter of Sudan grass (sorghum Sudanese) such as plant height, leaf length per plant, root number per plant, root length per plant, dry matter yield (t/ha) and its chemicals such as dry matter content, crud protein yield (t/ha), neutral detergent fiber, acid detergent fiber and acid detergent lignin were increased within advanced of plant maturity while, LSR, Ash and CP content were declined with an increasing of harvest age.

The current study showed that yield of Sudan grass (sorghum Sudanese) increased with harvesting age increased but a decline in chemical composition. However, the DMY and CPY at the early age of harvest were lower than at the middle and late harvesting age. A high proportion of ash content was recorded from the middle than early and late harvesting ages. However, DMY and CPY at early age of harvest were lower than middle and late harvesting age. The recorded NDF contents were recorded in the current study was 61.63, 72.18, and 73.43 at harvesting ages 30, 50 and 70 days, respectively.

Levels of fertilizer application affected some morphological characteristics and chemical compositions of Sudan grass where increases of CP and CPY were recorded with an increasing the level of fertilizer. The higher percentage of DM content, ash content and lower NDF content recorded from the 50 kg/ha level of fertilizer. Hence ,the result of the present study indicates that Sudan grass can be harvested at 50 days of age grown with application of 50 kg/ha level of fertilizer is recommended for exhibiting good results for yield and quality of the grass. Therefore, from this information, beneficiaries make their decisions based on the relative importance of forage yield, qualities, and cost of fertilizer.

5.2. Recommendations

Based on the above conclusions the following recommendations were forwarded for utilizations and further studies on Sudan grass (sorghum Sudanese):

- To obtain good quality forage with high dry matter and crude protein yield, Sudan grass should be harvested at the middle (50) harvesting age when grown at middle ago ecology of the country using irrigation schemes.
- Among level of fertilizer treatments, a 50kg/ha fertilizer dose is recommended for the production of higher dry matter and crude protein yield with minimum fertilizer cost.
- To fully utilize the potential of Sudan grass, further studies on agronomic performances, chemicals compositions, and animal feed trial evaluation are recommended.

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7. APPENDIX

7.1 Appendix Tables

Table7. 1. ANOVA table for plant height (PH)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	153428.4356	13948.0396	205.00	<.0001
Error	34	1632.9200	68.0383		
Corrected Total	35	155061.3556			

R-Square	Coeff Var	Root MSE	PH Mean
0.989469	5.274374	8.248535	156.3889

Source	DF	Type I SS	Mean Square	F Value	Pr > F
HA	2	151097.6939	75548.8469	1110.39	<.0001
FL	3	2163.5044	721.1681	10.60	0.0001
HA*FL	6	167.2372	27.8729	0.41	0.8653

Table7. 2ANOVA for Number of Tiller per Plant (NTPP)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	340.2222222	30.9292929	5.74	0.0002
Error	24	129.3333333	5.3888889		
Corrected Total	35	469.5555556			

R-Square	Coeff Var	Root MSE	NTPP Mean
0.724562	12.81754	2.321398	18.11111

Source	DF	Type I SS	Mean Square	F Value	Pr > F
HA	2	177.3888889	88.6944444	16.46	<.0001
FL	3	92.2222222	30.7407407	5.70	0.0043
HA*FL	6	70.6111111	11.7685185	2.18	0.0803

Table7. 3ANOVA for Number of Leaves per Plant (NLPP)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	5142.00000	467.45455	2.09	0.0630
Error	24	5356.00000	223.16667		
Corrected Total	35	10498.00000			

R-Square	Coeff Var	Root MSE	NLPP Mean
0.489808	14.36420	14.93876	104.0000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
HA	2	330.166667	165.083333	0.74	0.4878
FL	3	2799.333333	933.111111	4.18	0.0163
HA*FL	6	2012.500000	335.416667	1.50	0.2196

Table7. 4ANOVA for Leaf Length per Plant (LLPP)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	455.6388889	41.4217172	3.85	0.0028
Error	24	258.0000000	10.7500000		
Corrected Total	35	713.6388889			

R-Square	Coeff Var	Root MSE	LLPP Mean
0.638473	7.770500	3.278719	42.19444

Source	DF	Type I SS	Mean Square	F Value	Pr > F
HA	2	352.8888889	176.4444444	16.41	<.0001
FL	3	25.4166667	8.4722222	0.79	0.5124
HA*FL	6	77.3333333	12.8888889	1.20	0.3406

Table7. 5. ANOVA for Leaf to Stem Ratio (LSR)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F

Model	11	32.64578889	2.96779899	24.39	<.0001
Error	24	2.91980000	0.12165833		
Corrected Total	35	35.56558889			

R-Square	Coeff Var	Root MSE	LSR Mean
0.917904	34.89894	0.348796	0.999444

Source	DF	Type I SS	Mean Square	F Value	Pr > F
HA	2	32.35890556	16.17945278	132.99	<.0001
FL	3	0.13236667	0.04412222	0.36	0.7805
HA*FL	6	0.15451667	0.02575278	0.21	0.9695

Table7. 6.ANOVA for Number of Root Per Plant (NRPP)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	10358.55556	941.68687	6.88	<.0001
Error	24	3286.00000	136.91667		
Corrected Total	35	13644.55556			

R-Square	Coeff Var	Root MSE	NRPP Mean
0.759171	16.62356	11.70114	70.38889

Source	DF	Type I SS	Mean Square	F Value	Pr > F
HA	2	9171.722222	4585.861111	33.49	<.0001
FL	3	894.777778	298.259259	2.18	0.1168
HA*FL	6	292.055556	48.675926	0.36	0.8996

Table7. 7: ANOVA for Root Length Per Plant (RLPP)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F

Model	11	65.0897222	5.9172475	1.96	0.0816
Error	24	72.4800000	3.0200000		
Corrected Total	35	137.5697222			

R-Square	Coeff Var	Root MSE	RLPP Mean
0.473140	10.40435	1.737815	16.70278

Source	DF	Type I SS	Mean Square	F Value	Pr > F
HA	2	36.94888889	18.47444444	6.12	0.0071
FL	3	17.18305556	5.72768519	1.90	0.1571
HA*FL	6	10.95777778	1.82629630	0.60	0.7239

Table7. 8: ANOVA for Dry Matter Yield ton per hectare (DMY)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	504.8412750	45.8946614	23.18	<.0001
Error	24	47.5236000	1.9801500		
Corrected Total	35	552.3648750			

R-Square	Coeff Var	Root MSE	DMY Mean
0.913963	23.02132	1.407178	6.112500

Source	DF	Type I SS	Mean Square	F Value	Pr > F
HA	2	496.6646167	248.3323083	125.41	<.0001
FL	3	3.0975194	1.0325065	0.52	0.6716
HA*FL	6	5.0791389	0.8465231	0.43	0.8533

Table7. 9: ANOVA for Dry Matter (DM %)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	32.54172222	2.95833838	14.18	<.0001
Error	24	5.00640000	0.20860000		
Corrected Total	35	37.54812222			

R-Square	Coeff Var	Root MSE	DM Mean
0.866667	0.487474	0.456727	93.69278

Source	DF	Type I SS	Mean Square	F Value	Pr > F
HA	2	22.04960556	11.02480278	52.85	<.0001
FL	3	3.01712222	1.00570741	4.82	0.0091
HA*FL	6	7.47499444	1.24583241	5.97	0.0006

Table7. 10: ANOVA for Ash content

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	15.47167500	1.40651591	9.00	<.0001
Error	24	3.75200000	0.15633333		
Corrected Total	35	19.22367500			

R-Square	Coeff Var	Root MSE	Ash Mean
0.804824	3.030390	0.395390	13.04750

Source	DF	Type I SS	Mean Square	F Value	Pr > F
HA	2	4.17791667	2.08895833	13.36	0.0001
FL	3	1.46698611	0.48899537	3.13	0.0444
HA*FL	6	9.82677222	1.63779537	10.48	<.0001

Table7. 11: ANOVA for Neutral Detergent Fiber (NDF %)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	1152.568742	104.778977	153.46	<.0001
Error	24	16.386533	0.682772		
Corrected Total	35	1168.955275			

R-Square	Coeff Var	Root MSE	NDF Mean
0.985982	1.196135	0.826300	69.08083

Source	DF	Type I SS	Mean Square	F Value	Pr > F
HA	2	1008.073317	504.036658	738.22	<.0001
FL	3	45.602742	15.200914	22.26	<.0001
HA*FL	6	98.892683	16.482114	24.14	<.0001

Table7. 12: ANOVA for Acid Detergent Fiber (ADF %)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	364.6832750	33.1530250	55.73	<.0001
Error	24	14.2772000	0.5948833		
Corrected Total	35	378.9604750			

R-Square	Coeff Var	Root MSE	ADF Mean
0.962325	1.611408	0.771287	47.86417

Source	DF	Type I SS	Mean Square	F Value	Pr > F
HA	2	341.4436167	170.7218083	286.98	<.0001
FL	3	2.1115639	0.7038546	1.18	0.3370
HA*FL	6	21.1280944	3.5213491	5.92	0.0007

Table7. 13: ANOVA for Acid Detergent Lignin (ADL %)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	56.96609722	5.17873611	17.04	<.0001
Error	24	7.29546667	0.30397778		
Corrected Total	35	64.26156389			

R-Square	Coeff Var	Root MSE	ADL Mean
0.886472	5.592805	0.551342	9.858056

Source	DF	Type I SS	Mean Square	F Value	Pr > F
HA	2	36.27817222	18.13908611	59.67	<.0001
FL	3	1.25016389	0.41672130	1.37	0.2755
HA*FL	6	19.43776111	3.23962685	10.66	<.0001

Table7. 14: ANOVA for crude protein (CP %)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	769.6086972	69.9644270	437.66	<.0001
Error	24	3.8366667	0.1598611		
Corrected Total	35	773.4453639			

R-Square	Coeff Var	Root MSE	CP Mean
0.995040	3.893886	0.399826	10.26806

Source	DF	Type I SS	Mean Square	F Value	Pr > F
HA	2	731.1157056	365.5578528	2286.72	<.0001
FL	3	21.2012306	7.0670769	44.21	<.0001
HA*FL	6	17.2917611	2.8819602	18.03	<.0001

Table7. 15: ANOVA for Crude Protein Yield (CPY)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	1.81096389	0.16463308	15.90	<.0001
Error	36	0.24846667	0.01035278		
Corrected Total	47	2.05943056			

R-Square	Coeff Var	Root MSE	CPY Mean
0.879352	22.05268	0.101749	0.461389

Source	DF	Type I SS	Mean Square	F Value	Pr > F
HA	2	1.48467222	.48467222	71.70	<.0001
FL	3	0.19540833	0.06513611	6.29	0.0026
HA*FL	6	0.13088333	0.02181389	2.11	0.0899

7.2. Appendix Figures

Figure7. 1: photo on prepare seedbed and Agronomic data collection on sudangrass