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Effect of Fertilizer Application and Varieties on Morphological Parameters, Dry matter Yield and Nutritional Quality of Selected Grass Species under Rain Fed Conditions in Bahir Dar Zuria District of Ethiopia

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science (M.Sc.) in Animal production

Major Advisor: - Netsanet Beyero (Ph.D)

Co- Advisor: - Melkamu Bezabih (Ph.D)

March, 2024

Bahir Dar, Ethiopia

THESIS APPROVAL SHEET

As members of the Board of Examiners of the Master of Science (M.Sc.) thesis open defense examination, we have read and evaluated this thesis prepared by **Mr. Mekuanint Tadilo Tefera** entitled: **Effect of Fertilizer Application and Varieties on Morphological Parameters, Dry Matter Yield and Nutritional Quality of Selected Grass Species under Rain Fed Conditions in Bahir Dar Zuria District of Ethiopia**. We hereby certify that the thesis is accepted for fulfilling the requirement for the award of the degree of Master of Science (M.Sc.) in **Animal Production**.

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DECLARATION

This is to certify that this thesis in titled "**Effect of Fertilizer Application and Varieties on Morphological Parameters, Dry matter Yield and Nutritional Quality of Selected Grass Species under Rain Fed Conditions in Bahir Dar Zuria District of Ethiopia**" submitted in partial fulfillment of the requirement for the award of the degree of master of science in "**Animal Production**" to the graduate program of the College of Agriculture and Environmental Sciences, Bahir Dar University by **Mr. Mekuanint Tadilo Tefera** (ID. No. BDU1401230) is an authentic work carried out by him under our guidance. The matter embodied in this research work has not been submitted earlier for an award of any degree or diploma to the best of our knowledge and belief.

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(Co-Advisor) Signature Date

STATEMENT OF THE AUTHOR

I hereby declare that this thesis is my original work and that all references used in its preparation have been appropriately cited. This thesis has been sumitted for consideration toward the M.Sc. degree requirements at Bahir Dar University. It has also been deposited in the university library, where it will be accessible to users in accordance with library policies. I thus really declare that this thesis has not been submitted for consideration for any academic degree, diploma, or certificate to any other university, anywhere. Short quotes from this thesis are acceptable as long as the source has correctly cited and no special permission is needed. The head of the main department or the dean of the school of graduate studies may authorize requests for lengthy quotations from this document or for its full or partial reprint if, in their opinion, the proposed use of the material advances research. But in every other case, permission from the author is needed.

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LIST OF ABBREVIATIONS AND ACRONYMS

ADF	Acid Detergent Fiber
ADL	Acid Detergent Lignin
ANOVA	Analysis of Variance
ARC	Agricultural Research Council
BDZWOA	Bahir Dar Zuria Woreda Office Agriculture
CASCAPE	Capacity Building for the Scaling up of Evidence-Based Best Practices in Agricultural Production in Ethiopia
CP	Crude Protein
CPY	Crude Protein Yield
CSA	Central Statistical Agency
DM	Dry Matter
DMRT	Duncan Multiple Range Test
DMY	Dry Matter Yield
FAO	Food and Agriculture Organization
FIS	Forage Information System
FYM	Farm Yard Manure
GDP	Gross Domestic Product
GLM	General Linear Model
ILRI	International Livestock Research Institute
IVOMD	In-Vitro Organic Matter Digestibility
LLPP	Leaf Length per Plant
LSR	Leaf to Stem Ratio
LWPP	Leaf Width per Plant
ME	Metabolizable Energy
MJ	Mega Joule
NDF	Neutral Detergent Fiber
NGO	Non-Governmental Organizations
NIRS	Near-Infrared Reflectance Spectroscopy
NLPP	Number of Leaves per Plant

NTPP	Number of Tillers per Plant
OM	Organic Matter
PH	Plant Height
RCBD	Randomized Complete Block Design
SAS	Statistical Analysis System
SSDW	Sub-sample Dry Weight
SSFW	Sub-sample Fresh Weight
t/ha	Ton per hectare
TFW	Total Fresh Weight

Effect of Fertilizer Application and Varieties on Morphological Parameters, Dry matter Yield and Nutritional Quality of Selected Grass Species under Rain Fed Conditions in Bahir Dar Zuria District of Ethiopia

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ABSTRACT

The purpose of this experiment was to assess the morphological parameters, dry matter yield and nutritional content, of a few selected cultivars of Brachiaria, Desho, and Napier grasses grown for two years under various fertilizer treatments. The field experiment was carried out at Robit Bata Kebele in the Bahir Dar Zuria district of Amhara region, Ethiopia. In the trial, four fertilizer rates (0,100kgN, 300kg N and manure) and three grass varieties (Brachiaria decumbens ILRI-10871, Pennisetum glaucifolium Areka-DZF-590, and Cenchrus purpureus ILRI-16791) were used. Each 9-m2 plot in the treatments was arranged in a 3x4x2 factorial configuration arranged in a randomized complete block design with three replications. Hand labor was used for agronomic tasks like weeding, fertilizer application, and hoeing. Morphological data were collected from 10 randomly selected plants grown in the middle rows of each plot. The harvested forage samples were weighted, dried, and then grounded for chemical composition analyses using Near-infrared Reflectance Spectroscopy. All recorded dataset were managed using Microsoft excel 2010 and subjected to a general linear model procedure of SAS (9.0) and Pearson correlation analysis, at significance level of alpha <0.05. The findings demonstrated that the morphological characteristics, dry matter yield, and nutritional values were strongly impacted by the interaction of fertilizer application, year, and grass varieties. Cenchrus purpureus ILRI-16791 produced the tallest plant (175.0 and 187.0cm), and the highest dry matter yield (12.5 and 21.88 t/ha) when measured at manure fertilizer in the first and second year production, respectively. The lowest CP % was found in desho (6.21 t/ha) and B. decumbens (9.23 t/ha) cultivated without fertilizer in the first and second years, respectively, while the maximum CP % was found in Cenchrus purpureus ILRI-16791 (13.72 and 14.09%) at manure fertilizer. Cenchrus purpureus ILRI-16791 (34.09%) and Pennisetum *glaucifolium Areka-DZF-590 (35.68%) at manure fertilizer had the lowest ADL %, whereas B. decumbens (47.93 and 46.92%) had the greatest ADF % without fertilizer in the first and second years, respectively. The highest ME was found in Cenchrus purpureus ILRI-16791 (11.77 MJ/kg at 300 kg N and 12.84 MJ/kg with manure), whereas the highest IVOMD was found in Napier (60.36 and 68.09%) with manure fertilizer in the first and second years, respectively. Moreover, the highest net benefit was obtained from Napier grass at manure fertilizer (39337.5 and 73358.76 birr) and the lowest net benefit was recorded from B.decumbens at without fertilizer (21318.7 birr) and 100kg/ha N fertilizer (32241.51birr) in the first and second years, respectively. In conclusion, in the research areas and other agro-ecologies where there is similar agro-ecology, the Napier grass-16791 with manure fertilizer would have a more advantageous production performance to meet forage quantity, economic feasibility and nutritional value demands.*

Keywords: *Chemical composition, Fertilizer application, Forage yield, Grass varieties*

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CHAPTER ONE: INTRODUCTION

1.1. Background and Justification of the study

Ethiopia has the huge livestock population in Africa, it was estimated to be 70 million cattle, 42.9 million sheep, 52.5 million goats, 2.15 million horses, 10.80 million donkeys, 0.38 million mules, 8.1 million camels, 57 million chickens, and 6.99 million beehives (CSA, 2021). In the country, livestock is a main source of animal protein, means of transportation, power for crop cultivation, export goods, manure for agricultural cultivation and household energy, means of wealth accumulation, and security in times of crop failure. In addition to this, the sector contributed about 17–25.3% to the national GDP, 39–49% to the agricultural GDP, 12–15% of the export earnings, 60–70% employment opportunity and 50% of household incomes (Shapiro *et al.*, 2017). However, livestock productivity in Ethiopia in comparison to the livestock potential is low due to the attributes of inefficient nutritional and management practices, disease and parasitic occurrence, low genetic potential, lack of extension services, and inadequate information to improve animal performance (Alemayehu Mengistu *et al.*, 2017; Bizelew Gelayenew *et al.*, 2020). Among these constraints, mainly inadequate supply of feed and poor quality of feed are pioneer constraints in the country (Shapiro *et al.*, 2017; Abule Ebro *et al.*, 2022).

The country has various feed resources having different feed use shares, which include natural pasture (37%), crop residues (33 %), hay (14%), agro-industrial byproducts (5%), improved forages (1%) and non-conventional feeds (10%) (CSA, 2021). However, mainly the two large share feed resources (natural pasture and crop residues) are familiarized by low quantity and poor nutritional values; they do not provide sufficient nutrients for animals affecting livestock productivity (Shapiro *et al*., 2017; Sosena Fentahun *et al*., 2020; CSA, 2021). Besides this, the major limitations of natural pasture are low production of dry matter yield, crude protein and metabolizable energy contents which results in a critical shortage of animal feed (Ulfina Gelmesa *et al*., 2013; Endale Yadessa *et al.*, 2016). The adoption of crop residues as feed for livestock to improve productivity is low because of its poor quality. It is known that crop residues are low in protein and energy content, and high in fibre (Getnet Assefa *et al.,* 2022). To combat the livestock feed shortage in terms of quality and quantity, the introduction and cultivation of high-quality forages with high herbage yield and adaptability to biotic and abiotic stresses are recommended for the improvement of livestock production under smallholder farmers' conditions (Tessema Zewdu, 2005; Shapiro *et al.*, 2015). The entry of alternative, promisingly improved forages grown with the application of fertilizer is one of the forward strategies to alleviate the existing feed crisis in the country.

The fertilizer application is economically valuable by boosting forage production potentials in the livestock sector (Ashagre Abate, 2008).The application of fertilizer is to increase the productivity of forage biomass per small unit area through the efficient use of soil nutrients. It has its advantages in the productivity of forage, solving land shortages, yield stability, and soil fertility.The application of fertilizer rate is an extremely critical factor in achieving high yield and quality of feeds (Abou El-Magd *et al.*, 2005).

The most well-known potentials for high growth performance and biomass production in tropical regions are desho grass, brachiaria decumbens and Napier grass. Desho grass is native to tropical countries, including Ethiopia (Leta Gerba *et al.*, 2013; EPPO, 2014). In Ethiopia, Desho grass is a perennial plant, which was first identified in the Southern Nations Nationalities Peoples Regional State at Chencha in 1991 (Denbela Hidosa *et al.*, 2020). Farmers in many parts of the Ethiopian highlands adopted desho grass production because of its merits as year-round fodder animal feed (Leta Gerba *et al.*, 2013), and in soil and water conservation (Tekalegn Yirgu *et al.*, 2017). Desho grass planted for fodder in Northwestern highland of Ethiopia had a chemical composition values 28.98, 7.33, 73.58, 41.28, 5.24, 43.06 and 6.13 for dry matter, crude protein, neutral detergent fiber, acid detergent fiber, acid detergent lignin and Metabolozable energy, respectively (Bimrew Asmare *et al.*, 2017). There are many desho grass varieties, among those *Areka-DZF-590* is the best due to its higher survival rate, PH, DMY, DM, CP, and lower NDF and ADL content than other desho grass varieties (Solomon Mengistu *et al.*, 2017; Birmaduma Gadisa *et al.*, 2019; Teshale Jabessa *et al*., 2021). According to Teshale Jabessa *et al*. (2021), the highest DMY (30.53t/ha), PH (108.6cm), and survival rate (63.3%) were obtained from desho *Areka-DZF#590* compared to other desho grass varieties. The same author reported that the higher DM, CP, and less NDF and ADL content was recorded at the *Areka-DZF-590* variety than other desho grass varieties. Moreover, according to Birmaduma Gadisa *et al.* (2019), the higher PH (92.67cm) and LSR (0.71) were produced from *Areka-DZF*-590.

The other high-yielding potential improved forage to increase livestock productivity, which can be cultivated both in the dry and wet seasons of Ethiopia, is Napier grass (Feleke Assefa *et al*., 2015). Napier grass is a fast-growing perennial grass native to Sub-Saharan Africa that is widely grown across the tropical and sub-tropical regions of the world (Negasu Gamachu and Gizahu Wekgari, 2017). Napier grass has become an important forage for smallholder mixed crop-livestock farmers in the East African highlands changing to zero-grazing (Tessema Zewudu *et al.,* 2010). In addition, it possesses a high biomass yield per unit area, tolerates intermittent drought, and has high water use efficiency (Kabirizi *et al.,* 2015). It can withstand repeated cutting and will rapidly regenerate, producing palatable leafy shoots (Lowe *et al.,* 2003). Dry matter yields of Napier grass range from 2 to 85 DM t/ha depending on soil and environmental conditions (Muktar *et al*., 2022), while the concentration of nutrients, especially the crude protein content, could vary depending on the soil nitrogen levels (Kabirizi *et al.,* 2015). Among the Napier grass varieties, *Cenchrus purpureus*-16791 is the most well adapted and productive regarding the survival rate, regenerate and gave the highest dry matter yield, PH, tillering performance, CP yield, digestible yield and others, which is hopeful to fill the gap of poor quality and low quantity livestock feed supply (Habtie Arega *et al.*, 2020; Teshale Jabessa *et al.*, 2023). Many scholars recommended the Napier grass var-16791 for production and utilization in different areas of Ethiopia; at Holetta (Gezahagn Kebede *et al.*, 2016), at Nejo (Mamaru Tesfaye, 2018), in Banja district (Habtie Arega *et al.*, 2020), at North Shewa Zone (Firaol Legesse, 2023), in Lowland and highland Areas of Guji zone (Teshale Jabessa *et al.*, 2023).

The other most important improved grass is Brachiaria decumbens. Brachiaria decumbens is a rhizomatous, stoloniferous and vigorous perennial grass (Heuzé *et al.*, 2017).Brachiaria decumbens grass possesses many desirable characteristics, including high biomass yield per small unit area, tolerance to intermittent drought, and high water use efficiency, making it forage of choice (Diribi Mijena *et al.*, 2022). In addition, it protects soil from erosion and sustains its productivity (Mundia, 2021). According to Solomon Tiruneh *et al.* (2022), Brachiaria decumbens had 28.49cm, 109.71, 100.45, 13.35cm and 13.56 for PH, NTPP, NLPP, LL and DMY (t ha-1) and 89.0, 75.40, 13.60, 8.88, 62.55, 48.35, 9.97 and 1.2% for DM, OM, Ash, CP, NDF, ADF, ADL and CPY (t ha-1) in Western Dembia district, respectively.

Fertilizer application practices for forages in Ethiopia are not uniform in terms of application rates (Bimrew Asmare *et al.*, 2016). Therefore, there is a need to find the appropriate fertilizer rate that provides greater efficiency in profitability, dry matter production, and quality of Napier grass, desho, and Brachiaria decumbens varieties as livestock feeds. Due to this tangible reason, the organic (manure) and inorganic fertilizer (urea) are selected application practices on selected improved forages (Desho, Brachiaria decumbens and Napier grass) to evaluate the fertilizer application rates and grass varieties on morphological, forage yield and chemical composition of the forage grown under rainfed conditions. Due to this, one way of enhancing yield and quality of forage is through selecting the best grass varieties managing under different fertilizer application levels that should balance forage quality and quantity.

1.2. Statement of the problem

Inadequate quantity and quality of feed combined with high feed prices are the most important confronts for the livestock production sector. Low dry matter yield and poor nutritional values characterize the two major feed resources (Natural pasture and crop residues).These are the major available feed resources in the Bahir Dar Zuria District. The communal grazing lands in Bahir Dar Zuria District are overgrazed.In such cases, grasses were purchased from church and school compounds, and collected weeds from croplands were fed through a cut and carry system. As a result, animals could not get sufficient and balanced nutrients from natural pasture and crop residues due to high fiber and low protein content (Mekuanint Gashaw and Girma Defar, 2017). Therefore, to minimize such kinds of feed challenges, we should proceed to produce improved forages with fertilization for more than one year rather than depending on natural pasture and crop residue.

In response to these immense challenges, producing stable improved forage in the livestock sector is mandatory. For that reason, the application of fertilizer on improved forage over the years is important to increase the biomass and quality of feeds. Hence, Napier (*Cenchrus purpureus*)-16791, Desho (*Pennisetum glaucifolium*)-*Areka*-DZF-590 and *Brachiaria decumbens*-10871 are known for their higher plant height, biomass yield and nutritional values, and the application of fertilizer to enhance the forage yield and quality (Binyam Mihret *et al.*, 2018).

Therefore, those selected improved forage varieties with the application of fertilizer have the potential to increase the biomass and quality of forages and to ensure feed availability for year-round feeding. Reliance on long-term forage crops should ensure that animal feed is continuously available year-round. However, the application of fertilizer on the selected improved forage varieties and fertilizer application rate is an extremely critical issue to achieving high yield and quality of forages. Most of the livestock farmers in Ethiopia do not apply manure or chemical fertilizers on forage grasses. Even if the farmer applied fertilizer, there is a lack of knowledge on the optimum dosage of fertilizer application for improved grasses and the effect on quality and quantity of forage production have been a challenge for most livestock farmers. Even though, there is no comprehensive and adequately informative attempt or scientific evidence regarding the ideal level of fertilizer application rate for the highest herbage biomass and quality of grown forages, an appropriate fertilizer rate combination must be developed for the selected grass varieties. Due to the above profound problems, this research was designed.

1.3. Research Objectives

1.3.1. General objective

The study aimed to assess the impact of fertilizer application and variety on the morphological parameters, dry matter yield, and quality performance of specific grass species produced in the study region under rainfed conditions for two years

1.3.2. Specific objectives

- To evaluate the effect of fertilizer application and variety on the morphological parameters and dry matter yield of selected grass species in the study area
- To evaluate the effect of fertilizer application and variety on the nutritional quality of selected grass species in the study area
- To assess the economic feasibility of fertilizer application on selected grass varieties in the study area

1.4. Research Questions

- Do fertilizer applications and grass variety affect the morphological parameters, dry matter yields and nutrient composition of selected forage varieties?
- What is/are the fertilizer application and grass variety having the best morphological characteristics, dry matter yield and quality performance on selected forage varieties?
- Which fertilizer level is economically feasible for the selected forage grass varieties?

CHAPTER TWO: LITERATURE REVIEW

2.1. Major Livestock Feed Resources in Ethiopia

Livestock feed resources are classified as Green fodder, crop residue, improved forage feed, hay, industrial by-products, and non-conventional feeds (CSA, 2021). Green fodder is simply pasture grasses; crop residue includes harvested by-products (straw and chaff of cereals and pulses, etc.); improved forages are 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, noug cake, sunflower cake, etc.), bran and brewery residues.

Table 1: Coverage in proportion of livestock feed resources in Ethiopia

Feed resources	Percentage	Source
Natural pasture	37	
Crop residue	33	
Improved fodder or pasture	1	Central Statistical
Hay	14	Agency (CSA) (2021)
Agro-industrial by-products	5	
Non-conventional feeds	10	

2.1.1. Natural pasture

Natural grazing land is the land devoted to the production of home-grown forages (grasses, legumes, shrubs, forbs, and tree foliage) for harvest by grazing, cutting, or both (Peeters *et al*., 2014). According to CSA (2021) reported that the natural pastures are contributing a large share which is ahead of the others. However, because of continuous shifting to cropland, urbanization and overgrazing, overstockingcompletely year-round without any resting period leads to land degradation, which leads to low biomass yield, poor quality and seasonal fluctuation in feed availability, feed contribution and productivity has declined (Belay Duguma & Janssens, 2016; Abadi Nigus, 2017: Sosina Fentahun *et al*., 2020; CSA, 2021). For instance, a study conducted in the last decade to analyze land-use change in the last 27 years in Amhara Regional State revealed rapid shifting of grazing lands into arable land and 30.52% of grazing land has been converted to crop fields (Tadesse Amsalu & Solomon Addisu, 2014).

The availability and quality of natural pasture vary with altitude, rainfall distribution, cropping intensity, soil type and fertility (Malede Birhan and Takele Adugna, 2014). Natural pastures provide livestock feed during the rainy season from July to October in Bahir Dar Zuria district

(Sosina Fentahun *et al*., 2020). Study reports indicated that the dry matter yield of natural pastures is affected by forage species composition in the pastureland, rainfall distribution, fertilizer application, soil type, altitude, and season and management practices. The average herbage DM yield obtained from seasonally rested natural pastureis 4 t/ha, while continuously grazed pasture is 1 t/ha (Getnet Assefa, 2012). Similarly, Shiferaw Yalew *et al*. (2020) who conducted in the Mecha district of west Gojjam, showed that the highest yield of natural pasture was recorded from urea fertilization (6.33), followed by a mix of compost and urea (5.17) while the lowest was recorded at unfertilized pasture (3.2 t/ha). Moreover,the average dry matter yield of natural pasture in the Amhara Region was 4.4 t/ha with a low nutritive value of crude protein and invitro dry mater digestibility of 5.5 and 42-52 %, respectively (CASCAPE, 2015).

Table 2: Chemical compositions (%) of natural pasture in the central highland of Ethiopia

Treatments	DM	Ash	CP	NDF	ADF	ADL	IVDMD	Sources
100kg N+150kg DAP/ha	93.4	7.51	7.21	66.5	40.8	5.8	47.9	Fekadu Nemera *et al.* *(*2017)
7.5t/ha of cattle manure	91.3	9.19	8.65	64.5	39.65	7.46	55.4	
3t/ha of Wood ash	91.7	11.7	7.68	65.0	43.1	6.75	38.91	
2t/ha of Lime	92.3	9.79	8.28	65.1	40.8	7.66	50.0	
Control	91.5	9.62	5.65	66.3	43.3	7.56	46.9	
With out fertilizer	89.60	13.21	5.50	67.47	40.31	5.62	49.48	Ashagri *et al.*(2023)

2.1.2. Crop residues

Crop residues represent an important fibrous by-products feed resource that results from the cultivation of cereals, pulses, oil plants and others in the dry season in different parts of Ethiopia (Girma Chalchissa *et al.,* 2014; Alemayehu Mengistu *et al.*, 2017). After the separation of grain, cattle can be directly grazed aftermaths or residues in the form of dried fodder use, especially in the dry season when pasture from grazing area is not able to provide reasonable quantity. According to CSA (2021) reported that in the country crop residues arethe second livestock feed resource contributing about 33%, which is next to natural pasture. Similarly, crop residue was the second major feed resource next to natural pasture in the Bahir Dar Zuria district (Bimrew Asmare and Fentahun Meheret, 2018; Sosina Fentahun *et al*., 2020). The dry matter yield and nutritive values of crop residue are mostly affected by crop species and management practices. According to Mekuanint Gashaw and Girma Defar (2017) in the Bale zone, the annual dry matter yield of wheat, barley, teff straw and maize stover was 7.76, 1.82, 0.6 and 0.16 tons/ha/household, respectively. The potential and abundance of crop residues that could be used for livestock feeding in the country in most cases, drown from grain yield, using a multiplier is 13.7 million tons from cereals having digestibility level of about 40.7-54.1% with CP value ranging from 3.1-6.7% (Malede Birhan and Takele Adugna, 2014). Crop residues are generally characterized by low digestibility (<500 DOMg/kgDM), Metabolizable energy (<7.5 MJ/kg DM), crude protein (<60 g/kg DM) and low content of available minerals and vitamins, which is insufficient to provide nutrients beyond maintenance requirements and in most cases even severe weight lose occurs (McDonald *et al.*, 2002). With an increase in human population, more land is used for crop production and only fragments of marginal lands will be left for feed production in Ethiopia. Consequently, livestock feed largely depends on crop residues particularly on cereal straws as their basal diet (Dawit Assefa *et al*., 2013; Kasa Biratu *et al.*, 2022). The farmers were not applying either chemical or mechanical treatment methods to improve the palatability and nutritional quality of crop residues in the Bahir Dar Zuria district (Zewdie Wondatir *et al.*, 2015; Sosina Fentahun *et al*., 2020).

Table 3: Average nutritive values (%) of crop residues available in Ethiopia

Crop residues	DM	OM	ADF	NDF	ADL	CP	IVDMD	ME (Mcal/kg)
Finger millet Stover	89.7	89.9	40.9	69.5	4.0	4.1	55.5	2.0
Maize Stover	91.1	92.5	47.4	70.7	5.6	4.6	58.0	2.1
Sorghum Stover	91.2	88.6	39.5	73.6	6.1	4.7	59.5	2.0
Teff straw	92.2	92.5	44.4	81.2	5.2	3.6	-	-
Wheat straw	91.4	90.3	51.9	81.1	6.5	6.1	-	-
Barley straw	91.1	92.4	48.3	73.9	6.2	2.4	53.5	2.0
Oats straw	91.9	91.3	36.5	58.3	4.2	7.7	62.9	2.3
Faba bean straw	92.7	90.0	56.5	67.4	11.5	-	-	-
Chickpea straw	91.2	90.4	42.3	55.9	9.7	5.4	-	-
pea straw	90.8	95.6	11.3	58.1	0.9	-	-	-
Lentil straw	91.7	92.0	44.1	64.4	9.3	8.2	55.0	0.2
Linseed straw	92.5	93.3	52.6	64.6	14.0	5.2	48.8	1.8

Source: Ethiopian Feed Database available online (http://www.vslp.org/ETHFeed/default.asp)

2.1.3. Agro-industrial by-products

The major agro-industrial products commonly used in Ethiopia are obtained from different agro-industries such as flour milling industries (wheat bran, wheat middling,wheat short, and rice bran), edible oil extracting plants (peanut cake, Noug cake, cottonseed cake, sunflower cake, linseed cake, sesame cake, etc), breweries (wet or dried) and sugar factories (molasses) (Hussen Abduku, 2020; CSA, 2021). According to FAO (2019) reported that the annual total yield in Ethiopia on the availability and utilization of industrial by-products in DM base was 2.08, 2.02, 2.70, 6.35, 14.23, 1.71,4.164 million tons of cereal milling byproducts, oil milling by-products, pulse milling by-products, brewery industry by-products, horticultural/fruit and vegetable by-products, molasses sugar factory by-products, slaughterhouse (abattoir) and fishery by-products, respectively were produced. The current status of by-product utilization indicated that livestock producers were efficiently used as livestock feed except for slaughter house and fishery by-products; due to backyard slaughter.

Similarly, at the national level by-product utilization, the majority of livestock producer farmers in the Bahir Dar Zuria district were provided agro-industrial products like wheat bran and noug seed cake as supplemental feeds for their cattle (Bimrew Asmare and Fentahun Meheret, 2018; Sosina Fentahun *et al*., 2020). Agro-industrial by-products have a high quality in livestock feeding mainlyin urban and peri-urban livestock production system, as well as in situations where the productive potential of the animals is relatively high and requires a high nutrient supply (Shimelis Mengistu, 2018; Hussen Abduku, 2020). The fast-growing trend of agro-industries in different parts of the country to satisfy the growing demand for the edible main agricultural products is expected to create a big opportunity for the growth of agro-industrial by-products production, which can be used in livestock feeding (Koul *et al*., 2022). Most smallholder farmers could attribute this to the unaffordable price of the product, limited availability of the resources, and lack of awareness of the feeding values of these feed resources.

Table 4: Average nutritive values (%) of Agro-industrial by-products available in Ethiopia

Agro-industrial by-products	DM	OM	NDF	ADF	ADL	CP	$ME_{(Mcal/kg)}$
Wheat bran	89.3	95.0	46.4	13.6	3.3	16.8	-
Wheat middling	89.7	94.9	42.8	23.5	4.5	16.3	2.2

Noug cake	92.3	89.7	37.6	31.5	12.4	31.4	2.1
Cotton seedcake	92	92.2	38.4	20.7	6.3	41	2.5
Groundnut cake	92.7	95	16.4	8.7	1.7	55.5	3
Linseed cake	91.5	93.3	31.2	19.2	7.3	29.6	2.6
Sunflower cake	91.8	94	35.5	31	9.7	25.9	2.2
Sesame cake	91.4	88.6	32.7	27.8	4.9	25.5	2.6

Source: Firew Tegegne and Getnet Assefa (2010)

2.1.4. Non-conventional feeds

Non-conventional feed resources are the feeds that haven't been utilized traditionally for feeding cattle and are not used commonly in the production of livestock feeds (Santosh Onte *et al.*, 2021). Different non-conventional feed sources are available in Ethiopia out of which Sisal waste is produced in the southern part of the country. A non-conventional feed includes vegetable refusals, sugarcane leaves, enset leaves, fish offal, kitchen waste and coffee residues used as animal feeds. However, the categories of non-conventional feeds vary according to the feeding habits of the society (Endale Yadessa *et al.*, 2016). Thus, non-conventional feeds could partly fill the gap in the feed supply and contribute to self-sufficiency in nutrients from locally available feed sources (Santosh Onte *et al.*, 2021). However, non-conventional feeds are not available at large and make a limited contribution to livestock feeding and due to their low protein and high fiber content, small-holder farmers frequently use by-products from nearby breweries and distilleries as a source of non-conventional feeds (Ajebu Nurfeta, 2010;Yosef Mekasha *et al*., 2010).

Table 5: Chemical compositions (%) of non-conventional feeds

Non-conventional feeds	DM	Ash	OM	NDF	ADF	ADL	CP	$ME_{(Mcal/kg)}$
Coffee pulp	90.33	9.04	90.96	55.45	48.58	6.65	11.13	7.36
Bean hull	90.87	3.06	96.94	72.71	61.42	8.19	6.54	8.39
Pea hull	91.02	3.62	96.38	58.57	40.82	7.45	16.38	9.55

Source: - Zewdie Wondatir *et al.* (2010)

2.1.5. Improved forages

Ethiopia has diverse and very favourable climates for the development of forages. Historically, some forage species were imported in, but native species were also and still are present in the country. The introduction of improved forages in Ethiopia was formally started with the establishment of the Institute of Agricultural Research (IAR) in the mid-1960s (Alemayehu Mengistu and Getnet Asefa, 2012). Significant successes have been registered in identifying various adaptable and high-yielding fodder species belonging to grasses, herbaceous legumes and browse trees that have been recommended for use in the various agro-ecological zones of the country (Getnet Assefa *et al.,* 2016; Aemiro Ashagrie *et al.,* 2023). The most common cultivated improved forages include Napier grass (*Cenchrus purpureum*), Desho grass (*Pennisetum glaucifolium*), Rhodes grass (*Chloris gayana*), Guinea grass (*Panicum maximum*), oats (*Avena sativa*), Buffel grass (*Cenchrus ciliaris*), Phalaris grass (*Phalaris aquatica L*.) and others (Adugna Tolera *et al.,* 2019; Aranguiz & Creemers, 2019). Research results have indicated that improved forage species have higher herbage yield and nutritional quality than natural pasture and crop residues; native grasses in Ethiopia are of low quality (a CP content between 3 and 5 %) and cannot support good daily body weight gain, while improved forages had between 8 and 18% on a DM basis (Dey *et al.,* 2021). Besides its nutritional values, the length of the productive season of cultivated forage is longer than native pastures, which provides an opportunity for dairy and fattening production. Generally, improved forage production could provide useful nutrients, especially in rural areas where the availability and accessibility of agro-industrial by-products are problems.

2.2. Challenges and opportunities for improved forage production in Ethiopia

Improved forages are very important to improve soil fertility through their soil and water conservation activities and the natural rehabilitation of degraded areas, reduce pressure on natural pasture, and improve carbon sequestration to mitigate climate change, support systems substantially, and enhance natural assets and system reliance (ILRI, 2009). Despite the introduction of new forages, Ethiopia has poor management and utilization of forage resources (Solomon Tefera *et al.,* 2019). Hence, the contribution of improved forage to the total feed resource is still 1% (CSA, 2021). Generally, to improve forage production, selection of forage species, forage development strategies, preparation and servicing of extension practices, and formulation of forage seed production systems are the main consideration criteria (Getachew Assefa, 2021).

2.2.1. Opportunities

The major opportunities to produce improved forage in the country are high demand for animal products, suitable agroecology for the development of improved forage, forage development strategies, the availability of water and the presence of a sizable livestock population (Alemayehu Mengistu *et al.,* 2017). As a success of forage production in Ethiopia, farmers raised the improved forage production used for their dairy and fattening animals, increased their income, increased animal products, reduced their feed costs due to compensating concentrate cost, and enhanced the feed availability year-round (Getachew Assefa, 2021).

2.2.2. Challenges

Many researchers conducted various studies in different parts of the country with improved forage adaptation, evaluation, multiplication and utilization, while its contribution as a livestock feed resource-awaitingis as low as indicated at 1% due to several factors (CSA, 2021). Land shortage, poor extension service, lack of capital to purchase improved forage seed, high cost of planting materials, shortage of forage seed and planting materials; little awareness or technical know-how, poor coordination among stakeholders, how to cultivate the plants and where to find the planting materials were the most important constraints for improved forage cultivation and adoption in the Ethiopian farming system at smallholder farmers (Melese Workye *et al*., 2018; Lidetu Gebreselassie, 2019; Getachew Assefa, 2021).

Similarly, shortage of land, lack of awareness, seasonal availability of fodder, shortage of availability of forage seeds and farmers' emphasison food crops were the major problems for improved forage cultivation in the Bahir Dar Zuria district (the district in which this research was carried out) (Melkamu Bezabih *et al.,* 2020; Sosena Fentahun *et al.,* 2020). In the Farta district, which the results indicated that the free grazing production system was the most important factor limiting improved forage cultivation, followed by a lack of appropriate forage technologies, lack of awareness and a land shortage (Solomon Tefera *et al.,* 2019). In the East Gojjam zone, adoption of production and utilization of improved forage for animal feed is low due to land shortages (60.4%), lack of awareness (24%), lack of seed and planting materials (14.6%), fear of farmers birds set on forages (3.1%) and lack of capital to purchase seeds (3.1%) (Alemu Gashe, 2022).

2.3. Overviews of selected Experimental improved grass production

The improved grasses have better productivity, palatability and nutrient characteristics that make them desirable for inclusion in improved forage production programs (Alemayehu Mengistu *et al.,* 2017). This information provides a critical issue for smallholder dairy farmers and creates an opportunity to use these materials as a useful starting point for improved forage programs because of their adaptability and proven forage value. Among several improved forage species, some of them are listed below.

2.3.1. Desho grass (*Pennisetum glaucifolium*)

Desho grass is an indigenous tropical multipurpose herbaceous perennial forage species of Ethiopia with different names in different countries of Africa: As annual kyasuwa grass in Nigeria, Barrein in Mauritius and Desho in Ethiopia (EPPO, 2014). Desho grass can grow in an altitude range of 1500–2800 m.a.s.l. and performs in the range of 825-1146mm annual rainfall and 11–30^{0}c air temperature (Leta Gerba *et al.,* 2013; EPPO, 2014). It could attain the first harvest between 3 and 4 months after planting; the many-branched leafy leaves are15-25cm long and grow up to 1m and more in height (Leta Gerba *et al*., 2013) with high biomass productivity based on the moisture and condition of soil fertility (Abebe Shiferaw *et al*., 2011). Moreover, it can be used through a cut-and-carry system with more frequent harvesting in the presence of little moisture. It is used as fodder and is considered a very palatable grass species (Ecocrop, 2010). In addition, it is utilized for soil and water conservation practices, is considered the king of grass (Leta Gerba *et al*., 2013) and is used as a cash source in southern Ethiopia (Shimelis Mengistu, 2018). It is one of the major feeds for livestock with high DMY in midland and highland (Bimrew Asmare *et al*., 2017). Under good management practices, the grass provides a higher biomass yield of about 30-109t/ha and it respond well to fertilizer application (Leta Gerba *et al*., 2013). It is a highly popular, drought-tolerant species once established. However, desho grass is susceptible to water logging and frost (Ecocrop, 2010; FAO, 2010).

2.3.2. Napier grass (*Pennisetum purpureum Schumach*)

Napier grass is originated in sub-Saharan tropical Africa (Clayton *et al.,* 2013), and it grows and is best adapted in tropical and sub-tropical regions to high-rainfall areas (1,480-1,620 mm/year); altitude ranges up to 2,000 meters above sea level; optimum temperature 25-40^{o}c. It is the forage of choice worldwide due to its drought tolerance, adaptability to a wide range of soil conditions, and high photosynthetic and water-use efficiency (Negawo *et al.,* 2017). Napier grass is propagated vegetatively by using stem cuttings and root splitting, which usually vary across agroecologies (Getnet Assefa and Gezahagn Kebede, 2012; Mergia Abera *et al.,* 2022). Stem cuttings buried in 15cm furrows with 2 nodes in the soil and one exposed, but root splitting gives better performance than stem cutting and responds well to fertilizers applied after every cut (Mergia Abera *et al.,* 2022). Harvesting can be doneat a range of 45 to 90-day intervals, depending on location, genetic variation and management (FAO, 2015).The same author indicated it is well known for its high biomass-yielding capability and good morphological performance. It is a fast-growing habit and is mainly used in cut-and-carry systems. Moreover, Napier grass is a robust perennial with a vigorous root system, sometimes stoloniferous with a creeping rhizome, culms 180–360 cm high and deep roots that can help uptake moisture and minerals (Gezahegn Kebede *et al*., 2020).

In addition, Napier grass has good nutritional values.According to Deribe Gemiyo *et al.* (2017) at Areka, Southern Ethiopia on Napier grass accessions the ADL content was found <10%. Tessema Zewdu (2005), 3.46, 4.61 and 3.34% of ADL were recorded for Napier grass accessions of 14983, 149884 and Local, respectively.It is important to bear in mind that environmental factors like climate, soil fertility and management practices have a very profound influence on the nutritional quality and digestibility of Napier grass (Gezahagn Kebede *et al.,* 2017).

2.3.3. Brachiaria decumbens grass

Brachiaria grass is one of the tropical African origin forage grass (Ghimire *et al.,* 2019), improved in America through agronomic selection and breeding (Miles *et al.,* 2004) and demonstrated to be highly productive, nutritive and socially acceptable in Asia and Africa for different livestock production systems (Pizarro *et al.,* 2013; Vendramini *et al.,* 2014). It is one of the preferred improved grasses for ruminant grazing due to its aggressive growth habit of warm-season perennial grasses and it can be used for grazing or harvested and conserved for feeding when needed (Vendramini *et al*., 2014). In addition, it can grow over a wide range of soil types, including infertile acid soils with low pH (<3.5) and climates ranging from tropical to sub-tropical eco-climatic zones (Low, 2015; Heuze *et al.,* 2017). Moreover, it possesses large root systems, sequesters carbon into soils and receives more light exposure than some other plants

(Ghimire *et al*., 2019). Brachiaria decumbens is capable of producing 15–27metric tonsDM/ha/year (Abdullah, 2015).

2.4. Organic and inorganic fertilizer application

Fertilizing is one technique to boost the production of forages. The application of fertilizer is the process of giving plants the nutrients they require to thrive. There are two categories of fertilizers: organic fertilizers and inorganic fertilizers. Organic fertilizers are an important source of nitrogen for forage production in the smallholder sector. It helps farmers reduce their inputs of commercial fertilizer, thereby increasing their profit margin of the farmer. Nutrients contained in organic manures are released more slowly and are stored for a longer time in the soil, thereby ensuring a long residual effect (Sharma and Mittra, 1991). Thus, supporting better root development leads to increases dry matter yield of grass significantly without affecting the soil condition (Abou El-Magd *et al.,* 2005). Improvements in environmental conditions as well as public health are also important reasons for advocating increased use of organic fertilizer. Generally, additions of organic manures end in increased soil organic matter content and lead to increased water holding capacity, porosity, infiltration capacity, hydraulic conductivity, water-stable aggregation, decreased bulk density and surface crusting (Asmare Melese *et al.*, 2015). Whereas inorganic fertilizers can be used to replenish soil nutrients and increase forage yields up to 20 DMt/ha when fertilized with N-rich inorganic fertilizers (Skerman and Riveros, 1990), they are too costly for most smallholder farmers to afford to purchase them (Sanchez *et al.*, 1997). Inorganic fertilizers do not last longer in the soil and require frequent re-application, in contrast to organic manures like cow manure, which are known to last longer in the soil whilst allowing pastures to be re-grown several times without immediate replenishment (Lund and Doss, 1980). Generally, both organic and inorganic fertilizers can be applied to the soil to add nutrients and increase the yields of grasses as compared to unfertilized forages.

2.5. Effect of fertilizer application, production years and varieties on morphological characteristics and dry matter yield of grasses

2.5.1. Plant height (PH)

Plant height is the distance between the upper boundary of the main photosynthetic tissues (excluding inflorescences) on a plant and the ground level. It is an important factor contributing to yield and is an important component that helps determine the growth attained during the growing period, and it can be different among different species within the same management systems (Gebremedhin Beyene *et al.*, 2015).

The previous reports indicated that the PH was affected by the level and type of fertilizer application. According to a report by Biniyam Mihret *et al. (*2018), the PH of desho grass significantly affected by the types and levels of fertilizer, of which the highest PH was recorded from NPS fertilizer (55.23cm), followed by manure (52.22cm) and without fertilizer (42.01cm) at Injebera district in northwestern Ethiopia. Similarly, Mergia Abera *et al*. (2021) reported that as the levels of fertilizer increased from 0 to 41 and 73 kg N/ha, the mean PH of desho grass also increased from 21.25 to 22.08 and 23.92cm, respectively.Nitrogen fertilizer application on grasses increases the nitrogen content in the soil, which increase the plant height. Cattle manure application increases microbiological activity in the soil, which promotes plant growth (Campos *et al*., 2017).

On the other hand, the grass species could affect the height of the plant. According to Tobiyaw Tsegaye *et al. (*2021*),* in the west Gojjam zone of Ethiopia, the highest mean PH was recorded from Napier grass(101.99, 107.5 and 51.9cm) followed by Para (43.15,60.4 and 75cm) and Desho grass (28.95,39.2 and45.3cm) at 60, 90 and 120 days of cutting interval, respectively. Similarly, Susan *et al*. (2016) reported that the highest mean PH was recorded at Napier grass (103.8cm) and the lowest at Llanero (6cm) at week 16 in the Kenya dry lands.This indicates that PH can be different among different grass species with the same management system.

Regarding production years, the grass physiology and consequently, sward growth and structure are highly affected by production years. According to the findings of Mulisa Faji *et al.* (2021), the mean PH of desho grass was 89.43, 91.67, 105.30, 100.0, 95.47 and 65.57cm recorded from 2014 to 2019 experimental years, respectively, in Holetta Agricultural Research Center, Ethiopia. Similarly, Misganew Walie *et al.* (2022) reported that the mean PH of desho and Napier grasses was higher in 2019 (75.3 and 77.1 cm) than in 2018 (55.5 and 74.8 cm) production years in the Guder and Aba Gerima watersheds, Ethiopia, respectively.This shows that production years affected the plant height.

2.5.2. Number of tillers per plant (NTPP)

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, stolons, or above ground nodes (aerial tillers). Tillers are very important to understanding the growth and re-growth of grass (FIS, 2018).The NTPP is an important parameter to determine forage productivity and it has to be considered in the forage evaluation program; it increases the chances of survival and the amount of available forage production (Argel *et al*., 2007).

The previous reports indicated that NTPP was affected by the level and type of fertilizer. According to Worku Bekuma *et al*. (2017), there was a significant difference ($P<0.05$) in the NTPPof desho grass as the fertilizer rate increased from 100 to 250 kgN/ha, tillers per plant also increased from 43.6 to 79.6, respectively. Similarly, Biniyame Mihret *et al.* (2018) reported that the NTPP of desho grass was significantly affected by the type and level of fertilizer, of which the highest NTPP was recorded from NPS fertilizer (61), followed by manure (50) and without fertilizer application (37). Moreover, Awoke Kefyalew *et al.* (2021) found that the NTPP was also affected ($P<0.001$) by fertilizer application, in which the highest (78.39) were counted at a fertilizer level of 50 kg U/ha+6,000 kg C/ha, while the lowest (45.05) were counted from no fertilizer under irrigation conditions in Dehana district, waghemra zone, Ethiopia. Merga Abera *et al.* (2021) reported that the mean NTPP of desho grass was 47.34, 50.92 and 55.72 recorded from 0, 41 and 73 kg N/ha, respectively. Nitrogen triggers the activation of dormant buds and enhances vegetation sward filling through the highest rate of tiller replacement, which supports a higher proportion of very active, healthier young tillers for each plant, which results in higher tiller density (Mushtaque *et al*., 2010). This indicates that the application of different levels and types of fertilizers is a critical factor for NTPP.

A different study report on the number of tillers per plant was affected by grass species. According to Misganew Walie *et al.* (2022), the mean NTPP of desho grass (96.9) was lower than Napier grass (97.3) in the Aba Gerima, but desho grass (35.3) was higher than Napier grass (30.7) in the Guder watershed. Similarly,Tobiyaw Tsegaye *et al. (*2021) the research done in the West Gojjam zone of Ethiopia, the highest mean NTPP was recorded at desho grass (149, 181 and 236), followed by Para grass (148.8, 153.2 and 183) and Napier grass (40.48, 43.7and 45.88) at 60, 90 and 120 days of harvesting age, respectively. This indicates that the grass varieties under the same management practices and environmental conditions affected the NTPP.

On the other hand, the NTPP was affected by the production years. Misganew Walie *et al.* (2022) reported that the NTPP of desho and Napier grasses was higher in 2019 (99.6 and 95.9) than in 2018 (28.4 and 36.3) in the Guder and Aba Gerima watersheds, Ethiopia, respectively. There was a significant effect in the second year, but there was no significant effect on NTPP during the establishment year that determined the density of Napier grass (Tessema Zewdu, 2008). This shows that production years affected the NTPP.

2.5.3. Number and length of leaves per plant (N/LLPP)

Leaf length is a key factor determining the vegetative yield and quality of forage grasses, which plays an essential role in shaping the physical structure of the canopy and consequently in competition for light within the plant. One of the major adaptive responses to light competition in plants is an increase in plant height, *i.e*., leaf length, during the vegetative period in grasses (Barre *et al*., 2015).NLPP is an important parameter determining the dry matter yield and quality of the forage (Rodriguez *et al.*, 2014).

The NLPP and LLPP were affected by the type and level of fertilizer. According to Biniyame Mihret *et al.* (2018), the NLPP and LLPP of desho grass were significantly affected by the type and level of fertilizer in northwestern Ethiopia. The mean NLPP was highly decreased from 530 to 388 and 307 for NPS, manure and without fertilizer, respectively, while the mean leaf length was NPS (30.48 cm), manure (27.37 cm) and without fertilizer (19.87 cm). Similarly, Tessema Tesfaye *et al.* (2021) reported that the mean NLPP and LLPP of Napier grass varieties were affected by the level of fertilizer.The mean LLPP was 70, 74, 74.6 and 72.1cm, while the NLPP was 9.9, 10.6, 10.5 and 10.7 obtained from 0, 12.5, 25 and 50 kg NPS/ha respectively. The plant leaf expansion from fertilized grass was higher in length as compared to unfertilized grass (Mushtaque *et al*., 2010). There were increasing trends in the number of leaves and number of tillers with an increasing rate of fertilizer (Priyadarshani *et al.*, 2013).Therefore, fertilizer application at different levels and types has a critical effect on the NLPP and LLPP under the same management practices and environmental conditions.

On the other hand, the grass varieties affected the NLPP and LLPP.According to Tessema Tesfaye *et al.* (2021),on the Napier grass varieties in southern Ethiopia, the highest NLPP was recorded at ILRI-16815 (11.8), followed by ILRI-16902 (10.9), ILRI-15743 (10.1) and ILRI-16913 (8.8). While the longest LLPP was measured at ILRI-16815 (91.9cm), followed by ILRI-15743 (82.0cm), ILRI-16902 (61.5cm) and ILRI-16913 (55.4cm). Similarly, Tobiyaw Tsegaye *et al. (*2021) reported that the highest mean NLPP was recorded from Para grass (1336, 1563.7 and

2366.7), followed by desho grass (894.8, 1199.4 and 1588.4) and Napier grass (267.5, 325 and 414.88) at 60, 90 and 120 days harvesing age in the west Gojjam zone of Ethiopia, respectively. Moreover, according to a report by Misganew Walie *et al.* (2022), the LLPP of Napier grass (70.7cm) was significantly higher than desho grass (24.5cm) at Guder watershed.

The production years also affected the NLPP and LLPP. Misganew Walie *et al.* (2022) reported that the mean LLPP of desho and Napier grass was 2019 (51.9cm) higher than in 2018(43.2cm) in the Guder watershed of Ethiopia. Similarly, Hailegabriel Ajema *et al*. (2022) in the central highlands of Ethiopia reported that the NLPP and LLPP of desho grass were affected by production years.The highest NLPP of desho grass was recorded in 2021 (7.50) than 2020 (5.79), and the longer LLPP was recorded in 2020 (41.87cm) than in 2021(31.54cm).

2.5.4. Leaf to stem ratio (LSR)

Leaf to stem ratio is an important factor for grass evaluation, and the higher LSR are favoured in animal nutrition since it is an important factor affecting diet selection, quality and intake of forage (Garay *et al.*, 2017). Estimates of LSRs are commonly based on a labour-intensive process of hand separating of leaf and stem fractions (Smart *et al*., 2004). Reduced LSR is a major cause of the decline in forage quality with maturity, and also the loss in quality that occurs under adverse hay curing conditions. The leaf fraction has significant implications for the nutritive quality of the forage, as leaves contain higher levels of nutrients and less fiber than stems (Denbela Hidosa *et al*., 2015).

The types and levels of fertilizer affected the LSR. According to Mergia Abera *et al*. (2021) research conducted in southern Ethiopia, the LSR of desho grass was 0.7, 0.65 and 0.65 recorded at 0, 41 and 73kg N/ha, respectively. Hussen Ebrahim *et al.* (2020) in Mersa, Ethiopia reported that the LSR of Napier grass was significantly ($P<0.005$) affected by N-fertilizer application.The LSR of 0.97, 1.1, 1.0 and 0.9 was obtained from 0, 69, 115 and 161 kgN/ha at 7.5cm cutting height, respectively. Similarly, Tessema Tesfaye *et al*. (2021) reported that the mean LSR of Napier grass of 1.2, 1.3, 1.1 and 1.0 were recorded at 0, 12.5, 25 and 50 kg NPS/ha, respectively.

On the other hand, variations in LSR were observed among different grass species. According to Tessema Tesfaye *et al*. (2021) on Napier grass varieties, the highest mean LSR was recorded at ILRI-16902 (1.4), followed by ILRI-15743 (1.2), ILRI-16815 (1.1) and lowest was at ILRI-

16913 (0.9). Similarly,Tamrat Dinkale *et al.* (2021) who conducted Napier grass varieties in West Hararghe Zone, Oromia Region, Ethiopia reported that the mean LSR was recorded at ILRI-16800 (1.00), followed by Local (0.96), ILRI-16798(0.94), ILRI-16801 (0.88) and the lowest was ILRI-16840 (0.86). Misganaw Walie*et al.* (2022) reported that the highest mean LSR was recorded at Napier grass (2.3), followed by desho grass (1.9).

The production years also affected the LSR. According to Misganew Walie *et al.* (2022), the mean LSR of desho and Napier grasses in 2019 (2.2) was higher than in 2018 (2.0) production years in the Guder watershed of Ethiopia. Similarly, Hailegabriel Ajema *et al*. (2022) who conducted desho grass in the central highlands of Ethiopia reported that the LSR was affected by production years, which the highest LSR recorded in 2021 (0.94) compared to 2020 (0.48). Moreover, Denbela Hidosa *et al*. (2020) in South Omo Zone, South Western Ethiopia, reported that the highest mean LSR of desho grass was recorded in 2017 (1.11) than in 2018 (1.04).

2.5.5. Dry matter yield (DMY) (t/ha)

Dry matter yield is the most important parameter for livestock feeds without water.Forages, which have the highest DMYs,can supply the highest amount of forage to livestock.It is used to measure stocking rate and is an essential element of effective grazing management (Adane Kitaba and Berhan Tamir, 2007).

Various research reports indicated that different levels and types of fertilizer application scored different DMYs under the same management practices. According to Awoke Kefyalew *et al.*(2021), fertilizer application significantly ($P<0.001$) affected the DMY, which the highest DMY (5.54 t/ha) recorded at 50kg N+6,000 compost/ha, whereas the least (2.33t/ha) were obtained without fertilizer under irrigation in Dehana District, Waghemra Zone, Ethiopia. Similarly, Biniyame Mihret *et al.* (2018) who reported that the DMY of desho grass was significantly affected by fertilizer type and level. The highest mean DMY was recorded at NPS (24.08), followed by manure (14.05), while the lowest was without fertilizer (8.55). In addition, Worku Bekuma *et al*. (2017) indicated that there was a significant difference ($P<0.05$) in DMY of desho grass increased (8.32, 9.09, 12.73 and 13.6 t/ha) as the fertilizer level increased from 100 to 150 to 200 and 250 kgN/ha. The effectiveness of fertilizer application on forage grasses is strongly influenced by fertilizer levels, sources, times and methods of application (Malhi *et al.*, 2004). Nitrogen fertilizer at doses of 200 to 600 kg/ha tended to increase the DMYof Napier grass by 30 to 50% (Singh *et al*., 2013).

The variations among different grass species affected the DMY. According toTessema Tesfaye *et al*. (2021) on Napier grass varieties, the highest mean DMYwas recorded at ILRI-16815 (12.7 t/ha), followed by ILRI-15743 (9.1 t/ha), ILRI-16902 (4.8 t/ha) and ILRI-16913 (3.9 t/ha). Similarly, Aman Getiso and Diribi Mijena (2021) reported that the highest mean DMY (t/ha) of Napier grass varieties was recorded at ILRI-14983 (16.89), followed by ILRI-16788 (14.64), ILRI-15743 (14.20), ILRI-14984 (13.16), ILRI-16808 (11.74) and ILRI-16819 (9.61 t/ha) under rain fed conditions. In addition, Misganaw Walie *et al.* (2022) reported that the higher DMY (t/ha) was recorded at desho grass (6.0 t/ha) than Napier grass (5.6 t/ha).

There was a significant variation between production years affected the DMY. According to Misganew Walie *et al.* (2022), the DMY increased by 39.7% in the second year compared to the first year at Aba Gerima watershed in Ethiopia. Mulisa Faji *et al.* (2021) reported that the mean DMY of desho grass was 13.14, 33.41, 36.55, 34.48, 13.54 and 15.69 t/ha recorded in 2014, 2015, 2016, 2017, 2018 and 2019, respectively. In addition, Denbela Hidosa *et al.* (2020) who conducted on desho grass varieties in South Omo Zone, South Western Ethiopia reported that the higher mean DMY was recorded in 2018 (24.44 t/ha) than in 2017 (14.74 t/ha).

Table 6: Morphological characteristics and dry matter yieldof improved forages

Forage species	$PH_{(cm)}$	$NTPP_{(count)}$	$LLPP_{(cm)}$	$LWPP_{(cm)}$	LSR	$DMY_{(t/ha)}$	Sources
Brachiaria decumbens	72.57	-	-	-	-	14.61	Mulisa Fija *et al*.(2021)
Brachiaria decumbens	26.7	74	-	-	-	-	Susan *et al.(* 2016)
Napier grass	251.9	18.99	-	-	0.76	16.30	Diribi Mijena and Aman Getiso(2023)
Napier grass	101.1	35.3	73.9	2.8	2.3	9.2	Misganaw Walie
Desho grass	50.7	96.9	29.1	1.5	1.6	6.1	*et al.* (2023)
Desho *Areka DZF- 590*	108.6	134.2	44.7	-	0.38	24.57	Teshale Jabessa *et al.(*2021)
Desho grass	42.01	37	19.87	-	-	8.55	Bineyam Mihret *et al.* (2018)

PH= Plant height, NTPP= Number of tillers per plant, LSR= Leaf to stem ratio, NLPP=Number of leaves per plant, LLP= Length of leaves per plant

2.6. Effect of fertilizer application, grass varieties and production years on Nutritive Values

Feed composition is the chemical constituents making up a feedstuff. It involves profiling the nutrient composition and density of the feed material (Kasale, 2013). Determining the nutritional value of forages is important in livestock nutrition because effective livestock production is related to the amount of nutrients in the forage (Fazel Amiri and Abdul Shariff, 2012).

2.6.1. Dry matter content (DM)

The dry matter content of forages is the proportion of total components such as proteins, fibers, ash, water-soluble carbohydrates, lipids, etc. remaining after the water has been removed,and the moisture content reflects the amount of water present in the feed ingredient. Knowing the moisture content of a feed ingredient is important because the moisture content affects the weight of the feed but does not provide nutrient value to the animal. Dry matter content is important because all animal requirements are made on a dry matter basis, and the moisture content will give clues as to how forage will be preserved when stored by baling or ensiling (Schroeder, 2012).

According to the report of Awoke Kefyalew *et al.* (2020), the type and level of fertilizer had a highly significant ($P<0.01$) effect on the DM content of desho grass. The highest DM content was recorded at 12,000 kg compost/ha (95.0%), followed by 100 kg urea/ha (94.56%), 50 kg urea +6,000 kg compost/ha (94.56%) and control (94.22%). However, Biniyam Mihret *et al.* (2018) reported that the type and level of fertilizer had no significant effect on the DM content of desho grass. Similarly, Abdi Hassan *et al.* (2015) reported that nitrogen fertilizer level had no significant effect on the DM content of *Cenchrus ciliaris* and *Panicum maximum* at Gode, Somali Region of Ethiopia.

On the other hand, according to Denbela Hidosa *et al.* (2020) in South Omo Zone, South Western Ethiopia, the highest mean DM% was recorded at Kindokisha-DZF-589 (90.33%), followed by Kindokisha-DZF-592 (90%), Kulumisa-DZF-592 (89.67%) and the lowest was at Areka-DZF-590 (89.33%). Likewise, Teshale Jabessa *et al.* (2021) on desho grass varieties reported that the highest mean DM% was recorded at Areka-DZF-590 (95.02%), followed by Kindokisha-DZF-591 (94.7%), Kindokisha-DZF-589 (94.02%) and Kulumisa-DZF-592 (92.5%). Deribe Gemiyo *et al.* (2017) reported that the mean DM% was 93.2 ,91.9, 92.8, 92.9, 92.0, 93.0, 93.6, 93.1, 93.1 and 92.7% for Napier grass accessions of Local, 16902, 16783, 16794, 16817, 16913, 16791, 16819, 15743 and 16815 at Areka, Southern Ethiopia, respectively. Regarding the production years, its affect the DM content of grass as a report by Hailegabriel Ajema *et al.* (2022) who reported that the mean DM content of desho grass recorded in 2021 (93.07%) was higher than in 2020 (92.61%).

2.6.2. Ash and Organic matter (OM)

Ash is the inorganic (total mineral elements of a feed) residue remaining after the water and organic matter has been removed by heating in the presence of oxidizing agents or NIRS instrument. Grasses naturally contain 2 to 19% ash content (Lee, 2018).Organic matter includes any plant or animal material that returns to the soil and goes through the decomposition process.It was calculated as the ash content subtracted from 100 dry samples. In addition to providing nutrients and habitat to organisms living in the soil, organic matter also binds soil particles into aggregates and improves the water-holding capacity of the soil. Soil aggregation is improved by increased OM % and hence has a role in maintaining soil structure, drainage and aeration, all of which are necessary for good crop yield (FAO, 2014).

According to the report of Biniyam Mihret *et al.* (2018), the types and levels of fertilizer had a significant effect on ash and OM content of desho grass. The highest ash content was recorded at manure (17.77%), followed by without fertilizer (16.41%) and NPS fertilizer (15.76%), while the highest OM content was recorded as the inverse of ash contents. Similarly, Hussen Ebrahim *et al.* (2020) reported on Napier grass of the ash content of 13.2, 16.7, 13.9 and 13.4%, while the OM content of 86.8, 83.3, 86.1 and 86.6% was recorded from 0, 69, 115 and 161 kgN/ha at 7.5, 15 and 22.5cm cutting heights, respectively. However, Abdi Hassan *et al*. (2015) reported that fertilizer levels and grass varieties, as well as their interactions were not significantly different in terms of ash content, but significantly different in OM content, which the OM content increased as the level of fertilizer increased.

According to Denbela Hidosa *et al. (*2020), who reported that the ash and OM content were significantly ($p<0.005$) affected by desho grass varieties. The highest ash and lowest OM content were recorded from Kindokisha-DZF-592 (10.22 and 89.78 %), followed by Kindokisha-DZF-589 (7.85 and 92.15%), Kulumisa-DZF-592 (7.33and 92.67%) and Areka-DZF-590 (7.29 and 92.71%), respectively. Similarly, Tobiyaw Tsegaye *et al.*(2021) reported that the highest ash content was recorded from Napier grass (15.24%), followed by Para grass (15.1%) and desho grass (13.92 %) at 60 cutting interval in Mecha Woreda, West Gojjam Zone, Ethiopia. Misganew Walie *et al.* (2022) indicated that the higher ash content was obtained from desho grass (6.3%) than Napier grass (6.0%), whereas the higher OM content was obtained from Napier grass (93%) than desho grass (92.7%) at the Aba Gerima watershed, Ethiopia.

On the other hand, according to Hailegabriel Ajema *et al*. (2022), who reported that the ash content of desho grass was affected by production years, a higher mean ash content was recorded in 2021 (6.12%) than in 2020 (5.11%). Therefore, there is limited information regarding the effect of production years on these parameters of grass cultivars or related grass families in different countries, including Ethiopia.

2.6.3. Crude protein content (CP %) and crude protein yield (CPY)

Protein is commonly measured as crude protein, which is 6.25 times the nitrogen content of the forage grass. The crude protein content is one of the major nutrients in forage for the determination of nutritional quality since DM intake and rumen microbial growth increase with increasing levels of CP in a feed (Chanthakhoun *et al.*, 2012). According to Van Soest (1982) and Norton (1982) noted that the level of CP required for rumen function is 7.5% and for lactation is 15%, respectively. The minimum protein level required for maintenance is about 8% of CP, and the most productive animals such as rapidly growing lambs and lactating ewes need about 11% of CP (McDonald *et al.*, 2002). CPY is an important parameter thatis calculated as dry matter yield multiplied by the crude protein content of the forage. As a result, it is positively correlated with forage yield and quality.

The types and levels of fertilizer application affected the CP content and CPY of grasses.According to Biniyam Mihret *et al.* (2018), who reported that the application of fertilizer significantly affected the CP and CPYof desho grass. The highest CP content was observed at NPS fertilizer (10.95%), followed by manure (10.04%) and without fertilizer (9%), whereas the highest CPY (t/ha) was observed at NPS fertilizer (2.76), followed by manure (1.39) and without fertilizer (0.7). Similarly, Bizelew Gelayenew *et al.* (2020) reported that the application of N fertilizer affected the CP and CPY of Napier grass at Holetta and Debre Zeit, Ethiopia. The mean CP content at Holetta was 8.78, 9.22, 9.53 and 9.45%, while at Debre Zeit was 8.06, 8.61, 8.62 and 8.60% from 0, 50,100 and 150 kg/ha, respectively. The mean CPY (t/ha) was 4.48, 5.13, 6.12 and 6.00 at Holetta, while at Debre Zeit it was 9.00, 11.64, 13.47 and 13.35 from 0, 50,100 and 150 kg/ha, respectively. The application of fertilizer affected the CP content, and the amount of CP can increase with an increasing application rate of fertilizer (Dupas *et al.*, 2016).

On the other hand, the CP and CPY were affected by grass varieties. According to Mulisa Faji *et al.* (2022),CPY differed considerably among accessions, with the highest CPY (t/ha) was produced by desho grass, followed by B.decumbens ILRI-13205, B.decumbens ILRI-14721 and S.sphacelata-6543.Similarly, Denbela Hidosa *et al. (*2020) on desho grass varieties; Kulumsa, Areka, Kindokisha DZF-592 and Kindokisha DZF-589 had CP contents of 11.84, 14.12, 13.39 and 9.57 percent, respectively. Deribe Gemiyo *et al.* (2017) found that on Napier grass accessions, the highest CP content was obtained from Napier-16902 (6.66%), while the lowest was recorded from 16794 (4.23%).Tessema Zewdu (2005) reported that the highest CP content among Napier grass accessions was obtained from 16791 (15.7%), followed by 16853 (13.9%) and the lowest was local variety (13.2%).

According to Hailegabriel Ajema *et al*. (2022) reported that the CP content of desho grass was affected by production years in the central highlands of Ethiopia. The higher mean CP content of desho grass was recorded in year 2 (12.58%) than in year 1(8.36%). In addition, Misganew walie *et al*. (2022) reported that the CP content and CPY (g/kg) of desho and Napier grass were affected by production years in Ethiopia. The higher mean CP content was recorded in second year (115.8 g/kg) than in the first year (114.3g/kg) and a higher mean CPY (g/kg) was recorded in 2021 (1225.1) than in 2020 (80.7).

2.6.4. Neutral detergent fiber (NDF %)

Neutral Detergent Fiber (NDF) is a good indicator of "bulk" and thus feed intake (Miraeoh *et al.,* 2016).The NDF content contains the primary components of the plant cell wall, namely cellulose, hemicellulose, lignin and silica. NDF is negatively correlated with dry matter intake, which meansa high NDF level in forage leads the animal to eat less feed (Lardner *et al.,* 2015) and hence affects animal productivity. A better prediction of forage intake can be made using NDF; therefore, better rations can be formulated (Schroeder, 2012).According to Singh and Oosting (1992), NDF content of feed <45, 45-65 and >65% are categorized into high, average and low quality feeds, respectively.

According to Biniyam Mihret *et al. (*2018), who reported that the NDF content of desho grass was affected by type and level of fertilizer, with the highest NDF was observed without fertilizer

(61%), followed by manure (55%) and NPS fertilizer (51%). Similarly, Bizelew Gelayenew *et al.* (2020) reported that the NDF content of Napier grass was affected by levels of nitrogen fertilizer at Holetta was 65.24, 64.64, 64.50 and 64.39% obtained from 0, 50, 100 and 150 kg/ha, respectively. Misganew Walie *et al.* (2022) who conducted on Napier and desho grass at the Aba Gerima watershed, the highest NDF was observed Desm plus FYM fertilizer (72%), followed by FYM (71.3%), control (70.9%), while the lowest observed at desmodium (70.6%). This elucidates that the fertilizer application to the forage raises new leaves and shoots, which minimizes the NDF content as the fertilizer level increases. The type and level of fertilizer could affect the NDF content of grass.

On the other hand, according to Denbela Hidosa *et al. (*2020), the NDF content of Kulumsa, Areka, Kindokisha DZF-592 and Kindokisha-DZF-589 was 57.73, 55.12, 56.7 and 63.42%, respectively. Similarly, Misganew Walie *et al.* (2022) reported that the NDF content of Napier grass and desho grass was significantly affected by grass species, which the higher NDF content was recorded from Napier grass (72.50) than desho grass (69.9%) at the Aba Gerima watershed. Moreover, Deribe Gemiyo *et al.* (2017), among Napier grass accessions, the highest NDF was found at acc.16794 (83.6%), while the lowest NDF from acc.16913 (78.6%) at Areka, Southern Ethiopia.

Regarding the production years, according to Hailegabriel Ajema *et al*. (2022) who reported that NDF content of desho grass was affected by production years, which the higher NDF content was recorded in year 1(75.23%) than in year 2 (71.76%). Besides, Misganew Walie *et al.* (2022) reported that the NDF content of Napier grass and desho grass was significantly affected by production years, which the higher NDF content was recorded in year 2 (73.20) than year 1 (69.2%). Therefore, grass species, fertilizer application and year was affected the NDF content.

2.6.5. Acid Detergent Fiber (ADF %)

Acid detergent fiber is the fiber portion of the forage, and include cellulose, lignin and silica.It is a good indicator of digestibility and thus, energy intake (Van Soest, 1994). As the ADF increases, the forage becomes less digestible (Schroeder, 2012).

The ADF content of grass was affected by the type and level of fertilizer. As stated by Biniyame Mihret *et al.* (2018), who conducted a research study on desho grass the ADF content was significantly affected by the types and levels of fertilizer, of which the highest ADF observed at without fertilizer (52%), followed by manure (44%) and NPS fertilizer (41%). Similarly, Bizelew Gelayenew *et al.* (2020) who reported that the ADF content of Napier grass of 40.96, 40.65, 40.54 and 40.16% was obtained from 0, 50, 100 and 150 kgN/ha at Holetta, respectively. But, Misganew Walie *et al.* (2022) reported that the ADF content was not significantly affected by fertilizer sourses, which the ADF content at desm plus FYM (42.6), manure (42.0 %), control (39.1) and Desmodium (38.6) at the Aba Gerima watershed. The highest ADF content was observed in the unfertilized grass as compared to fertilized grass, and it tends to mean that as the fertilizer level increased, the ADF content also decreased.

The grass varieties were significantly affected the ADF content. According to Deribe Gemiyo *et al.* (2017) among Napier grass accessions, the highest ADF was found from acc.16783 (44.8%), followed by acc.16791 (44.5%) and the lowest at acc.16815 (41.4%). But, Misganew Walie *et al.* (2022) reported that the ADF content was not significantly affected by grass species, which the ADF content of Napier grass (41.7) and desho grass (39.5%) at the Aba Gerima watershed. Susan *et al.* (2016) reported that the highest ADF content was recorded from Brachiaria decumbens (42.9%) followed by B. brizantha La Liberated (42.2%), Brachiaria Marandu (38%) and the lowest at Brachiaria hybrid Mulato-II (37.5%) at 90 days of harvesting age.

Regarding the effect of production years, according to Hailegabriel Ajema *et al*. (2022) who conducted a research study on desho grass in the central highlands of Ethiopia, the ADF content was affected by production years. A higher ADF content of desho grass was recorded in 2020 (41.56%) than in 2021 (41.20%). However, Misganew Walie *et al.* (2022) reported that the ADF content was not significantly affected by grass species, which the ADF content in 2018 (41.2%) and in 2019 (40.0%) at the Aba Gerima watershed. Therefore, the production year affect the ADF content.

2.6.6. Acid Detergent Lignin (ADL %)

Lignin is the prime factor influencing the digestibility of plant cell wall material. As concentrations of lignin increase, cellulose's digestibility, intake and animal performance usually decreases because lignin is indigestible, limiting the amount of energy accessible to the animal (Hancock, 2017). Lignin limits cell wall digestion by providing a physical barrier to microbial attack, and the concentration of both cell walls and lignin increases as plants mature (Van Soest, 1994). Therefore, forages with lower ADL content are more desirable (McDonald *et al*., 2002).

ADL content of grass species was affected by the type and level of fertilizer. The ADL content of desho grass was significantly affected by fertilizer type, of which the highest ADL content was observed without fertilizer (13.5%), followed by manure (9.8%) and the lowest observed at NPS fertilizer (8.3%) (Biniyame Mihret *et al*., 2018). But, Misganew Walie *et al.* (2022) reported that the ADL content was not significantly affected by fertilizer sourses, which the ADL content at desm plus FYM (11.7%), manure (11.3%), control (11.1%) and Desmodium (10.2%) at the Aba Gerima watershed. Similarly, Diribe Mijena *et al.* (2022) conducted a research study on Bracharia grass, the ADL content was no significantly affected by the level of N-fertilizer application.

The ADL content was affected by grass species. According to Misganew Walie *et al.* (2022) reported that the ADL content was significantly affected by grass species, which the higher ADF content was recorded from Napier grass (12.7) than desho grass (11.0%) at the Guder watershed. Deribe Gemiyo *et al.* (2017) on Napier grass accessions, the highest ADL content was found at acc.16817 (8.80%) and the lowest from acc.16913 (7.83%). Besides, Susan *et al.* (2016), the highest ADL content was recorded from Brachiaria hybrid Mulato-II (6.4%), followed by Brachiaria decumbens (4.9%), Brachiaria Marandu (3.6 %) and the lowest was recorded at Brachiaria brizantha La Liberated (3.3%) at 90 days of harvesting age.

According to Hailegabriel Ajema *et al*. (2022) on desho grass, the ADL content was affected by production years. The higher ADL content was recorded in 2020 (4.57%) than in 2021 (4.47%). Misganew Walie *et al.* (2022) who conducted a research study at the Aba Gerima watershed reported that the ADL content was significantly affected by grass species, which the higher ADL content was recorded in 2018 (12.1%) than in 2019 (10.0%). Therefore, the ADL % was affected by production year.

2.6.7. In Vitro Organic Matter Digestibility (IVOMD)

The critical threshold level of IVOMD was 50% for required feeds to be considered to have acceptable digestibility (Owen and Jayasuriya, 1989). The higher digestibility could be partially attributed to the higher CP content of forages. Nevertheless, the lower digestibility records might be associated with a higher proportion of NDF, ADF and lignin (Moore and Jung, 2001)

The IVOMD content was affected by the type and level of fertilizer. According to Merga Abera *et al.* (2022) reported that IVOMD % was affected by nitrogen fertilizer levels. The IVOMD was obtained at 0 kg N/ha (68.25, 57.86 and 57.41%), 41 kg N/ha (67.13, 65.02 and 60.19%) and 73 kg N/ha (65.09, 60.68 and 61.37%) at 112, 133 and 154 days of harvesting age, respectively. Correspondingly, Diribi Mijena *et al.* (2022), who conducted a research study at Wondogenet, on Bracharia mulato II grass also reported that the IVOMD significantly (P<0.001) affected by NPS fertilizer, and the highest IVOMD was obtained from 200kg/ha (55.28 %), followed by 150 kg/ha (54.44%), 100 kg/ha (54.31%), 50 kg/ha (54.10%), and 0 kg/ha (53.17%).

On the other hand, the grass species was affected the IVOMD content. Gezahagn Kebede *et al.* (2017) reported that the IVOMD content of Napier grass accessions showed a significant (P<0.05) variation at Holetta, with the highest IVOMD (g/kg) recorded from acc.16783 (534.7), followed by acc.16794 (518.8), acc.16792 (515.2) and the lowest was recorded from acc.16815 (488). The same authors at Areka, the highest and lowest IVOMD were recorded from acc.16813 (430.8 g/kg) and 16794 (358.8 g/kg), respectively. Regarding the production years, according to Hailegabriel Ajema *et al.* (2022) described that the production years were affected the IVOMD of the desho grass. A higher IVOMD was recorded in 2021 (66.95%) than in 2020 (58.22%).

2.6.8. Metabolizable Energy (ME)

Metabolizable energy is the amount of energy present in the feed that is available to an animal for maintenance, production, reproduction and activity. Energy is usually the most important feed component needed to produce milk. The value of feed is related to the amount of energy it can supply since energy is usually the chief limiting nutrient (Wilson and Brigstocke, 1983). According to McDonald *et al. (*1988), the energy requirement of animals is most commonly expressed as the absolute quantities of energy gained or lost by animals. The lower critical threshold value of Metabolizable energy is 7.5 MJ/kg DM (Owen and Jayasuriya, 1989). A feed containing <9, 9-12 and >12.0 MJ/kg DM ME are catagoried as low, medium and high energy, respectively (Lonsdale, 1989).

The ME content was affected by the type and level of fertilizer. According to Diribi Mijena *et al.* (2022) conducted a research study on Bracharia mulato II grass, the ME had a significantly

(P<0.001) affected by NPS fertilizer level, which the ME increased as the levels of NPS fertilizer increase. The highest ME was obtained at 200 kg/ha (8.78MJ/kg), followed by 150 kg/ha (8.74MJ/kg), 100 kg/ha (8.65MJ/kg), 50 kg/ha (8.56MJ/kg) and 0 kg/ha (8.49MJ/kg). On the other hand, the grass varieties significantly affected the ME content. Mutimura Mupenzi *et al.* (2017) reported that the highest ME was obtained from B.decumbens (8.4 MJ/kg), followed by B. La Liberated (8.1 MJ/kg), B.hybrid Mulato-I (8 MJ/kg), B.Mulato-II (7.7 MJ/kg) and B. Marandu (6.5 MJ/kg) at 90 harvesting days. Regarding the production years, according to Hailegabriel Ajema *et al.* (2022) stated that the ME of desho grass was affected by production years, with the highest ME (MJ/kg) recorded in 2021 (10.71) than in 2020 (9.31).

Table 7: Nutritive values (%) of some improved forages in Ethiopia

Grasses	DM	OM	CP	NDF	ADF	ADL	IVOMD	$ME_{(MJ/kg)}$	Sources
Brachiaria decumbens	89.00	75.40	8.88	62.55	48.35	9.97	-	-	Solomon Tiruneh *et al.*, 2022
Brachiaria decumbens	-	87.9	8	68.1	42.2	3.4	56.1	-	Susan *et al.*(2016)
Brachiaria decumbens	-	87.3	18.2	41.7	-	-	41.1	-	Mutimura *et al.(*2017)
Napier grass	92.04	82.87	7.47	64.28	41.1	5.51	64.8	1.22	Firew Tegegne and Getnet Assefa(2010)
Napier grass	-	93.4	9.0	64.1	37.6	8.4	56.2	7.8	Misganaw Walie *et al.* (2023)
Desho grass	30.16	89.78	7.86	71.81	42.5	5.37	-	6.18	Bimrew Asmare *et al.* (2017)
Desho -*Areka DZF- 590*	95.5	86.8	17.2	71.6	47.7	6.98	-	-	Teshale Jabessa *et al.(*2021)
Desho grass	82.98	83.78	9.00	61	52	13.5	-	-	Bineyam Mihret *et al.* (2018)

Where: -DM=Dry Matter; OM=Organic Matter; CP=Crude Protein; NDF=Neutral Detergent Fiber; ADF=Acid Detergent Fiber; ADL=Acid Detergent Lignin and IVOMD=Invitro organic Matter Digestablity

CHAPTER THREE: MATERIALS AND METHODS

3.1. Location and description of the study area

Thecurrent study was conducted at Robit Bata Kebele, Bahir Dar zuria district, in the West Gojjam Zone of the Amhara Regional State of Ethiopia (Figure 1). It is bordered on the south byYilmana Densa, on the southwest by Mecha, on the northwest by the Gilgel Abay River, which separates it from Semien Achefer, on the north by Lake Tana, and the east by the Abay River, which separates it from the south Gondar Zone. The area is located at a distance of 564 km northwest, far from the national capital city, Addis Ababa. Its geographically coordination is between 11°25′N-11°55′N latitude and 37°04′E-37°39′E longitude. Its altitude ranges from 1750 to 2300 m.a.s.l, with the mean annual rainfall ranging from 800 to 1250 mm and the mean annual temperature ranging between 10 and 32 °C (BDZWoA, 2016). The major soil types are 10% brown, 34% reddish, and 56% black. The land use pattern of the district includes 69.09% agricultural land, 17.04% vegetation covered, 2.3% covered with water, and 11.51% covered by built up area (Fentahun Abebe *et al.*, 2023). The Population in the study area is dependent on agricultural farming for their economy, which practices a mixed farming system, i.e., crop along with livestock production, to secure their family's food supply and income. Natural pasture (communal and private), crop residues, hay, crop aftermath, attela and birint, agro-industrial by-products, indigenous browse trees/shrubs and improved forage are being used as livestock feed resources (Sosena Fentahun *et al.*, 2020).

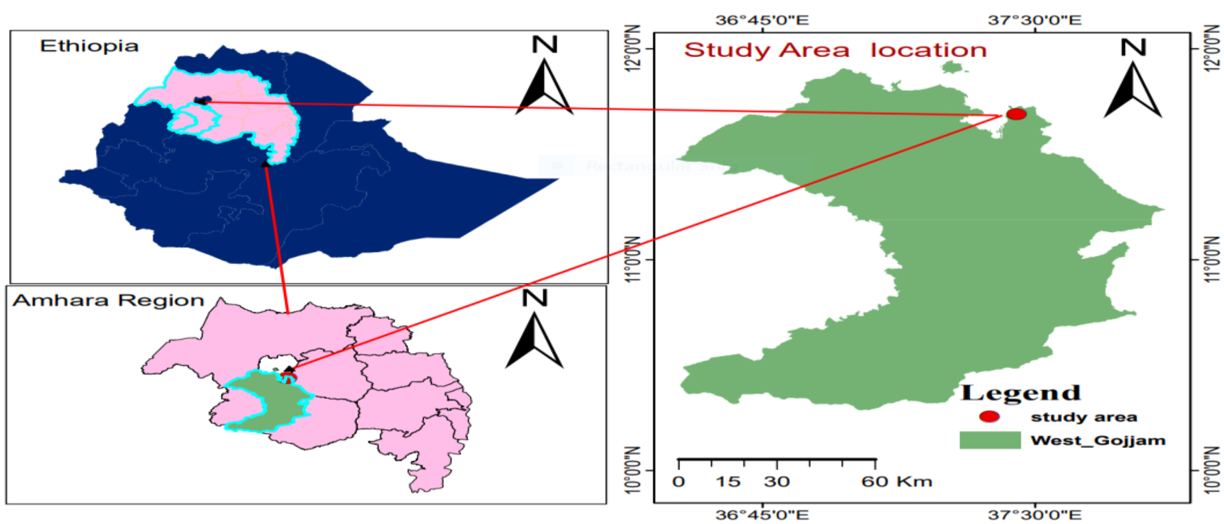

Figure 1: Map of the study area

3.2. Site selection, land preparation and planting

The experimental site was selected purposely based on the preference of the ILRI project, which is based on suitable agro-ecological conditions for forage development. After selecting the site, the land was cleared of weeds and unwanted debris, then ploughed three times by oxen and harrowed to a fine tilth before planted, plots and blocked were outlaid. Based on the slope and fertility of the experimental land, the homogeneity of the experimental plots in each block was considered.

After proper land preparation, the experimental forage varieties, such as Napier grass ILRI-16791, Desho grass-*Areka*-DZF-590 and *Brachiaria decumbens*-10871, were obtained from the International Livestock Research Institute (ILRI), and planted in rows on well-prepared soil on June, 2021 by using the root-splitting method. The root-splitting method had a higher survival rate and faster growth than other methods (Mergia Abera *et al.,* 2022). The planting method for Napier grass was to cut the stems at ground level to remove all the green material; then dig up the clump of roots and shoots growing under the ground. After that, separate each seedling from the clump; each seedling must have both roots and a shoot; trim the roots to about 5 cm long; plant the seedlings in small holes or a furrow; finally, cover the roots with soil, but leave the shoots open to the air. Whereas for desho grass and Brachiaria decumbens, two-thirds of the root splits were buried at a depth of 10-15cm, and the apical third was left on the ground (Cameron and Lemcke, 2008). The experiment was carried out for two consecutive years (2021 and 2022).

The experimental site was kept free of weeds throughout the experimental period (for two consecutive years) by manual weeding for each year as necessary until the final harvesting was accomplished to eliminate the re-growth of undesirable plants and remove the dry root to promote fodder the re-growth by increasing soil aeration. To ensure wild or domestic animals did not destroy the trials; the entire experimental area was fenced off and kept by guard.

3.3. Fertilizer collection, analysis and application

Cattle manure was purchased from Robit Bata kebele farmers, while urea fertilizer was purchased from the Bahir Dar City local market. According to the recommendation of Erikson Kadoshe *et al. (*2022), the cattle manure was collected 14 days before the application and sub-samples were taken for chemical analyze before application to determine the quantities of the nutrient composition of the fertilizer to be applied. The cattle manure used in the experiment had a moisture (47%), pH (7.4), total nitrogen (TN) (1.5%), organic carbon (OC) (17.5%), and available phosphorus (Pav) (32.8 mg/kg) properties.

On the same day, manure and artificial fertilizer were manually applied to the surface.Split applications of fertilizer have been recommended, as the growth response is greater in the period immediately following the application of fertilizer (Watson, 1977). Urea fertilizer application, in which one half was applied at the time of planting and the remaining half was applied for second harvesting, while for manure, in which about 2/3 was applied at the time of planting and the remaining 1/3 was applied for second harvesting due to the slow release of nutrients. In the second year, the same amount of urea and manure was applied at the start of the rain after the uniform cutting of all the plots as in the first year.

3.4. Experimental layout, design and treatments

Thestudy was conducted under a 3x 4x 2 factorial arrangement in a randomized complete block design (RCBD) with three replications. The treatments were composed of control with no fertilizer, 30tons/ha cattle manure, 100kg N/ha and 300kg N/ha, and three (3) types of grass varieties, such as Napier (*Cenchrus purpureus*)-16791, Desho (*Pennisetum glaucifolium*) *Areka*-DZF-590 and *Brachiaria decumbens*-10871 were observed over two production years (2021 and 2022). The experiment has 12 treatment combinations (Table 8) and 36 experimental plots. Therefore, the experimental area was laid down using the 3, 4, and 5 triangular methods, and the total experiment size was $540m^2$ (15m*36m) with an individual plot size of $9m^2$ (3m*3m). The plot size of each treatment was $9m^2$ and from each plot, the net harvestable plot area was $4m^2$ (2m*2m) with a total harvestable area of $144m^2$ from 36 plots used by excluding one outer row on both sides of each plot used to calculate dry matter yield. The space between the plot and block was 1m and 1.5m, respectively. The spacing between rows and plants was 0.5mx0.25m for Brachiaria decumbens and Desho grass (Birmaduma Gadisa *et al.,* 2019) and 0.5m x 0.5m for Napier grass (Tessema Zewdu, 2008), respectively. There were seven (7) rows per plot and seven (7) plants per row in Napier grass-16791, seven (7) rows per plot and 12 plants per row in Desho-*Areka*-DZF-590 and *Brachiaria decumbens*-10871 grass. The treatments were assigned randomly into plots within each replication.

Table 8: Experimental treatment combinations

Treatments	Treatment combinations	
	Grass varieties	Fertilizer level/types
T1	Napier grass *(Pennisetum purpureum Schumach.)*var.16791	control
T2	Napier grass *(Pennisetum purpureum Schumach.)*var.16791	100kg N/ha
T3	Napier grass *(Pennisetum purpureum Schumach.)*var.16791	300kg N/ha
T4	Napier grass *(Pennisetum purpureum Schumach.)*var.16791	30t/ha manure
T5	Desho grass(*Pennisetum glaucifolium*) *Areka*-DZF#590	control
T6	Desho grass(*Pennisetum glaucifolium*) *Areka*-DZF#590	100kg N/ha
T7	Desho grass(*Pennisetum glaucifolium*) *Areka*-DZF#590	300kg N/ha
T8	Desho grass(*Pennisetum glaucifolium*) *Areka*-DZF#590	30t/ha manure
T9	Brachiaria decumbens var.ILRI #10871	control
T10	Brachiaria decumbens var.ILRI #10871	100kg N/ha
T11	Brachiaria decumbens var.ILRI #10871	300kg N/ha
T12	Brachiariadecumbens var.ILRI #10871	30t/ha manure

3.5. Morphological Parameter Sampling and Data collection methods

The samples were collected year-round for two consecutive years. On the same day, harvests were made 2 times per year by hand using a sickle, leaving a stubble height of 5-10cm from the soil to allow for more growth of new shoots as recommended by Tudsri *et al.* (2002). In each plot, ten plants were randomly selected to record the plant height, number of tillers per plant, number of leaves per plant, leaf length per plantand leaf width per plant from each grass variety. Fresh biomass yield (kg), dry matter yield (t/ha), and leaf to stem ratio were also determined.

3.5.1. Plant height (PH) (cm)

The plant height was measured on the primary shoot from the soil surface (base) to the tip of the upper leaves of the main stem by using a measuring tape (Rayburn *et al.*, 2007). The mean plant height from each treatment was determined by measuring the height of ten randomly selected plants from the middle rows of each plot, leaving the outer edge rows due to the border effect, and then the average height was calculated.

3.5.2. Number of tillers per plant (NTPP)

The number of tillers per plant was recorded by counting all shoots that arise from the main plant and excluding the main shoot from which the shoots arise (Diribi Mijena*et al.*, 2022).The number of tillers per plant was counted from the same-tagged ten randomly selected plants from the middle rows and then the mean was calculated.

3.5.3. Number of leaves per plant (NLPP)

The number of leaves per plant was counted from all tillers, including the main shoot by taking ten randomly selected plants from the middle rows. By multiplying the NLPT by the NTPP, the total NLPP was obtained, and then the mean number of leaves per plant was calculated.

3.5.4. Leaf length per plant (cm)

The leaf length per plant was measured from the base of the collar region of the leaf to the tip of fully expanded leaves. It was measured from ten randomly selected sample plants in the middle rows by using a meter.

3.5.5. Leaf width per plant (cm)

The leaf width per plant was measured from the middle region of the leaf. It was measured from ten randomly selected sample plants from the middle row by using a meter.

3.5.6. Leaf-to-stem ratio (LSR)

The leaf–to-stem ratio was determined by manually separating sub-samples into leaves and stems, and weighed separately for leaf and stem. The dried sample of each component was weighed and LSR was calculated as the ratio of the dry weight of leaves (g) to the dry weight of stems (g) (Nguku *et al.*, 2016).

3.5.7. Sampling Methods for Fresh Biomass and Dry Matter Yield (DMY) (t/ha)

The harvestable plant for fresh biomass and dry forage yield determination of each grass was cut down at 5-10cm above the ground (Tudsri *et al*., 2002). The plot size of each treatment was 9m^2 and from each plot, five middle rows (2nd, 3rd, 4th, 5th and 6th) with a net harvestable area of 4m^2 per plot and 144m^2 per total harvestable area from 36 plots by considering border effects, which left 50cm lengthwise from each side. A fresh biomass yield of each grass was measured immediately after harvesting and weighed on the field soon after mowing using a portable balance with a sensitivity of 0.01g. Based on the fresh biomass yield from the sample area of each plot, the total dry matter yields for each plot were thereafter converted to metric tons per hectare (Bizelew Gelayenew*et al.,* 2020). The dry matter percentage was determined by taking about 500g (weighted by a field sensitive balance) of sub-samples of fresh weight from each plot and chopped into short lengths (2-5cm) and then packed with an airtight bag and subjected to oven drying at 65ºC for 72 hours to estimate the dry matter yield (ton/ha). The dry matter percentage was determined by dividing the dry weight of the subsample by the weight of the fresh subsample and multiplying by 100.

DMY (t/ha) = (10x TFWx SSDW)/ (HAxSSFW) (Bizelew Gelayenew *et al.,* 2020).….eq.(1)

Where: 10=constant for conversion of yields in kg/m ^{2}to tone/ha;

TFW = Total Fresh Weight from harvesting area (kg);

SSDW = Sub-Sample Dry Weight (g);

HA = Harvestable Area (m^2), and

SSFW=Sub-Sample Fresh Weight (g).

CPY (t/ha) = [DMY (t/ha) * CP (%)]/100 (Diribi Mijena *et al*., 2022). ………………..…eq. (2)

3.6. Chemical Composition Determination

For nutritional quality analysis, samples from each harvest cycle of the two years were taken and transported to the International Livestock Research Institute (ILRI) Animal Nutrition Laboratory in Addis Ababa. The samples were given a laboratory number and dried to a constant dry weight in an oven set at a temperature of 65ºC for 72 hours to determine the dry weight before any analytical procedure (AOAC, 1990). Then the partially dried sample was ground to a 1mm mesh size using a Wiley mill and packed into paper bags and stored pending further laboratory work. Near Infrared Reflectance Spectroscopy (NIRS), prediction was employed for the analysis of the intended nutritional values of forage samples. For scanning purposes, the partially dried sample was filled into an NIRS cup and scanned using Foss NIRS 5000 with the software package WinISI II in the 1108-2492nm spectra ranges (Win Scan version 1.5, 2000, Intrasoft International) for 3.0 minutes per sample. All chemical analyses of samples were scanned in duplicate and then calculated on a dry matter basis. Finally, NIRS scanned information of the partially dried sample was used for the prediction of Ash (%), nitrogen (N%), ME (MJ/kgDM), In-Vitro Organic Matter Digestibility (IVOMD%), and fiber fractions (NDF, ADF and ADL) contentsusing predictive equations developed based on previously conducted conventional analyses.

3.7. Partial Budget Analysis

The information on all variable costs related to the cost of manure and urea fertilizer was recorded during the purchasing at Robit Bata farmers and Bahir Dar City local market, respectively. The biomass yield of each treatment was recorded in each production year. The purchased price of manure per quintal was 6,000 birr for each year, while the price of urea was 1,800 and 4,500birr per quintal in 2021 and 2022 at Bahir Dar City during our experimental periods, respectively. There was no field price or market price for fresh grass in the study district. Therefore, to estimate the price of fresh grass, we used the average related prices for 1 kg of hay and green grass in different locations in Ethiopia. According to ALRC (2018) and Shimelis Mengistu (2018), 1 kg of hay was valued at 4.44 birr/kg at Andasa and 2.6 birr/kg in Damot Gale District of Wolaita Zone, SNNPR, respectively. Similarly, the price of green forage in the local market of Amhara Region, like Debre Tabor town was estimated at 5.05 birr per kg (personal observation in the open market in September 2022).Therefore, the averages of these prices were assumed to be market price estimations of grass varieties in the current study. The market price for grass= (4.44+5.05+2.6)/3=4.03 birr/kg. The partial budget analysis was employed using the procedure recommended by CIMMYT (1988).

Adjusted DM yield (ADMY): it was the experimental yield scaled down by a given proportion to approximate the yield that farmers can obtained on their farms. The farmers using the same technologies would obtain yields 10% less than those obtained by the researchers would.

ADMY = Biomass yield – (biomass yield × 0.1)

Gross benefit (GB): This was calculated by multiplying the average estimated market price of grass by the adjusted dry matter yield. GB =ADMY× field/farm gate price for the grass

Total variable costs (TVC): This was calculated as the sum of all variable costs for a particular treatment.

Net benefit (NB): This was calculated by subtracting the total variable costs from the gross field benefit for each treatment. Net benefits are not the same thing as profit because the partial budget does not include the other costs of production that are not relevant to this particular decision.

NB = GB – total variable cost

Dominance analysis (D): This was carried out by first listing the treatments in order of increasing costs that vary or increasing net benefits. Any treatment that has net benefits that are less or equal to those of a treatment with lower costs that vary is dominant.

Marginal rate of return (MRR): was calculated by dividing the change in net benefit by a change in the total variable cost multiplied by 100 and expressed as a percentage. The marginal rate of return is a measure of the increase in net income that is associated with each cost.

$$MRR = \frac{\text{NB from superior dominant plot- NB from preciding inferior dominant plot}}{\text{TVC from superior dominant plot- TVC from preciding inferior dominant plot}} \times 100$$

3.8. Statistical data analysis

Microsoft Excel (2010) was utilized for the management and recording of data. Following the collection and recording of data, the normality of the data was assessed using the Shapiro-Wilk test. Following the validation of data normality, the General Linear Model (GLM) approach of the Statistical Analysis System (SAS, 2004 version 9.0) was utilized to conduct an Analysis of Variation (ANOVA) on data related to morphological parameters, DM yields, and chemical composition. As per Duncan's (1995) description, a mean comparison was conducted with the assumptions met, utilizing Duncan’s Multiple Range Test (DMRT) at a 5% level for variables whose F-values showed significant differences at $P<0.05$. Using Proc Corr of SAS, a Pearson correlation analysis (r) was performed to investigate the connections between forage morphological characteristics, DM yield, and quality measures. The summarized data was presented in the form of tables.

The statistical model for the analysis of the data was:

$$Y_{ijk} = \mu + F_i + G_k + Y_j + F_i*G_k + F_i*Y_j + G_k*Y_j + F_i*G_k*Y_j + E_{ijk}$$

Where; Y_{ijk}=all dependent variables (morphological data, DM yield, and nutritional quality)

μ = overall mean

F_i= the fixed effect of i^{th} fertilizer levels (i=0, 30t/ha cattle manure, 100kg U/ha and 300kgU/ha)

Y_j = the random effect of j^{th} production years (j=1st year and 2nd year)

G_k=the fixed effect of k^{th} grass varieties (k= Napier grass ILRI-16791, Desho grass-*Areka*-DZF-590 and *Brachiaria decumbens*-10871)

$F_i * Y_j$ = interaction effect between fertilizer application and production years

$F_i * G_k$ = interaction effect between fertilizer application and grass variety

$G_k * Y_j$= interaction effect between grass variety and production years

$F_i * G_k * Y_j$ = interaction effect between fertilizer application, grass variety and production years

E_{ijk} = residual error

CHAPTER FOUR: RESULTS AND DISCUSIONS

4.1. Effect of fertilizer levels, grass varieties and years on morphological characteristics

Overall analysis of the current study revealed that the morphological characteristics and dry matter yield were significantly ($P<0.001$) influenced by the intraction between fertilizer rate, grass varieties, and production years (Table 9).

4.1.1. Plant Height (PH) (cm)

The interaction effects of grass varieties, fertilizer rate and production years had a very high significant ($P<0.001$) effect on the plant height (Table 9). The highest PH (175.0 and 187.0cm) was measured from Napier grass ILRI-16791 at application of manure fertilizer in the first and second years, respectively. The shortest PH (33.67 and 51.3cm) was recorded from desho grass-Areka-DZF-590 grown at unfertilized plot in the first and second years, respectively, with the overall mean of 91.01cm. This might be due to the reason, the application of manure to improves soil nutrient availability, which includes organic matter (OM), total nitrogen (TN), dissolved organic carbon (OC) and ammoniam ($NH4^+$) contents which are necessary for plant growth (Ma *et al.* 2022). This in turn could be due to the genetic potential of species to extract minerals and associated with massive root development and efficient nutrient uptake, allowing the plant to continue to increase in height. As indicated by Gebremedhin Beyene *et al*. (2015), plant height can be different among different species within the same management systems.

In the current study of the PH at manure >300kg >100kg N>zero application of fertilizer levels and types from three grass varieties in both years. This result in line with the report of Mergia Abera *et al*. (2021), who reported that the level of nitrogen fertilizer increased from 0, 41 and 73 kg/ha, the PH of desho grass was also increased from 21.25, 22.08 and 23.92cm, respectively. This result also supported by other scholars Worku Bekuma *et al.* (2017), who reported that the PH of desho grass increased from 0.9 to 1.3 m as the fertilizer level increased from 100 to 350 kgN/ha, respectively. Similarly, the PH of current result was agrees with the findings of Nafatul *et al.* (2015), who noted that PH increased as the level of NKP fertilizer increased. In this study, manure fertilizer applied to all three-grass varieties in both years was higher than the value reported by Biniyame Mihret *et al*. (2018) on desho grass by application of NPS fertilizer (55.23cm), manure (52.22cm) and without fertilizer (42.01cm). This difference might be the genetics of grass varieties, environment conditions, levels and types of fertilizer, harvesting stages and management practices.

The greatest height recorded from Napier grass ILRI-16791 in this experiment might be attributed to the morphological and physiological growth habits of the Napier grass species, which had a vertical growth habit than desho and B.decumbens grass species. This result was in line with the report of Misganew Walie *et al.* (2022), who reported that Napier grass (88.2cm) was the larger and taller than desho grass (42.7cm) at Guder watershad. The plant height recorded from Napier grass ILRI-16791 at 0, 100kg, 300kg N/ha and manure fertilizer levels in both years of this experiment was lower than the value reported by Aman Getiso and Diribi Mijena (2021) for Napier grass (2.78m) under supplimentary irrigation. Similarly, the PH of the current study measured from manure fertilized Napier grass ILRI-16791 in years 1 (175cm) and 2 (187cm) was lower than the finding of Rica Sari *et al.* (2021), who reported that different results from cow manure (224.85cm), chicken manure (228.43cm) and goat manure (229.85cm) of Napier grass. The current result of PH from Napier grass ILRI-16791 at 0, 100kg, 300kg N/ha and manure in years 1 and 2 except control in year 1 (51.13cm) was higher than the result of Rambau *et al*. (2016), and Susan *et al*. (2016) reported that PH for Napier grass was 58.5cm and 103.8cm at weeks 12 and 16, respectively. The benefit of supplemental irrigation, soil fertility and type, fertilizer type and levels, harvesting stage, management, and variations in temperature, yearly rainfall amount, and distribution across the experimental years could all be contributing factors to this different in results.

The interaction result revealed that for three variety with 0, 100, 300 kg N/ha and manure fertilizer, the maximum PH recorded in year 2 compared to year 1. The significant difference of PH across the experimental years suggests that the different distribution of rainfall, temperature, and grass adoptability varied during those years. This result was consistent with the finding of Misganew Walie *et al.* (2022), who conducted a research on desho and Napier grass at Guder watershed that the PH of second year (75.3cm) taller than the first year (55.5cm). The current result was also in line with Denbela Hidosa *et al.* (2020) who conducted a research on desho grass that the PH of second year (143.34) was taller than the first year (89.33%). This could be because of various accessions shown a very distinct reaction to certain environmental factors (temperature, rainfall, and soil).

4.1.2. Number of tillers per plant (NTPP) (counts)

The result of the current study showed that there was very highly significant (P<0.001) effect of grass varieties, fertilizer rate and production years on the NTPP (Table 9). Significantly (P<0.001), the maximum number of tillers per plant (49.33 and 127.13) were counted at desho grass-*Areka*-DZF-590 with manure fertilizer in the first and second years, respectively. Whereas, the minimum number of tillers (15.4 and 24.0) was observed from unfertilized *Brachiaria decumbens*-10871 in the first and second years, respectively, with the overall mean of 51.65. The difference of this result under the same management condition might be attributed to the genetic variations among the grass varieties to adapt to a given environment, and the effect of fertilizer levels and types. The result of this study was similar to the findings reported by Aman Getiso and Diribi Mijena (2021), where the number of tiller differed among all tested Napier grass accessions at Wondo Genet of Ethiopia.

The more NTPP were produced from desho grass-*Areka*-DZF-590 at cattle manure applied in second year than all grass varieties with all fertilizer levels in first year and other grasses with other fertilizer levels in second year. The addition of manure can increase the growth of tillers and improve the structure of the soil to become more crumb by increasing the root growth of the soil pores, thus making it easier for new shoots to grow through the soil surface. This suggests that a stronger effect of genetic makeup and tillering capacity. This result is supported by the finding of Charouvanh Bouathong *et al. (*2011), who reported that application of manure fertilizer (160.41) has scored the highest NTPP than NPS (131.78) and control plot (97.84) of Brachiaria *Mulato II* grass. The present study was also consistent with reported by Misganew walie *et al*. (2022), who reported that desho grass (97.3) a higher NTPP than Napier grass (30.7) at the Guder watershed, Ethiopia. The NTPP of B.decumbens-10871 at 0, 100kg, 300kg N and manure fertilizer levels and types in the first year of the current finding was lower than the findings of Beyadglign Hunegnaw *et al.* (2019), who noted that the overall interaction means of the NTPP of Brachiaria grasses were 34.34. But, the current result was higher than the values reported by Teshale Jabessa *et al.* (2022), who reported that the overall mean NTPP of Napier grass accessions was 12.0. Tiller number is an important attribute of grasses because it increases the chances of survival and the amount of available forage production (Van Saun, 2006). Increased tillering is probably an adaptive feature to tolerate frequent defoliation by reestablishing the lost photosynthetic area and maintaining the basal area. Moreover, it is an indicator of the efficient utilization of all-important resources applied to it by the different grass species.This difference might be come from environmental conditions, the management system and the harvesting stage.

In the current study, the NTPP at manure >300kg >100kg N>zero application of fertilizer levels and types from three grass varieties in both years. This current result was in line with Worku Bekuma *et al.* (2017), who indicated that there was a significant (P<0.05) difference on the NTPP of desho grass increased from 54.6 to 79.6 as the fertilizer levels increased from 100 to 350 kgN/ha. The current result was also in line with the finding of Biniyame Mihret *et al.* (2018), who reported that the fertilized desho grass had more NTPP than unfertilized desho grass. This might be due to the nitrogen triggers the activation of dormant buds and enhances the vegetation sward filling through the highest rate of tiller replacement, which is supports a higher proportion of very active, healthier young tillers for each plant (Mushtaque *et al.*, 2010). The grass varieties appear to efficiently absorb the increased nitrogen provided in the soil and use it to form new plants, as indicated by the increased tillage number associated with fertilizer and, at the same time, the increased synthesis rate of nitrogenous substances in the plant tissues, either as protein or non-protein nitrogen.

The NTPP increased when the producton years was extended.This study was in line with Misganew Walie *et al.* (2022), who reported that the mean NTPP of desho and Napier grasses increased when the producton years extended, which in the 2018 (36.3) lower than 2019 (95.9) production years in the Aba Gerima watershed. The development of new shoots bearing on each plant results in a greater number of tillers and increase the yield for grasses as the plant fertilized and increases in tiller density (Campos *et al.,* 2013).

4.1.3. Number of leaves per plant (NLPP) (counts)

The interaction effect of grass varieties, fertilizer application and production years had a very highly significant (P<0.001) effect on the NLPP (Table 9). The maximum NLPP (236.22 and 753.32) was recorded from desho grass-*Areka*-DZF-590 at 300kg N/ha in the first and second years, respectively, while the minimum NLPP was obtained from Napier grass ILRI-16791 (81.97) and *Brachiaria decumbens-10871* (138.12) without application of fertilizer in the first and second years, respectively, with the overall mean of 313.11. The difference in number of leaves produced per plant among evaluated grass varieties could be due to the attribute of genetic variations of varieties and their adaptation performance to the given environmental condition. Number of leaves determines the photosynthetic capacity of the plants for the newly emerging leaves (Beyadglign Hunegnaw *et al.*, 2019).

In the current study, the higher NLPP was recorded from fertilized grass as compared to unfertilized grass which is 300kgN/ha >manure >100kgN/ha >0 at all grass in both years. This result was in line with findings of Priyadarshani *et al. (*2013), there were increased trends in the number of leaves with increased the levels of fertilizer application. However, this result was disagreed with Riyana *et al.* (2018), who showed that the manure has no significant effects on number of leaves per plant. The NLPP from desho grass-*Areka*-DZF-590 (707.12) at manure in the second year of the current study was higher than Biniyame Mihret *et al.* (2018) reported that mean NLPP was NPS (530), manure (388) and without fertilizer (307). Similarly, the NLPP of Napier grass ILRI-16791 at 0, 100kg, 300kg N/ha and manure fertilizer levels in years1 and 2 was higher than the values reported by Tessema Tesfaye *et al.* (2021); the NLPP of Napier grass (9.9-10.7) recorded from NPS fertilizer from 0 to 50kg/ha. This difference might come from genetics, soil type and fertility, type of fertilizer, environment condition, altitude, and management practice.

The maximum NLPP was recorded from desho grass-*Areka*-DZF-590 than others experimental grasses. This result was in line with Tobiyaw Tsegaye *et al.* (2021) reported that desho grass (894.8) had more number of leaves than Napier grass (267.5). Nevertheless, this result was contradacted with Firaol Legesse, (2023) showed that grass had no significant (P>0.05) difference in the number of leaves per plant. The NLPP of desho grass-*Areka*-DZF-590 at 0,100kg, 300kg N/ha and manure fertilizer levels and types in the first year of the current result was lower than the values reported by Beyadglign Hunegnaw *et al.* (2019), who noted that the overall mean NLPP of Brachiaria grass was 212.76. The difference might be due to genetic variation in grass, environmental variations, harvesting stage and soil fertility.In the livestock feed, the NLPP is an important parameter determining both the quantity and quality of the forage (Rodriguez *et al.*, 2014).

On the other hand, the current finding was in agreement with with Hailegabriel Ajema *et al*. (2022), who reported that the NLPP of desho grass increased when the production years extended. The NLPP of desho grass in the 2021 (7.50) was significantly higher than in the 2020

(5.79). This could be due to the difference in harvesting time of the experiment and environmental factors like temperature, soil nutrient and management.

4.1.4. Leaf length per plant (LLPP) (cm)

The interaction between grass varieties, fertilizer application and production years had a very highly significant ($P<0.001$) effect on the LLPP (Table 9). The longest length of leaves per plant (79.55 and 92.08cm) was recorded from Napier grass-16791 at manure application of fertilizer in the first and second years, respectively, while the shortest (12.75 and 15.95cm) was obtained from Brachiaria decumbens-10871 without application of fertilizer in the first and second years, respectively, with an overall mean of 37.24cm. The longest length of leaves per plant was produced from Napier grass-16791 with cattle manure applied in the second year. This could be attributed to slow release of nutrients in the manure fertilizer used by plants, which resulted in taller plants and better leaf growth. Leaf length is a key factor determining the vegetative yield of forage grasses.

In the current study, the longer length of leaf was obtained from fertilized grass as compared to unfertilized grass. This result was in line with Biniyame Mihret *et al.* (2018), longer LLPP of desho grass was recorded at NPS (30.48 cm) and manure (27.37 cm) than without fertilizer (19.87 cm). The LLPP at desho grass areka-DZF-590 and B.decumbes-10871 in both years of the current finding was shorter than Tessema Tesfaye *et al.* (2021) reported on Napier grass varieties the mean LLPP from 70-74.6cm, obtained from 0-50 kg NPS/ha. This difference might come from genetic variation of grass species, environmental conditions, fertilizer levels and types and management practices where both studies were conducted as well as the interaction effects of the current study.

The current result of Napier grass ILRI-16971 at zero, 100kg, 300kg N/ha and manure fertilizer levels and types in both years had the longest length of leaves than desho-Areka-DZF-590 and B.decumbens-10871 grass in respective fertilizer type and level. This is due to the fact that Napier grass had fast growth habits than other grass varieties (Rusdy, 2016). This result was in line with Misganew Walie *et al.* (2022), who reported that the longer LLPP obtained from Napier grass (70.7cm) than desho grass (24.5cm) in the Guder watershed, Ethiopia. The LLPP of current finding at Napier grass ILRI-16971 with manure in year 2 was longer than Tessema Tesfaye *et al.* (2021),who reported that the LLPP of Napier grass varieties from 70-74.6 cm. The current study from B.decumbens-10871 with manure in both years, and 300 kg N/ha in year 2, were longer LLPP than Wubetie Adnew *et al.* (2018), the length of leaves of Brachiaria brizantha grass ecotypes of Eth. 13809 (20.1cm), Eth. 13726 (17.29cm) and Eth. 1377 (16.22cm). However, the current result of desho grass Areka-DZF-590 at 0, 100kg, 300kg N/ha and manure fertilizer levels and types in both years were shorter than Teshale Jabessa *et al.* (2021) reported that the LLPP of desho grass cultivars of 37.6, 45.2, 45.5 and 42.3cm was measured from Kindo Kosha-DZF-591, Areka-DZF-590, Kulumsa-DZF-592 and Kindo Kosha-DZF-589, respectively. The differences beteween current and previous findings might be fertilizer levels and types, agroecology, management practice i.e., supply of nitrogen, soil type, and fertility, maturity stage, weather condition and season of experiment conducted. The leaf growth increased prominently following flower induction and before any visible stem elongation (Crowder and Chheda, 1982).

The present finding of LLPP in year 2 at 0, 100kg, 300kg N/ha and manure fertilizer levels and types of three grass varieties were longer than year 1 in their respective fertilizer levels and types. The difference among production years might be species adaptability to the tested agroecology, climatic condition, which is the variation of distribution and amount of rainfall, besides to the interaction of environment and genetics. This result was in line with Misganew Walie *et al.* (2022) who conducted a research in the Guder watershed reported that the mean LLPP of desho and Napier grass in year 2 (51.9cm) was higher than in year 1 (43.2cm). However, this result was disagree with Hailegabriel Ajema *et al*. (2022), who reported that the LLPP in year 1(41.87cm) was longer than year 2 (31.54cm). The main variations in the case of current and prior findings might be due to soil type and fertility, altitude, and species adaptability to the tested agroecology. One of the major adaptive responses to light competition in plants is an increase of plant height, *i.e*., leaf length during the vegetative period in grasses (Barre *et al*., 2015).

4.1.5. Leaf width per plant (LWPP) (cm)

The interaction between grass varieties, fertilizer rate and production years had shown very a highly significant ($P<0.001$) effect on the LWPP (Table 9). The widest leaf width per plant (2.58 and 5.57cm) was recorded from Napier grass-16791 at manure fertilizer application in the first and second years, respectively, whereas the narrowest leaf width (1.13 and 3.11cm) was recorded from desho grass-*Areka*-DZF-590 without fertilizer in the first and second years, respectively, with the overall mean of 2.99cm. This might be due to leaf development, which has been most extensively described for grasses because different grasses have different leaf sizes and their attachments to stem.The current result of leaf width per plant increased from the 0 to 100kg to 300kg N and manure from the establishment year to the next production year at all grass varieties.

In the current study, Napier grass-16791 showed a widest LWPP than other varieties at all fertilizer in both years. This due to Napier grass is more adaptable, which makes it more effective. This result was in line with Misganew Walie *et al.* (2022), who reported that the longer LWPP obtained from Napier grass (2.2 and 2.8 cm) than desho grass (1.4 and 1.5cm) in the Guder and Aba gerima watershed, respectively. This result was also in line with Aysheshim Bantihun *et al.* (2022), who reported that the Napier grass had wider LWPP than desho and Brachiaria mutica grass. The current finding of Napier grass at 0, 100kg, 300kg N/ha and manure fertilizer in both years except control of year 1 was wider LWPP than the values reported by Aysheshim Bantihun *et al.* (2022), the LWPP was 2.13, 2.4, and 2.99cm at 60, 90 and 120 harvesting days, respectively. This difference might be due to management practices, forage variation, altitude, soil type, rainfall, and temperature. Grasses with broad leaves have a bigger surface area that enhances the photosynthetic activity, thereby producing more carbohydrates that stimulate regrowth of leaf width and length. This is due to cell division, elongation, and maturation zones occurring sequentially along the base of the developing leaf.

Regarding the production year, the second year at all fertilizer type and level applied in all varieties had wider LWPP than the first year. This result was in line with Misganew Walie *et al.* (2022) who conducted a research in the Aba gerima watershed reported that the mean LWPP of desho and Napier grass in year 2 (2.2cm) was higher than in year 1 (2.1cm).

4.1.6. Leaf to stem ratio (LSR)

The interaction of grass varieties, fertilizer levels and production years had a very highly significant ($P<0.001$) effects on the LSR (Table 9). The highest leaf to stem ratio (1.27 and 1.85) was measured from desho grass-*Areka*-DZF-590 at manure fertilizer in the first and second years, respectively, whereas the lowest LSR was observed from desho grass-*Areka*-DZF-590 (0.31) and Napier grass-16791 (0.71) at control in the first and second years, respectively. The overall mean value of the current results was 1.13, which means, the dry weight of the leaf was greater than the dry weight of stem of grasses. Number leaf per tiller, leaf length, leaf width, and tiller number is the most important characteristics used to determine the leaf to stem ratio and forage quality. The leaf fraction has significant implications for the nutritive quality of the forage, as leaves contain higher levels of nutrients and less fiber than stems (Denbela Hidosa *et al.*, 2015). The higher LSR was obtained from desho grass with manure fertilizer in year 2. This difference might be due to the variation in genetic make of the grass varieties to produce leaf and stem mass, which produced more leaf (prolific tiller) before emerging more nodes.This, could be due to the reason that new leaves raise when a plant gets advance.

In the current study, the LSR increased from 0 to 100 to 300kg N/ha and manure at all grass varieties in both years.This result was disagreed with Mergia Abera *et al.* (2021), who reported that the LSR of desho grass decreased from 0.70-0.65 as the levels fertilizer increased from 0-73 kgN/ha. This result also disagreed with Tessema Tesfaye *et al.* (2021) reported that the LSR of Napier grass decreased from 1.2 to 1.0 as the application of NPS increased from 0 to 50 kg/ha. The current finding of Napier grass at 0,100kg, 300kg N/ha and manure fertilizer in both years was lower than the values reported by Misganaw Walie *et al.* (2022) who said that the overall mean LSR of Napier and desho grass was 2.3. According to Tessema Zewdu *et al.* (2010), the LSR of Napier grass increased as the frequency of defoliation increased, probably due to undisturbed development for a longer duration. The longer periods of physiological growth with reduced defoliation frequency stimulate stem growth at the expense of leaf formation, resulting in a decrease in LSR.

In the current study, highest LSR recorded from desho grass at all fertilizer type and level in both years except control in year 1 than other varieties. This result was disagree with Misganew Walie *et al.* (2022), who reported that the higher LSR obtained from Napier grass (2.3) than desho grass (1.6) Aba gerima watershed.The increasing of LSR might be due to the growth new leaves, especially from the bottom part of the plants, which were assumed the causes of fertilizer application. Therefore, treatments with a higher LSR might improve feed intake under practical grazing conditions. The current result of LSR from desho grass at 100kg, 300kg N/ha and manure fertilizer levels and types in both years was higher than Tekalegn Yirgu *et al.* (2017) on different desho grass accessions which the overall mean LSR of (0.57). This difference might be come from tillering performance and plant height, which affect the proportion of LSR of the plant and the genetic variation of grass varieties, environmental condition, altitude, soil type, rainfall, temperature and management practices (Mamaru Tesfaye, 2018).

The LSR of this finding increased when the production years extended.This result was in line with Misganew Walie *et al.* (2022) reported that the LSR of desho and Napier grasses in 2019 (2.2) was higher than in 2018 (2.0) at the Guder watershed of Ethiopia. Similarly, Hailegabriel Ajema *et al.* (2022) reported that the higher LSR of desho grass was recorded in 2021 (0.94) than in 2020 (0.48). In addition, the other scholars Birmaduma Gadisa*et al.* (2019) reported that the second harvesting cycle generated a significantly higher LSR than the first. However, the present study contradicted the findings of Denbela Hidosa *et al.* (2020) on desho grass where the higher LSR was recorded in 2017 (1.11) than in 2018 (1.04). The variation in LSR in the current study from the previous findings might be due to the grass variety difference, the amount of rainfall, management practices, altitude, soil type and fertility where both experiments were conducted.

4.1.7. Dry matter yield (DMY) (t/ha)

The interaction effect among grass varieties, fertilizer rate and production years on dry matter yield in this study was highly significant ($P<0.001$) effect (Table 9). The highest dry matter yield (12.5 and 21.88 t/ha) was recorded from Napier grass-16791 at manure application in the first and second years, respectively, while the lowest DMY was produced from *Brachiaria decumbens*-10871(5.88 and 9.23t/ha) without fertilizer in the first and second years, respectively, with the overall mean of 11.47 t/ha. The superior DMY (t/ha) was recorded from Napier grass-16791 with manure fertilizer reflects that the ability of Napier grass which is rapidly regenerate, increasing in plant height, number of leaves per tiller, number of tillers per plant, and other morphological parameters of grass could be increasing forage yield. In addition, it could be attributed to the formation of additional tillers, which conveyed an increase in leaf formation, leaf elongation and stem development as interaction effect.

In the current study, the DMY (t/ha) increased from 0 to 100 to 300kgN/ha and manure at all grass varieties in both years.This rsult was in line with Worku Bekuma *et al*. (2017) indicated that DMY of desho grass was increased from 8.32 to 13.6 t/ha as the fertilizer level increased from 100 to 250 kgN/ha. The current DMY (t/ha) of desho grass-*Areka*-DZF-590 at 0, 100kg, 300kg N/ha and manure fertilizer in the second year was higher than the finding of Awoke Kefyalew *et al.* (2020), who stated that the mean DMY of desho grass was recorded from

FL4HA3(11.38 t/ha) and FL3HA3 (8.99 t/ha). This differences could be comes from a variation on management system, the amount and distributed rainfall, the interaction response to the tested agro-ecology, soil type and fertility, fertilizer type and level, and probably the physiological stages of the plant at harvest.

In the current study, the highest DMY (t/ha) recorded from Napier grass at all fertilizer type and level in both years than other grass varieties. This result was in line with Misganaw Walie *et al.* (2022) reported that the higher DMY (t/ha) was recorded at Napier grass (9.2 t/ha) than desho grass (6.1 t/ha) at Aba Gerima watershad. The current study of Napier grass all fertilizer type and level in year 2 was higher than the result made by Aman Getiso and Diribi Mijena (2021), who reported that the mean DMY of Napier grass varieties from 9.61-16.89 t/ha under rain fed conditions. This result was also higher than Tessema Tesfaye *et al*. (2021), the DMY of Napier grass varieties from 3.9-12.7 t/ha. Inversely, the current result was lower than that of Tekalegn Yirgu *et al*. (2017), the overall mean DMY (t/ha) obtained from all tested desho accessions (25.05). This difference might be the soil type and fertility, harvesting stage, management systems and agro-ecology.

The current result of DMY increase as the production year extended.The second year at all fertilizer type and level applied for all varieties had more DMY than the first year with its respective fertilizer type and level, and grass variety. This result was agreed with Denbela Hidosa *et al.* (2020) reported that the higher DMY of desho grass varieties was recorded in 2018 (24.44 t/ha) than in 2017 (14.74 t/ha). A comparable trend was also stated by Misganew Walie *et al.* (2022) reported that the DMY of desho and Napier grasses in 2019 (11.5) was higher than in 2018 (3.9) at the Aba Gerima watershed. This could be attributes to the genetic potential of grass adapting to the tested environmental factors such as soil characteristics, moisture, and temperature over a year. All these physiognomies would contribute to increased photosynthetic activity and, hence, higher DMY production.

Table 9: Interaction effects of fertilizer application, production years and grass varieties on morphological characteristics

Factors			Parameters							
Fertilizer rate	Grass Varieties	Years	$PH_{(cm)}$	$NTPP_{(counts)}$	$NLPP_{(counts)}$	$LLPP_{(cm)}$	$LWPP_{(cm)}$	LSR	$DMY_{(t/ha)}$
Control	B. decumbens	2021	42.57^{k}	15.40^{j}	154.20^{o}	12.75^{j}	1.26^{v}	0.68^{l}	5.88^{o}
100kg N	B. decumbens	2021	57.30^{ij}	27.60^{hij}	167.04^{n}	13.57^{j}	1.60^{p}	0.88^{j}	6.76^{mn}
300kg N	B. decumbens	2021	58.50^{i}	28.27^{hij}	172.75^{n}	14.11^{j}	1.54^{r}	1.11^{h}	7.26^{lm}
Manure	B. decumbens	2021	61.93^{hi}	30.67^{ghi}	172.70^{n}	17.51^{ij}	1.58^{q}	1.18^{e}	7.32^{lm}
Control	B. decumbens	2022	57.30^{ij}	24.00^{h}	138.12^{p}	15.95^{ij}	3.40^{k}	0.88^{j}	9.23^{k}
100kg N	B. decumbens	2022	73.33^{g}	75.47^{d}	394.50^{j}	16.51^{ij}	3.84^{i}	0.96^{i}	10.13^{j}
300kg N	B. decumbens	2022	101.67^{f}	93.60^{c}	485.17^{f}	17.87^{ij}	3.93^{h}	1.12^{h}	10.77^{ij}
Manure	B. decumbens	2022	102.33^{f}	120.53^{ab}	527.08^{d}	45.17^{d}	3.71^{j}	1.15^{g}	11.43^{hi}
Control	Desho grass	2021	33.67^{l}	24.27^{hij}	113.62^{q}	17.11^{ij}	1.13^{y}	0.31^{m}	6.21^{no}
100kg N	Desho grass	2021	55.27^{ij}	29.67^{hi}	150.72^{o}	28.31^{fgh}	1.35^{t}	1.11^{h}	7.32^{lm}
300kg N	Desho grass	2021	69.93^{g}	44.67^{ef}	236.22^{l}	25.30^{ghi}	1.20^{x}	1.16^{f}	7.47^{lm}
Manure	Desho grass	2021	68.93^{gh}	49.33^{ef}	206.18^{m}	31.03^{efg}	1.93^{o}	1.27^{f}	10.76^{ij}
Control	Desho grass	2022	51.30^{j}	37.77^{fgh}	428.09^{i}	20.53^{hij}	3.11^{k}	1.16^{f}	11.65^{h}
100kg N	Desho grass	2022	57.30^{ij}	108.7^{b}	494.50^{e}	31.03^{efg}	4.1^{g}	1.78^{b}	16.04^{e}
300kg N	Desho grass	2022	75.33^{g}	125.07^{a}	753.32^{a}	37.35^{def}	4.22^{f}	1.79^{b}	17.52^{d}
Manure	Desho grass	2022	75.33^{g}	127.13^{a}	707.12^{b}	30.09^{fgh}	4.69^{d}	1.85^{a}	17.55^{d}

Table 9 (continued)

Fertilizer rate	Grass Varieties	Years	$PH_{(cm)}$	$NTPP_{(counts)}$	$NLPP_{(counts)}$	$LLPP_{(cm)}$	$LWPP_{(cm)}$	LSR	$DMY_{(t/ha)}$
Control	Napier grass	2021	51.13^{j}	18.87^{ij}	81.97^{r}	21.90^{ghij}	1.43^{s}	0.79^{k}	6.21^{no}
100kg N	Napier grass	2021	149.2^{de}	20.53^{ij}	83.98^{r}	58.29^{c}	2.46^{n}	0.99^{i}	7.57^{l}
300kg N	Napier grass	2021	153.0^{cd}	28.55^{hij}	112.05^{q}	74.37^{b}	2.57^{m}	1.14^{g}	8.57^{k}
Manure	Napier grass	2021	175.00^{b}	20.73^{ij}	108.72^{q}	79.55^{b}	2.58^{l}	1.16^{f}	12.50^{g}
Control	Napier grass	2022	103.67^{f}	44.17^{efg}	378.87^{k}	40.19^{de}	4.57^{e}	0.71^{k}	13.34^{f}
100kg N	Napier grass	2022	159.83^{cd}	45.07^{ef}	438.68^{h}	77.05^{b}	5.53^{b}	1.37^{d}	19.92^{c}
300kg N	Napier grass	2022	163.30^{c}	45.90^{ef}	451.94^{g}	76.17^{b}	5.46^{c}	1.65^{c}	21.07^{b}
Manure	Napier grass	2022	187.00^{a}	53.53^{e}	557.04^{c}	92.08^{a}	5.57^{a}	0.94^{i}	21.88^{a}
Overall mean			91.01	51.65	313.11	37.24	2.99	1.13	11.47
SEM±			7.26	13.92	8.57	9.9	0.003	0.002	0.77
CV%			5.79	7.23	0.94	8.45	1.92	3.64	7.65
R^2			0.99	0.99	0.99	0.98	0.99	0.99	0.98
Frt*Frg			<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Frg*yr			<.0001	<.0001	<.0001	0.0001	<.0001	<.0001	<.0001
Frt*yr			<.0001	<.0001	<.0001	0.0104	<.0001	<.0001	<.0001
Frt *Frg*yrs			<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0006

Where: Means in the same column followed by different letters were significantly different, PH=plant height, NTPP= Number of tiller per plant, NLPP=Number of leaves per plant, LLPP= Length leaf per plant, LWPP= Length width per plant, LSR=leaf to stem ratio, DMY (t/ha) =Dry matter yield ton per hectare, SEM= Standard error of mean, CV= Coefficient of variation, R^2=Coefficient of determination

4.2. Effects of fertilizer, varieties and production years on the nutritional quality of grasses

Overall analysis result showed that there were significant interaction effects among fertilizer application, grass varieties and production years on DM, CP, NDF, ADF, ADL, IVOMD, CPY and ME ($P<0.001$), Ash and OM ($P<0.05$) as shown in Table 10.

4.2.1. Dry Matter content (DM %)

The interaction effect between fertilizer application, grass varieties and production years in the current study had a significant ($P<0.05$) effect on dry matter content (Table 10). The highest DM% was recorded from Napier grass-16791(93.56%) and desho grass-*Areka*-DZF-590 (94.36%) at manure fertilizer in the first and second years, respectively, while the lowest DM% was observed from *Brachiaria decumbens*-10871 (89.4%) and desho grass-*Areka*-DZF-590 (89.31%) without fertilizer in the first and second years, respectively, with the overall mean of 91.51%. This might be due to the forage itself and the variation in nutrient status of feeds. Dry matter is significant, as the moisture content will give evidence as to how forage will be preserved when stored by baling or ensiling. The higher dry matter content, the lower fresh weight of forage needed to achieve a target nutrient intake, whether this is grazed grass or conserved forage.

The interaction effect between fertilizer application, grass varieties and production years in the current study had a significant ($P<0.05$) effect on dry matter content. This result was disagree with Biniyam Mihret *et al.* (2018) reported that the type and level of fertilizer had no significant effect on the DM content of desho grass. The DM content of current study was lower than the findings of Awoke Kefyalew *et al.* (2020) at control, 12,000 kg compost/ha, 100kg N/ha and a mixture of 50 kgN+6,000 kg compost/ha had a DM% of 94.22, 94.05, 94.56 and 94.56, respectively. This difference might be due to soil condition, genetic variation of grass, harvesting age, the levels of fertilizer, the interaction effect and the drying methods of samples.

Additionally, the current study of DM % recorded from desho grass at all fertilizer types and levels in both years was lower than Teshale Jabessa *et al.* (2021), the mean DM% of desho grass varieties from 92.5-95.02%. However, the current study of DM % at Napier grass-16791 with manure fertilizer in both years was higher than Deribe Gemiyo *et al.* (2017), who reported that the mean of DM% of Napier grass accessions ranged from 91.9 to 93.6%. In the current study in the case of B. decumbens, the dry matter content at all fertilizer types and levels in years 1 and 2 was higher than the value reported by Wubetie Adnew *et al.* (2018) on Brachiaria brizantha grass accessions of DM content was Eth. 13809 (37.75%), Eth.13727 (36.71%) and Eth.1377 (35.71%). This difference among current and previous reports might be due to the amount of rainfall, the season of sowing, type and levels of fertilizer, soil fertility and type, harvesting stage, as the DM content increased with delayed harvesting because of decreased moisture content in leaves as the plants aged, and total field management system where the experiment was conducted.

On the other hand, the interaction result revealed that for three vartiety with 0, 100, 300 kg N/ha and manure fertilizer, the maximum DM% recorded in year 2 compared to year 1. This result was disagreed with the value reported by Hailegabriel Ajema *et al.* (2022), who reported that the higher mean DM % of desho grass recorded in 2020 (93.07%) than in 2021 (92.61%). This difference might be due to the environmental conditions from year to year, and management practices.

4.2.2. Ash and Organic Matter (OM)

The interaction effects among fertilizer appication, grass varieties and production years in the current study were significant ($P<0.05$) effect on Ash and organic matter contents (Table 10). The highest ash content (10.67 and 14.01%) was recorded from desho grass-*Areka*-DZF-590 without fertilizer in the first and second years, respectively. The lowest ash content was from *Brachiaria decumbens*-10871 (6.32 and 7.37%) at manure fertilizer in the first and second years, respectively. While the highest organic matter content was found at the lowest ash content and the lowest organic matter content was recorded from the highest ash content. The overall mean of ash and organic matter content was 9.52 and 90.55 percent, respectively. The concentration of ash in forage species varies from species to species under the same management conditions, which might be due to variations in genetic makeup and adaptability to climatic conditions.

In the current study, the ash content decreased from 0 to 100 to 300kg N/ha and manure at all grass varieties. This result was disagreed with Biniyame Mihret *et al.* (2018), who stated that the highest ash content was recorded at manure (17.77%) than without fertilizer (16.41%) and NPS fertilizer (15.76%), while the highest OM content was the inverse of ash cotent. This difference might be due to the genetic variations of grasses, soil type, altitude, harvesting ages and management systems (Campos *et al.*, 2013).

The current study was lower than Nigesu Dessie *et al.* (2018) indicates that the Ash content of Napier grass was 16.40%. but, the mean OM content obtained from desho grass (89.21%) and Napier grass (88.78%) was lower than the present findings of OM content in case of desho and Napier grass at all fertilizer levels and types in both years. In this result, the higher ash content (14.0%) was recorded from unfertilized desho grass in year 2, which had a lower content of OM (86.0%), and the lower content of ash (6.32%) was recorded from B.decumbens at manure in year 1, which had also a higher content of OM (93.68%). This indicates that when the content of ash becomes higher, it might be due to soil contamination during harvest of the plant material.

The current interaction result revealed that for three variety with 0, 100, 300 kg N/ha and manure fertilizer, the higher ash content recorded in year 2 compared to year 1. The significant difference of ash content across the experimental years might be due to the high amount and distribution of rainfall in year 2 cases comtamination of plant materials. This result was in line with the value reported by Hailegabriel Ajema *et al*. (2022), who reported that the higher mean ash content of desho grass was recorded in 2021 (6.12%) than in 2020 (5.11%).

Generally, the increasing trend in Ash content or decreasing of OM as fertilizer application level decreased and the production years extended. This could be a result of a decrease in silicic acid, the major Ash component, which reduces with a decline in water uptake by the plants, thereby reducing the total Ash content of the plants (Quigley and Anderson, 2014). Forage grasses grown in different environments had ash content ranging from 2 to 19% (Lee, 2018). Therefore, the ash content of this study ranged from 6.32 to 14.01% with an overall mean of 9.49 % was within this range.

4.2.3. Crude protein content (CP %)

The interaction effects between fertilizer application, grass varieties and years in the current study were significant ($P<0.001$) effect on the crude protein content (Table 10). The highest CP content (13.72 and 14.09 %) was recorded from Napier grass-16791 at manure fertilizer in the first and second years, respectively, while the lowest CP content (8.26 and 10.0 %) was obtained from *Brachiaria decumbens*-10871 without fertilizer in the first and second years, respectively, with an overall mean of 11.88%. The variability in CP content between the tested treatment groups might be due to species differences to uptake of fertilizer, in quality traits and growth rate performance in the given environmental conditions.

The CP content of fertilized grass varieties in both years was higher as compared to unfertilized grass varieties. This might be because of application of fertilizer allowed for continuous developing of new leaves, which increase the CP content. This result was in line with Biniyame Mihret *et al.* (2018) who reported that the CP content of desho grass recorded from NPS fertilizer (10.95) and manure (10.04%) was higher than without fertilizer (9%). The current result of CP content increased as the fertilizer levels increased. This result was in line with Abdi Hassan *et al.* (2015), who reported that the CP content of *Cenchrus ciliaris* and *Panicum maximum grasses* were increased from 13.54 to 19.84% as the level of fertilizer increased from 0 to 100 kgN/ha under irrigation conditions.

In the current study, Napier grass-16791 at all fertilizer levels in both years showed a higher CP content than other varieties. This result was in line with Misganaw Walie *et al.* (2022) reported that the higher CP content was recorded at Napier grass (91.3g/kg) than desho grass (70.0g/kg) at Aba Gerima watershad. The current result of Desho grass areka-DZF-590 at all fertilizer types and levels in both years was higher than the finding of Geberemariyam Terefe *et al.* (2022) for Desho grass (9.85% CP). The variations between the current and the previous research findings might be attributed to varietal genetic variability, differences in rainfall, soil fertility, and other climatic conditions in which the studies were carried out (Tessema Zewdu *et al.*, 2011).

In the current study, the CP content increased as the production year extended. Means the first year at all fertilizer type and level from all grass varieties had less CP content than the second year. The reason for the reduction in CP content might be due to the increments of fiber contents indicate that more cellulo-lignose formation and decrement insoluble fractions of the feeds. This result was in line with the result reported by Hailegabriel Ajema *et al.* (2022) who conducted a research on desho grass; the first year harvest (8.36%) had less Crude protein content than the second year harvest (12.58%). However, this result antagonist with Misganew Walie *et al.* (2022) who conducted a research at the Aba Gerima watershed reported that the CP content of desho and Napier grasses was not affected by production years.

Generally, forage species with a CP content range of 9-12% are characterized as highly palatable (Machogu, 2013). The overall CP content of the current study was 11.88%, this shows that the CP content was higher than the recommended minimum maintenance CP requirement (7.2%) of ruminants (Singh and Oosting, 1992) and the minimum threshold level (7%) for optimal rumen microbial activity (like satisfactory development of ruminal cellulolytic bacteria) (Van Soest, 1994). According to Lonsdale (1989), feeds that have <120,120-200 and >200gCP/kg DM are classified as low, medium and high protein sources. Therefore, the present experimental grass varieties was a medium protein source and highly palatable for ruminants.

4.2.4. Crude protein yield (CPY) (t/ha)

The interaction effects between fertilizer application, grass varieties and production years of the current study were highly significant (P<0.001) effect on the crude protein yield (t/ha) (Table 10). The highest CPY (1.72 and 3.08 t/ha) was recorded from Napier grass-16791 at manure fertilizer in the first and second years, while the lowest CPY was obtained from *Brachiaria decumbens*-10871 (0.49 and 0.92 t/ha) without fertilizer in the first and second years, respectively, with an overall mean of 1.41t/ha. This variation might be related to the amount of dry matter yield and CP content of plot, which obtained by multiplication of dry matter yield by crude protein content.

The higher CPY of the current study was recorded from fertilized grass as compared to unfertilized grass. This result was in line with the result reported by Biniyame Mihret *et al. (*2018), on desho grass the highest CPY was obtained from NPS fertilizer (2.76 t/ha) and manure (1.39 t/ha) than without fertilizer (0.7 t/ha). This result also agree with Bizelew Gelayenew *et al.* (2020), the CPY of Napier grass increased from 4.48 to 6.00 t/ha as the levels of fertilizer increased from 0 to 150 kg N/ha. The present findings of desho grass-*Areka*-DZF-590 at all fertilizer types and levels in year 2 were higher than the result of Awoke Kefyalew *et al*. (2020) stated that the CPY of 0.9, 0.77 and 0.67 t/ha was recorded at a mixture of 50kg N/ha and 6,000kg compost/ha,100 kg N/ha and control, respectively. This difference might come from levels and types of fertilizer application, soil type and fertility, altitude, interaction effect and harvesting age.

The interaction effect of variety, fertilizer application and years in the current study had significant effect on the CPY. This result is in line with Wubetie Adnew *et al.* (2018), on Brachiaria brizantha grass the highest CPY was recorded from Eth.13809 (0.66 t/ha), followed by Eth.1377 (0.52 t/ha) and Eth.13726 (0.38 t/ha). The current result from desho grass-*Areka*-DZF-590 at all fertilizer types and levels in year 2 was higher than the result reported by Bimrew Asmare *et al.* (2017) for the CPY of desho grass at 90 (1.21 t/ha) and 120 (1.21 t/ha) days of harvesting ages. This difference might be due to genetic potentials of grass varieties, dry matter yield production, harvesting age and environmental conditions as reported by (Ashagre Abate, 2008).

The CPY increase as the production year increased. Means that the CPY in year 2 all fertilizer types and levels of three grass varieties was higher than in year 1 at. This might be related to the higher DMY and CP% recorded in the year 2.This result was in line with the result reported by Misganew walie *et al*. (2022) the CPY(g/kg) of desho and Napier grass was affected by production years, of which the year 2 (1225.1) higher than the year 1 (80.7).

4.2.5. Neutral detergent fiber (NDF)

The mean NDF content were highly significantly (P<0.001) affected by the interaction effects between fertilizer application, grass varieties and years (Table 10). The highest NDF content (68.23 and 68.9%) was obtained from *Brachiaria decumbens*-10871 without fertilizer in the first and second years, respectively, while the lowest NDF content (50.77 and 50.65%) was recorded from Napier grass-16791 at manure fertilizer in the first and second years, respectively, with the overall mean of 59.03%. This variation might be due to the differences in genetic makeup difference and physiological performance that responds for the environment under the same management practices.The highest mean NDF content of the current study was recorded from unfertilized grass varieties as compared to fertilized grass varieties in years 1 and 2. This might be attributed to decrease NDF content, increased growth rate of new leaves and shoot which are lower in plant structural components because of fertilizer application (Abdi Hassan *et al.*, 2015).

The current study of NDF content at manure < 300 <100kg N/ha <0 at all grass varieties in both years. This might be the application of fertilizer to raise new leaves, tillers and shoots, which minimize the NDF content in the fertilizer level increased, but there is a low renewal of leaves and tillers in the unfertilized grass, as a result, plant tissue matures and accumulates more NDF. This result was in line with Biniyame Mihret *et al.* (2018) who reported that the highest NDF content was observed without fertilizer (61%), than manure (55%) and NPS fertilizer (51%). This result was also in line with Bizelew Gelayenew *et al.* (2020), the NDF content of Napier grass increased from 64.39 to 65.24% as the levels of fertilizer decreased from 150 kgN/ha to zero. The NDF% from Napier grass-16791 at manure in both years was lower than Hussen Ebrahim *et al.* (2020) reported that the NDF content of Napier grass was unfertilized (60.6%), 69 kg/ha (58.1%) and 115 kg/ha (57.5%) at cutting height of 7.5cm. The NDF content of *Brachiaria decumbens*-10871 at 0, 100kg, 300kg N/ha and manure fertilizer levels in both years of the current result was higher than the values made by Mutimura *et al.* (2017), who reported that the NDF content of Brachiaria decumbens (52.3%) and Brachiaria hybrid mulato (42.9%). This difference might be due to the variation in environmental condition, genetic potential of varieties, season of sowing; harvesting stage, altitude, soil type and fertility, fertilizer types and levels where the current and previous experiments were conducted. Jung and Engles (2002) suggested that as stems mature, the protein content decreases and NDF content increases, which generally estimates the percentage of total fiber (cellulose, hemicellulose and lignin) increases due to increases in xylem tissue. NDF % is adversely associated with digestibility and feed intake indicates as the NDF content in forages increased, animals were able to poor digestibility and consume less forage. A better prediction of forage intake can be made using NDF; therefore, better rations can be formulated (Harper and McNeill, 2015), and a decrease in NDF content has been associated with increasing digestibility and hence feed intake (McDonald *et al.,* 2002).

The current interaction result revealed that for three vartiety with 0, 100, 300 kg N/ha and manure fertilizer, the maximum NDF recorded in year 1 compared to year 2. This might be due to the first year had a lower rainfall distribution than the second year, which causes a more rapid maturation of plants, which increases the cell wall content, including lignin. This result was in line with Misganew walie *et al*. (2022) the NDF content of desho and Napier grass in the first year was higher than in the second year. Similarly, this result agree with the result reported by Hailegabriel Ajema *et al*. (2022), the NDF content of desho grass was affected by production years, which year 1 (75.23%) higher than year 2 (71.76%). This could be attributed to an increase in fiber content, which is accompanied by a decrease in CP content, as well as an increase in the fraction of lignified structural tissue (McDonald *et al.,* 2002). Environmental conditions such as temperature and water stress might also influence cell content, resulting in reduced the NDF content.

Forage grasses grown in different environments had NDF content ranging from 27 to 90 % (Lee, 2018). So, the present result was under this range. According to Schroeder (2012), high NDF content is above 72% results in decreased or low voluntary feed intake and digestibility of forage, feed conversion efficiency and longer rumination time. Therefore, this result ranged from

50.65 to 68.90 % was observed to be below this threshold level, which indicates no effect on digestibility and feed intake.

4.2.6. Acid detergent fiber (ADF %)

The acid detergent fiber content of this study was highly significantly ($P<0.001$) affected by the interaction effects among fertilizer application, varieties and years as shown in Table 10. The highest mean ADF content (47.93 and 46.92%) was found from *Brachiaria decumbens*-10871 without fertilizer in the first and second years, respectively, while the lowest ADF content was recorded from Napier grass-16791 (34.09%) and desho grass-*Areka*-DZF-590 (35.68%) at manure fertilizer in the first and second years, respectively. The overall mean of ADF content was 39.52%. The fertilizer application increased from zero to 100 kg/ha to 300 kgN/ha and manure, and years was extended, the ADF content become decreased. This might be due to associated with the fertilizer application, which promotes the growth of new leaves and shoots, resulting in low lignin that compensates for the increase in lignin content of other tissues.

The current study of ADF content at unfertilized grass in both years was higher than fertilized grass and it tends that as the application of fertilizer level increased, the ADF concentration decreased. This result was in line with Biniyame Mihret *et al.* (2018), who reported that ADF content of desho grass was significantly affected by types and levels fertilizer application. The highest ADF was observed without fertilizer (52%) than manure application (44%) and NPS fertilizer (41%). This result was also in line with Bizelew Gelayenew *et al.* (2020) reported that the ADF content of Napier grass decreased from 40.96 to 40.16% as the levels of fertilizer increased from 0 to 150 kgN/ha at Holetta. The deviations in the tested grass varieties of ADF in the present and earlier studies might be due to agroecology, environmental conditions (rainfall, soil type and fertility), harvesting stage, distinction in CP, a decrease in leaf to stem proportion, increase in cell wall lignification.

The current study of ADF content from unfertilized desho grass-*Areka*-DZF-590 in year 1(44.84 %) was higher than the report made by Denbela Hidosa *et al.* (2020) on desho grass-Kulumsa variety of the ADF was 44.63 % in South Omo, Ethiopia. This difference might be due to associated with the genetic variation of grasses, altitude differences, soil type and fertility, fertilizer types and the environment in which the experiment was done where the previous and current experiments were conducted.

The current interaction result revealed that for three vartiety with 0, 100, 300 kg N/ha and manure fertilizer, the maximum ADF recorded in year 1 compared to year 2. This might be due to the lower LSR and CP % which rise the components of structural cell wall (Ammar *et al.*, 2010). This result was in line with the result reported by Hailegabriel Ajema *et al*. (2022) the higher ADF content of desho grass was recorded in year 1 (41.56%) than year 2 (41.20%). According to the recommendation of Mass *et al. (*2015), roughage feeds with less than 40% ADF are categorized as high quality and those with greater than 40% as low quality, which will cause a low intake and digestibility of forage. Hence, the ADF value of all evaluated grass varieties at all fertilizer levels and types in both years of the current study except unfertilized grasses in both years was lower than 40%, ranging from 35.68-47.93%; this could be indicative of its better digestibility.

4.2.7. Acid detergent lignin (ADL)

The interaction effects between fertilizer application, grass varieties and production years on the acid detergent lignin content in the current study were highly significant ($P<0.001$) effect as shown in Table10. The highest ADL content was recorded from *Brachiaria decumbens-10871*(7.02%) and desho grass-*Areka*-DZF-590 (6.27%) without fertilizer in years 1 and 2, respectively. While the lowest ADL content was recorded from desho grass-*Areka*-DZF-590 (4.30%) and Napier grass-16791(3.08%) at manure fertilizer in years 1 and 2, respectively, with the overall mean of 5.27%. It is the lignin part of the forage varieties and is inversely related with digestibility, showing that the higher the ADL content, the lower digestibility of the feed and vice versa. High ADL content might be the result of the concentration of structural carbohydrates at unfertilized grass than fertilized grass.

The ADL content of fertilized grass varieties in year 2 was lower than fertilized grass varieties in year 1 and unfertilized grass varieties in both years. This is due to the application of fertilizer, which the formation of a fresh and new more leaves than without fertilizer. This result was in line with Abdi Hassan *et al.*(2015) reported that the ADL content of *Cenchrus ciliaris* and *Panicum maximum* grasses was decreased from 10.25 to 9.3 and 6.59% as the levels of nitrogen fertilizer increased from 0 to 50 and 100 kg/ha, respectively. This result was also in line with Biniyame Mihret *et al.* (2018), who indicated that the highest ADL content was recorded from without fertilizer (13.5%), than manure (9.8%) and NPS fertilizer (8.3%).

The current interaction results of three-tested grass varieties at all fertilizer types and levels in both years were significantly difference on the ADL content. This result was disagree with Misganew Walie *et al.* (2022) reported that the grass species had no significant effect on the ADL content at aba gerima watershed. The current study was lower than Ghiwot Wanania (2019), who conducted a research on *Cenchrus ciliaris* and Awoke Kfyalew *et al.* (2020) on desho grass with value of 8.96 and 12.21%, respectively. The ADL content of desho-*Areka*-DZF-590 at all fertilizer types and levels in both years of the current study were higher than H/Gabriel Ajema *et al.* (2022) reported that ADL content of desho grass (4.93%). The lignin concentration of the cell wall rose dramatically as the overall cell wall concentration of the grasses increased.

The current interaction result revealed that for three variety with 0, 100, 300 kg N/ha and manure fertilizer, the maximum ADL recorded in year 1 compared to year 2. This result was in line with the result reported by Hailegabriel Ajema *et al*. (2022), the maximum ADL content of desho grass was recorded from 2020 (4.57%) than 2021 (4.47%). Forages with higher ADL content had a low overall digestibility of the feed by limiting nutrient availability and forages with lower ADL concentrations are more desirable for livestock production and productivity (Van Soest, 1994). According to the recommendation of Reed *et al.* (1986), the feeds with less than 10% ADL content are categorized as high quality and those with greater than 10% as low quality, which is limits DM intake. According to this, the present findings were classified under a good range of quality. Forage grasses grown in different environments had ADL content ranging from 1 to 21% (Lee, 2018). Therefore, the present result was under this range (1 to 21%).

4.2.8. In Vitro Organic Matter Digestibility (IVOMD) (%)

The interaction effects of fertilizer application, type of varieties and production years in the current study were highly significant ($P<0.001$) effect on In vitro organic matter digestibility (Table 10). The highest IVOMD % was obtained from *Brachiaria decumbens*-10871 (65.14%) and Napier grass-16791(68.09 %) with manure fertilizer in years 1 and 2, while the lowest IVOMD % (50.39% and 51.61%) was recorded from Napier grass-16791 without fertilizer in years 1 and 2, respectively, with the overall mean of 56.39 %. It shows that varieties and fertilizer application have to be considered not as independent factors since they will be cultivated under certain conditions of climate, management and soil.

In the current study, a higher IVOMD content was obtained from fertilized grass in both years than unfertilized grass, which might be associated with a higher and lower proportion of CP content. This result was in line with Diribi Mijena *et al.* (2022) on Bracharia mulato II grass the levels of NPS fertilizer increased from 0 to 200kg/ha, the IVOMD content was increased from 53.17 to 55.28%. IVOMD was affected by variety in the current study agrees with the report of Nguku Susan (2015) reported that IVOMD was affected by species of Brachiaria grass, the highest IVOMD was obtained from Brachiaria hybrid Molto-II (53.3), Brachiaria decumbens (52.3), Brachiaria la liberated (46.4) while the lowest (46) for Brachiaria marandu. The current result of B.decumbens grass at all fertilizer types and levels in both years, except control groups in year 1 was higher than Susan *et al.* (2016) reported that the IVOMD in the case of B.decumbens grass was 52.3%. The differences between the existing and earlier findings might be environmental conditions, the interaction effect, altitude, soil type and fertility, management practices and type of fertilizer as well as interaction effects between environment and genetics where both studies were conducted. In the current study of IVOMD content, significantly ($P<0.001$) higher and lower IVOMD was obtained from manure fertilized Napier grass in year 2 (68.09%) and unfertilized Napier grass in year 1 (50.39%), respectively, which might be associated with a higher and lower proportion of CP %. The current results of IVOMD% from desho grass at all fertilizer types and levels in both years were comparable with the result made by Melkamu Berhanu *et al.* (2022), who reported that the IVOMD % of desho grass was 56.10.

The current result of IVOMD content in year 2 at all fertilizer types and levels of three grass varieties was higher than year 1. This result was in line with the result reported by Hailegabriel Ajema *et al*. (2022), who reported that the higher IVOMD of the desho grass was recorded in 2021 (66.95%) than in 2020 (58.22%). It is important to bear in mind that environmental factors like climate, soil fertility, and managements like cutting interval and other management practices have very profound influence on digestibility of grass (Gezahagn kebede *et al,*. 2017). The current result of IVOMD content was higher than the critical threshold level of 50% required for feeds to be considered to have acceptable digestibility (Owen and Jayasuriya, 1989). The higher digestibility could be partially attributed to the higher CP content of the feeds. This would be true, especially for those grasses that have a relatively higher amount of CP content, which in turn is known to favor high digestibility by animals. However, the lower digestibility records might be associated with a higher proportion of NDF, ADF and lignin (Moore and Jung, 2001).

4.2.9. Metabolizable energy (ME) (MJ/kg)

The interaction effects of grass varieties, fertilizer application and production years in the current study were highly significant ($P<0.001$) effects on Metabolizable energy (Table 10). The highest ME (11.77 and 12.84 MJ/kg) was recorded from Napier grass-16791 with manure in the first and second years, respectively, while the lowest ME (7.43 and 7.46 MJ/kg) was obtained from *Brachiaria decumbens*-10871 without fertilizer in years 1 and 2, respectively, with the overall mean of 10.05 MJ/kg. It indicates that at Napier grass-16791 with manure have better energy sources for Animals. The variations might be the interaction effect; the genetic potential of grass used the soil nutrients.

The current study of ME at manure >300 >100kgN/ha>zero from all grass varieties in both years. This result was in line with Diribi Mijena *et al.* (2022) reported that the ME (MJ/kg) of Bracharia mulato II grass the ME increased from 8.49 to 8.78 MJ/kg with the increase the levels of fertilizer from 0-200 kg NPS/ha. The current result of ME from Napier grass at all fertilizer types and levels in both years was higher than Turano *et al*. (2016) reported 7.1MJ/KgDM for Napier grass in Tanzania, but unfertilized Napier grass in both years of the current result was lower than the report of Maleko *et al. (*2019), the ME values of 7.94 MJ/KgDM. Regarding production years, the current result of ME in year 2 at all fertilizer types and levels of three grass varieties was higher than year 1 in respective fertilizer levels and variety. This result was in line with the result reported by Hailegabriel Ajema *et al*. (2022), the higher ME was recorded in 2021 (10.71 MJ/kg) than in 2020 (9.31 MJ/kg). The differences among the current and earlier reports might be the environmental conditions, amount and distribution of raainfail, soil type and fertility, management system, and interaction effects between environment and genetics.

According to Lonsdale (1989), feeds that have <9, 9-12 and >12 MJ ME/kg DM are classified as low, medium and high energy sources, respectively. The critical threshold of ME of feeds is 7.5 MJ/kg DM (Owen and Jayasuriya, 1989). Based on this classification, the current study of three grass varieties fertilized with manure and 300kg in both years was categorized under high-energy feeds, and three experimental grass varieties fertilized with 100kg in year 2 were categorized under medium energy feeds, while the remaining had low energy values of feeds.

Table 10: Interaction effect of fertilizer, production years and grass varieties on chemical composition of the grasses

Factors			Parameters (dry matter basis)									
Fertilizer Rate/type	Grass varieties	Year	DM (%)	Ash (%)	OM (%)	CP (%)	CPY(t /ha)	NDF (%)	ADF (%)	ADL (%)	IVOMD (%)	ME (MJ/kg)
control	B.decumbens	2021	89.4^{n}	10.62^{d}	89.38^{j}	8.26^{u}	0.49^{n}	68.23^{b}	47.93^{a}	7.02^{a}	50.4^{n}	7.43^{k}
100kg N	B.decumbens	2021	90.16^{l}	8.21^{i}	91.79^{e}	11.62^{l}	0.79^{l}	59.66^{f}	39.42^{f}	5.83^{abcd}	54.49^{fghij}	8.24^{i}
300kg N	B.decumbens	2021	90.78^{i}	7.11^{l}	92.89^{b}	12.06^{i}	0.87^{k}	59.30^{g}	39.33^{f}	5.79^{abcd}	56.17^{e}	10.26^{f}
manure	B.decumbens	2021	93.39^{c}	6.32^{m}	93.68^{a}	11.93^{j}	0.87^{k}	57.32^{i}	34.26^{k}	5.28^{abcdef}	65.14^{b}	10.77^{de}
Control	B.decumbens	2022	90.74^{i}	11.22^{c}	88.78^{k}	10.00^{o}	0.92^{j}	68.90^{a}	46.92^{b}	6.07^{abcd}	54.76^{fghi}	7.46^{k}
100kg N	B.decumbens	2022	91.32^{g}	9.84^{f}	90.16^{h}	11.66^{l}	1.18^{i}	56.58^{k}	38.52^{g}	5.90^{abcd}	55.18^{efgh}	10.19^{f}
300kg N	B.decumbens	2022	91.43^{f}	8.83^{g}	91.17^{g}	12.67^{g}	1.37^{h}	56.53^{kl}	38.43^{g}	5.67^{abcd}	60.23^{d}	12.66^{ab}
Manure	B.decumbens	2022	93.58^{b}	7.37^{l}	92.63^{b}	12.59^{h}	1.44^{g}	55.60^{l}	36.52^{j}	5.08^{abcdef}	67.09^{a}	12.67^{ab}
control	Desho grass	2021	89.66^{m}	10.67^{d}	89.33^{j}	10.48^{m}	0.65^{m}	61.26^{d}	44.84^{c}	6.83^{ab}	50.85^{n}	7.44^{k}
100kg N	Desho grass	2021	90.90^{h}	8.03^{j}	91.97^{d}	11.78^{k}	0.86^{k}	59.81^{e}	39.56^{f}	5.61^{abcde}	53.13^{kl}	8.54^{h}
300kg N	Desho grass	2021	90.96^{h}	7.26^{l}	92.74^{b}	11.66^{l}	0.87^{k}	58.58^{h}	39.43^{f}	5.25^{abcdef}	53.49^{ijkl}	10.54^{e}
manure	Desho grass	2021	93.53^{b}	7.64^{k}	92.36^{c}	12.71^{f}	1.37^{h}	56.59^{k}	36.03^{j}	4.30^{cdef}	54.30^{fghijk}	11.03^{d}
Control	Desho grass	2022	89.31^{o}	14.01^{a}	86.00^{m}	10.65^{m}	1.24^{i}	60.84^{d}	43.96^{d}	6.27^{abc}	52.50^{lm}	$7. 95^{j}$
100kg N	Desho grass	2022	91.27^{g}	10.61^{d}	89.39^{j}	12.08^{i}	1.94^{f}	57.60^{i}	38.60^{g}	5.04^{abcdef}	54.79^{fgh}	9.70^{g}
300kg N	Desho grass	2022	91.47^{f}	10.07^{e}	89.93^{i}	12.92^{e}	2.27^{e}	56.70^{j}	38.59^{g}	5.64^{abcde}	55.57^{efg}	12.45^{b}
Manure	Desho grass	2022	94.36^{a}	9.57^{g}	90.43^{g}	13.54^{c}	2.37^{d}	56.40^{k}	35.68^{j}	4.13^{cdef}	55.62^{ef}	12.53^{b}

Table 10 (continued)

Fertilizer Rate/type	Grass varieties	Year	DM (%)	Ash (%)	OM (%)	CP (%)	CPY(t /ha)	NDF (%)	ADF (%)	ADL (%)	IVOMD (%)	ME (MJ/kg)
control	Napier grass	2021	90.34^{k}	9.71^{f}	90.29^{h}	8.31^{p}	0.52^{n}	65.83^{c}	40.76^{e}	6.84^{ab}	50.39^{n}	7. 48^{k}
100kg N	Napier grass	2021	90.55^{j}	8.62^{h}	91.38^{f}	11.94^{j}	0.99^{j}	59.89^{e}	39.74^{f}	4.67^{bcdef}	53.41^{jkl}	8.47^{hi}
300kg N	Napier grass	2021	90.76^{i}	8.45^{h}	91.55^{f}	13.04^{d}	1.02^{j}	58.99^{h}	37.73^{h}	4.75^{abcdef}	54.03^{hijk}	10.76^{e}
manure	Napier grass	2021	93.56^{b}	8.25^{i}	91.75^{e}	13.72^{b}	1.72^{f}	50.77^{m}	34.09^{k}	4.61^{bcdef}	60.36^{cd}	11.77^{c}
Control	Napier grass	2022	90.72^{i}	12.9^{b}	87.10^{l}	10.18^{n}	1.36^{h}	66.60^{c}	44.76^{c}	4.86^{abcdef}	51.61^{mn}	7.60^{k}
100kg N	Napier grass	2022	91.84^{d}	11.38^{c}	88.62^{k}	13.56^{c}	2.70^{c}	57.60^{i}	39.70^{f}	4.61^{bcdef}	60.27^{d}	9.54^{g}
300kg N	Napier grass	2022	91.71^{e}	11.35^{c}	88.65^{k}	13.71^{b}	2.89^{b}	56.43^{j}	37.23^{i}	3.35^{ef}	61.59^{c}	12.80^{a}
Manure	Napier grass	2022	94.32^{a}	9.83^{f}	90.17^{h}	14.09^{a}	3.08^{a}	50.65^{l}	36.15^{j}	3.08^{f}	68.09^{a}	12.84^{a}
Overall mean			91.51	9.49	90.51	11.88	1.41	59.03	39.52	5.27	56.39	10.05
SEM±			0.05	0.16	0.16	0.02	0.03	0.03	0.04	0.02	0.54	0.001
CV%			0.23	4.16	0.44	0.93	8.09	0.27	0.47	2.29	1.3	0.26
R^2			0.99	0.97	0.97	0.95	0.98	0.97	0.97	0.91	0.98	0.98
Frg*Frt			<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Frg*Yr			0.0002	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Frt*Yr			0.0071	0.0022	0.0022	<.0001	<.0001	<.0001	<.0001	<.0001	0.0005	<.0001
Frg*Frt*Yr			<.0001	0.0309	0.0309	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Where:- DM = Dry Matter, OM = Organic Matter, CP = Crude Protein, CPY = Crude Protein Yield, NDF = Neutral Detergent Fiber, ADF = Acid Detergent Fiber, ADL = Acid Detergent Lignin, IVOMD = In Vitro Organic Matter Digestibility, ME = Metabolizable Energy, MJ = Mega Jule, SEM =Standard error of mean, Means within the same column followed by the same letters are not significantly different, CV = Coefficient of Variation and R^2 = coefficient of determination

4.3. Partial budget analysis

The overall partial budget analysis of the current study was presented in Table 11 for 1st year and Table 12 for 2nd year). The highest net benefit in the first year was obtained from Napier grass-16791(39337.5birr), followed by desho grass-*Areka*-DZF-590 (33010.4birr) at manure and Napier grass-16791 (25671.3birr) at 300kg/ha, while the lowest net benefit was recorded from unfertilized *Brachiaria decumbens*-10871(21318.7birr) (Table 11.). Similar with year 1, the highest net benefit in the second year was obtained at manure fertilized Napier grass-16791 (73358.76 birr), followed by the same variety (65464.83 and 62920.89 birr) at 100kg N/ha and 300kg N/ha fertilizer, respectively while the lowest net benefit was recorded from *Brachiaria decumbens*-10871 (32241.51birr) with 100kg N/ha fertilizer application (Table 12). According to dominance analysis, all grass varieties except unfertilized Napier grass-16791 in both years were dominated by other treatments with fertilizer application, hence, eliminated from further economic analysis. Based on the marginal analysis, Napier grass-16791 (280.16 and 416.243%), desho grass-*Areka*-DZF-590 (174.71 and 154.49%) at manure fertilizer, and desho-*Areka*-DZF-590 (123.89 and 117.62%) and Napier grass-16791 (173.14 and 379.57 %) at 100kg N/ha fertilizer were superior marginal rate of return (MRR) to other treatments in year 1 and 2, respectively (Table 11 and 12).

The net benefits among forage varieties, fertilizer application and production years were quite different. This is due to the production potential of DMY differences among experimental grass varieties at all fertilizer type and levels and production years. As result of the current study, the marginal rate of return was obtained from Napier grass-16791 (280.16 and 416.243%), desho grass-*Areka*-DZF-590 (174.71 and 154.49%) at manure fertilizer, and desho grass-*Areka*-DZF-590 (123.89 and 117.62%) and Napier grass-16791 (173.14 and 379.57 %) at 100kg N/ha fertilizer. This implies that for one Birr investment on grass production, the producer can get Birr (2.8016 and 4.16243), (1.7471 and 1.5449), (1.2389 and 1.1762) and (1.7314 and 3.7957) in year 1 and 2, respectively. The marginal rate of return above 100% is high and acceptable to farmers (CIMMYT, 1988). Based on this, the current results of MRR on these varieties were recorded above the minimum acceptable rate of return. Generally, manure fertilizer application at three forage varieties in both production years had more responses to high net benefits, and MRR of Napier-16791 and desho grass-*Areka*-DZF-590 in the current study without considering other benefits and costs that are fixed throughout all treatment groups.

Table 11: Partial budget analysis of each grass varieties in different fertilizer level and type grown in year 1

Descriptions	Grass varieties with fertilizer type and levels (Treatments)											
	BD (WO)	Desho (WO)	NG (WO)	BD (100 kg urea)	Desho (100 kg urea)	NG (100kg urea)	BD (300kg urea)	Desho (300kg urea)	NG (300kg urea)	BD (M)	Desho (M)	NG (M)
DMY (Kg)	5880	6210	6210	6760	7320	7570	7260	7470	8570	7320	10760	12500
ADMY (Kg) (A)	5290	5590	5590	6080	6590	6810	6530	6720	7710	6590	9680	11250
Cost of urea	0	0	0	1800	1800	1800	5400	5400	5400	0	0	0
Cost of FYM	0	0	0	0	0	0	0	0	0	6000	6000	6000
(TVC) (B)	0	0	0	1800	1800	1800	5400	5400	5400	6000	6000	6000
Price (birr/ kg) (C)	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03
Gross benefit (A*C)(D)	21318.7	22527.7	22527.7	24502.4	26557.7	27444.3	26315.9	27081.6	31071.3	26557.7	39010.4	45337.5
Net benefit (D-B)(birr)	21318.7	22527.7	22527.7	22702.4	24757.7	25644.3	20915.9	21681.6	25671.3	20557.7	33010.4	39337.5
Change in TVC (ΔTV)	0	0	0	1800	1800	1800	5400	5400	5400	6000	6000	6000
Change in net benefit (ΔNR)	16028.7	16937.7	0	174.7	2230	3116.6	-1611.8	-846.1	3143.6	-1970	10482.7	16809.8
MRR (%) = (ΔNR/ΔTVC)*100	ND	ND	ND	9.71	123.89	173.14	D	D	58.21	D	174.71	280.16

Where: BD=Brachiaria decumbens, NG =Napier grass, WO= without fertilizer, ND= Not determine, D=dominated, DMY= Dry matter yield, ADMY= Adjusted dry matter yield, M=manure, MRR= Marginal rate of return, TVC=Total variable cost

Table 12: Partial budget analysis of each grass varieties in different fertilizer level and type grown in year 2

Descriptions	Grass varieties with fertilizer type and levels (Treatment)											
	BD (WO)	Desho (WO)	NG (WO)	BD (100 kg urea)	Desho (100 kg urea)	NG (100kg urea)	BD (300kg urea)	Desho (300kg urea)	NG (300kg urea)	BD (M)	Desho (M)	NG (M)
DMY (Kg)	9230	11650	13340	10130	16040	19290	10770	17520	21070	11430	17550	21880
ADMY (Kg) (A)	8307	10485	12006	9117	14436	17361	9693	15768	18963	10287	15795	19692
Cost of urea ETB Kg-1	0	0	0	4500	4500	4500	13500	13500	13500	0	0	0
Cost of manure in ETB Quintal-1	0	0	0	0	0	0	0	0	0	6000	6000	6000
(TVC) (B)	0	0	0	4500	4500	4500	13500	13500	13500	6000	6000	6000
Price (birr/kg) (C)	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03
Gross benefit (A*C)(D)	33477.21	42254.55	48384.18	36741.51	58177.08	69964.83	39062.79	63545.04	76420.89	41456.61	63653.85	79358.76
Net benefit (D-B)(birr)	33477.21	42254.55	48384.18	32241.51	53677.08	65464.83	25562.79	50045.04	62920.89	35456.61	57653.85	73358.76
Change in TVC (ΔTV)	0	0	0	4500	4500	4500	13500	13500	13500	6000	6000	6000
Change in net benefit (ΔNR)	25170.21	31769.55	0	-16142.7	5292.9	17080.65	-22821.4	1660.86	14536.71	-12927.6	9269.67	24974.58
MRR (%) = (ΔNR/ΔTVC)*100	ND	ND	ND	D	117.62	379.57	D	12.30	107.67	D	154.49	416.24

Where: BD=Brachiaria decumbens, NG =Napier grass, WO= without fertilizer, ND= Not determine, D=dominated, DMY= Dry matter yield, ADMY= Adjusted dry matter yield, M=Manure, MRR= Marginal rate of return, TVC=Total variable cost

4.4. Correlation among morphological, dry matter yield and quality parameters of grasses

Simple linear bivariate correlation analysis among morphological characteristics, DMY and nutritional quality of Brachiaria decumbens-10871, Napier-16791 and desho grass-*Areka*-DZF-590 were presented in (Table 13).The PH was positively correlated to NTPP, LWPP, LLPP, NLPP, DMY, DM, CPY, NDF, ADF and ADL, but negatively correlated with Ash, LSR, ME, CP and IVOMD. The PH was negatively correlated with LSR, ash, and NDF, which was in line with Tirust Tesfaye *et al.* (2019), but disagreement negatively correlated with CP in the current study with the finding of the same author. The negative correlation of PH with IVOMD was in agreement with the result of Beyadglign Hunegnaw *et al.*(2019) in the case of Brachiaria grass. The positive correlations of most morphological parameters with each other and negative correlation with LSR in the current study are in line with desho grass as reported by (Bimrew Asmare *et al.*, 2017). The direct relationship between PH with NTPP, LWPP, LLPP, NLPP, and DMY was to be expected, as plants were taller had more NTPP and NLPP.

The NTPP was positively correlated with all morphological and quality parameters except LWPP, NDF, and ADF and ADL. This would imply that increase in the number of tillers might have contributed to the decreases in LWPP, NDF, ADF, and ADL and increases in the remaining parameters. The NTPP was positively correlated with NLPP, DMY, ash, CP and CPY in the current study was in line with desho grass as reported by Tiruset Tesfaye *et al.* (2019); however contradicts in the case of LSR and DMof the same author. The NTPP was negative correlated with DM and ADF was similar to the previous study of Beyadglign Hunegnaw *et al.* (2019) in the case of Brachiaria grass. The reason might be due to the complimentary effects of species that used soil nutrients efficiently. On the other hand, the NLPP was positively correlated with all morphological and quality parameters except LWPP, DM, ADF, ADL and Ash in the current study that disagrees with desho grass as reported by Tiruset Tesfaye *et al.* (2019) except DM that is negatively correlated with NLPP, but not consider LWPP and ME. The LLPP was positively correlated with all morphological and quality parameters except DM, ash, NDF, ADF and ADL was in line with desho grass as reported by Genet Tilahun *et al.* (2017). The LWPP was positively correlated with all morphological and quality parameters except DM, ash, NDF, ADF and ADL. The LSR was negatively correlated with all morphological and nutritional quality except Ash, CP, CPY, NDF, IVOMD and ME.This in line with desho grass as reported by Bimrew Asmare *et al.* (2017) on IVOMD and ME, and disagrees with ash and agree with NDF with the result made by Tiruset Tesfaye *et al.*(2019), but not consider ME. The DMY was positively correlated with all morphological and nutritional quality except Ash, and IVOMD. The DMY was positively correlated with DM, CPY and NDF in the current study was in line with desho grass as reported by Genet Tilahun *et al.* (2017), but disagrees with desho grass as reported by Tiruset Tesfaye *et al.* (2019) on DM and NDF content. The DM content was positively correlated with all morphological and quality parameters except CP, Ash and IVOMD, and these negative correlations of DM with CPY and ADL in the current study was in line with desho grass made by Tiruset Tesfaye *et al.* (2019), but opposed with desho grass as reported by Genet Tilahun *et al.* (2017). The Ash content was positively correlated with all morphological and chemical composition except CP, ADL, IVOMD and ME and this positive correlation of ash with CP in the current study wasfaced with desho grass as reported by Tiruset Tesfaye *et al.*(2019), but disagree the positive correlation of ash with NDF. The CP content was negatively correlated with NDF, ADF and ADL was similar with the result reported by Shiferaw Yalew (2019) in North Mecha District, Ethiopia in the case of natural pasture. The CP content was positively correlated with CPY, IVOMD and ME, and the positive correlation of CP with CPY, IVOMD and ME in the current study was in line with Brachiaria grass reported by Beyadglign Hunegnaw *et al.*(2019), but dissimilar with desho grass made by Genet Tilahun *et al.*(2017) the positive relation of CP content with CPY. This would imply that CP content might have a reverse contribution to all fibers.The CPYwas negatively correlated with NDF, ADF and ADL, and it wasdisagree with Brachiaria grass reported by Beyadglign Hunegnaw *et al.* (2019). Furthermore, the negative correlation of CPY with NDF in the current finding is also dissimilar with desho grass made by Genet Tilahun *et al.* (2017).

The fiber contents wasnegatively correlated to IVOMD and ME, but positively correlated with each other's. The positive relation of NDF with ADF and ADL in the current study was agreed with desho grass as reported by Tiruset Tesfaye *et al.* (2019).The negative relation of NDF with IVOMD and ME in the current study was in line with the report of Beyadglign Hunegnaw *et al* (2019) in the case of desho grass. This was due to the fact that as the fiber content of grasses increased, the digestibility and CP was decreased and vice versa. The IVOMD and ME contents were positively correlated with each other and negatively correlated with fiber fractions (NDF, ADF and ADL), which was in line with the result of Beyadglign Hunegnaw *et al.* (2019) in case of Brachiaria grass.

Table 13: Correlation among morphological characteristics, dry matter yield, and chemical compositions of grass varieties

	PH	NT	NLPP	LLPP	LW	LSR	DMY	DM	Ash	CP	CPY	NDF	ADF	ADL	IVOMD	ME
PH	1.0	0.2	0.17^{**}	0.94^{**}	0.57	-0.13^{**}	0.58^{**}	0.43^{**}	-0.29	-0.64^{**}	0.63^{**}	-0.5^{***}	0.44^{**}	0.71^{**}	-0.53^{**}	-0.5^{**}
NTPP		1.0	0.87	0.02^{**}	-0.54	0.08^{**}	0.51	0.44^{**}	0.02^{**}	0.40^{**}	0.49	-0.39^{**}	-0.36^{**}	-0.25^{*}	0.32^{**}	0.61^{**}
NLPP			1.0	0.18	-0.78	0.12	0.77^{**}	-0.41	-0.41^{**}	0.45^{**}	0.74^{*}	0.40	-0.26^{*}	-0.39^{**}	0.39^{**}	0.6^{**}
LLPP				1.0	0.54^{**}	0.18	0.63^{**}	-0.44^{**}	-0.35	0.61^{**}	0.68^{**}	-0.52^{**}	-0.42^{**}	-0.72^{**}	0.48^{**}	0.45^{**}
LWPP					1.0	0.28^{*}	0.88^{*}	-0.37^{*}	-0.67^{**}	0.49^{*}	0.85^{*}	-0.32^{*}	-0.18	-0.58^{**}	0.47^{**}	0.46^{**}
LSR						1.0	-0.09	-0.31^{*}	0.51^{*}	0.38^{*}	0.33	0.001^{*}	-0.43^{*}	-0.29^{*}	0.06	0.35^{*}
DMY							1.0	0.51^{***}	-0.62^{**}	0.61^{*}	0.98^{**}	0.49^{*}	0.34^{*}	0.69	-0.48^{*}	0.58^{*}
DM								1.0	-0.10^{*}	-0.67^{*}	0.57	0.69	0.77	0.66	-0.73	0.76
Ash									1.0	-0.01^{*}	0.55	0.11^{**}	0.36	-0.24^{*}	-0.02^{**}	-0.13
CP										1.0	0.71^{*}	-0.85^{*}	-0.75^{*}	-0.74	0.63	0.77
CPY											1.0	-0.59^{*}	-0.44	-0.74	0.55^{*}	0.65
NDF												1.0	0.85^{**}	0.57^{**}	-0.66^{**}	-0.79^{**}
ADF													1.0	0.57^{*}	-0.63^{**}	-0.78^{**}
ADL														1.0	-0.56^{**}	-0.64^{**}
IVOMD															1.0	0.72
ME																1.0

Where: PH= Plant height, NTPP= number of tiller per plant, NLPP =number of leaves per plant, LLPP=leaf length per plant, LWPP = Leave Width per plant, LSR = Leaf to steam ratio, DMY = Dry matter yield, DM=dry matter content, CP=crude protein, CPY crude protein yield, NDF=neutral detergent fiber, ADF=acid detergent Fiber, ADL=acid detergent lignin, IVOMD = In Vitro Organic Matter Digestibility and ME = Metabolizable Energy

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The interaction effects of fertilizer application, grass varieties and production years had significant effect on morphological characteristics ($p<0.001$), dry matter yield ($p<0.001$), and nutritional quality observed in this study. The fertilized grass in both production years on the morphological characteristics, dry matter yield, DM, CP, IVOMD and ME was better as compared to unfertilized grass in both production years. The second year (2022) at all fertilizer type and levels of the three grass varieties on morphological characteristics, dry matter yield and nutritional quality were better than the first year (2021) in respective fertilizer levels and variety. Napier grass-16791 with manure fertilizer had better in most morphological characteristics, dry matter yield and nutritional quality like high in CP, IVOMD and lower in NDF, ADF and ADL contents followed by desho-*Areka*-DZF-590 and *Brachiaria decumbens*-10871. The current result of fiber fraction contents (NDF, ADF and ADL) was found under a good range of quality, this could be indicative of its better digestibility. The CP content of the current study can fulfill the minimum requirements of a ruminant animal, which ranges from 10 to 14.09%. Moreover, the current result of IVOMD was higher than the critical threshold level of 50% and metabolizable energy was found in and above minimum maintenance requirement of ruminant animals (7.5MJ/kg) required feeds to be considered as having acceptable digestibility. Additionally, the highest net benefit and MRR was found from Napier grass-16791 with manure fertilizer application in both production years. The highest net benefit in the year 1 was obtained from Napier grass ILRI-16791(39337.5birr), followed by desho grass-*Areka*-DZF-590(33010.4 birr) at manure fertilizer application and Napier grass ILRI-16791(25671.3birr) at 300kg/ha, while the lowest net benefit was recorded from *Brachiaria decumbens*-10871(21318.7birr) without fertilizer application. Where as, the highest net benefit in the year 2 was obtained from Napier grass ILRI-16791 (73358.76 birr) at manure fertilizer followed by the same varieties (65464.83 birr and 62920.89 birr) at 100kg N/ha and 300kg N/ha fertilizer, respectively while the lowest net benefit was recorded from *Brachiaria decumbens*-10871(32241.51birr) with 100kg N/ha fertilizer application. Based on the all aspects of evaluations, Napier grass ILRI-16791 at manure fertilizer application was recommended due to adaptive and better production performance to fulfill the forage quantity and quality shortage to enhance the livestock production and productivity.

5.2. Recommendations

- Based on the current results the following suggestions were forwarded for future research and uses:
- Livestock keepers and forage producers are advised to apply Napier grass *(Pennisetum purpureum Schumach.)Var.16791* with manure fertilizer based on their morphological adaptations and nutritional quality in the study area and similar agro-ecologies of Ethiopia to get better yield and to be profitable.
- Further research is needed on different organic and inorganic fertilizer levels in different agro-ecological zones across more than two years under rainfed and irrigation condition.
- Further studies on animal performance evaluation and economic benefit future research are recommended.

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CHAPTER SEVEN: APPENDICES

Appendix table 7.1. Summary on Analysis of Variance Tables

Appendix table 7.1.1: ANOVAfor morphology and DMY of grass varieties

Parameters	DF	Sum Squares	MS	FValue	Pr > F	SL	R^2	CV	Root MSE
PH	71	152965.1044	6650.6567	915.51	<.0001	***	0.997	5.79	2.695263
NTPP	71	90620.54747	3940.02380	282.88	<.0001	***	0.992	7.23	3.732036
NLPP	71	2892985.208	125781.966	14673.7	<.0001	***	0.999	0.936	2.927787
LLPP	71	43211.32307	1878.75318	189.76	<.0001	***	0.989	8.445	3.146572
LWPP	71	164.4033184	7.1479704	2159.36	<.0001	***	0.999	1.923	0.057535
LSR	71	9.29027817	0.40392514	238.24	<.0001	***	0.991	3.643	0.041176
DMY	71	1710.425528	74.366327	96.60	<.0001	***	0.978	7.645	0.877419

Where: PH= Plant height, NTPP= number of tiller per plant, NLPP=number of leaves per plant, LLPP= leaf length per plant, LWPP= leaf width per plant, LSR= leaf to stem ratio, DMY= dry matter yield, DF=Degree of freedom, SL=significant Level, MS=mean Square

Appendix table 7.1.2: ANOVA for chemical compositions and digestibility of grass varieties

Parameters	DF	Sum Squares	Mean Square	F Value	Pr > F	SL	R^2	CV	Root MSE
DM%	71	155.648	6.767	148.30	<.0001	***	0.986	0.233	0.213
Ash%	71	248.516	10.805	69.17	<.0001	***	0.970	4.162	0.395
OM%	71	248.51	10.805	69.17	<.0001	***	0.970	0.436	0.395
CP%	71	172.285	7.4906	612.25	<.0001	***	0.996	0.930	0.110
CPY(t/ha)	71	39.334	1.7101	132.02	<.0001	***	0.984	8.089	0.113
NDF%	71	1470.94	63.954	2599.77	<.0001	***	0.999	0.265	0.156
ADF%	71	958.899	41.691	1208.10	<.0001	***	0.998	0.470	0.185
ADL%	71	70.377	3.0598	209.86	<.0001	***	0.990	2.290	0.120
IVOMD%	71	1772.171	77.050	143.18	<.0001	***	0.985	1.300	0.733
ME(MJ/kg)	71	276.38	12.016	16964.6	<.0001	***	0.999	0.264	0.026

Where: DM= Dry matter content, OM= Organic matter, NDF=Neutral detergent fiber, ADF=Acid detergent fiber, ADL=Acid detergent lignin, CP= Crude protein, CPY= Crude protein yield, IVOMD= In vitro organic matter digestibility, ME = Metabolizable energy, DF=Degree of freedom, SL=significant Level

Appendix table 7.1.3: ANOVA on main and interaction effects on morphology and DMY of grass

Variables	Parameters						
	PH	NTPP	NLPP	LLPP	LWPP	LSR	DMY
Forages varieties	***	***	***	***	***	***	***
B.Decumbens	68.95[b]	51.94[b]	276.45[b]	19.18[b]	2.61[b]	0.99[c]	8.59[c]
Desho grass	60.88[c]	68.33[a]	386.22[a]	27.59[b]	2.61[b]	1.30[a]	11.81[b]
Napier grass	142.77[a]	34.67[c]	276.65[b]	64.95[a]	3.77[a]	1.10[b]	14.01[a]
Overall mean	90.87	51.65	313.11	37.24	2.99	1.13	11.47
SEM	7.26	13.92	8.57	9.9	0.003	0.002	0.77
CV%	5.79	7.23	0.94	8.45	1.92	3.64	7.65
Fertilizers rate	***	***	***	***	***	***	***
100kg N	92.04[c]	51.17[b]	288.24[c]	37.46[b]	3.15[b]	1.18[c]	11.29[c]
300kg N	103.62[b]	61.35[ab]	368.58[b]	40.87[ab]	3.16[b]	1.32[a]	12.11[b]
Manure	111.20[a]	66.64[a]	379.81[a]	49.24[a]	3.21[a]	1.26[b]	13.57[a]
Control	56.61[d]	27.41[c]	215.81[d]	21.41[c]	2.48[c]	0.76[d]	8.92[d]
Years	***	***	***	NS	***	***	***
2021	81.09[b]	28.21[b]	146.68[b]	32.82	1.65[b]	0.96[b]	7.90[b]
2022	100.64[a]	75.08[a]	479.54[a]	41.67	4.35[a]	1.28[a]	15.04[a]
Interactions	***	***	***		***	***	
Frt*Frg	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Frg*yr	<.0001	<.0001	<.0001	0.0001	<.0001	<.0001	<.0001
Frt*yr	<.0001	<.0001	<.0001	0.0104	<.0001	<.0001	<.0001
Frt*Frg*yr	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0006

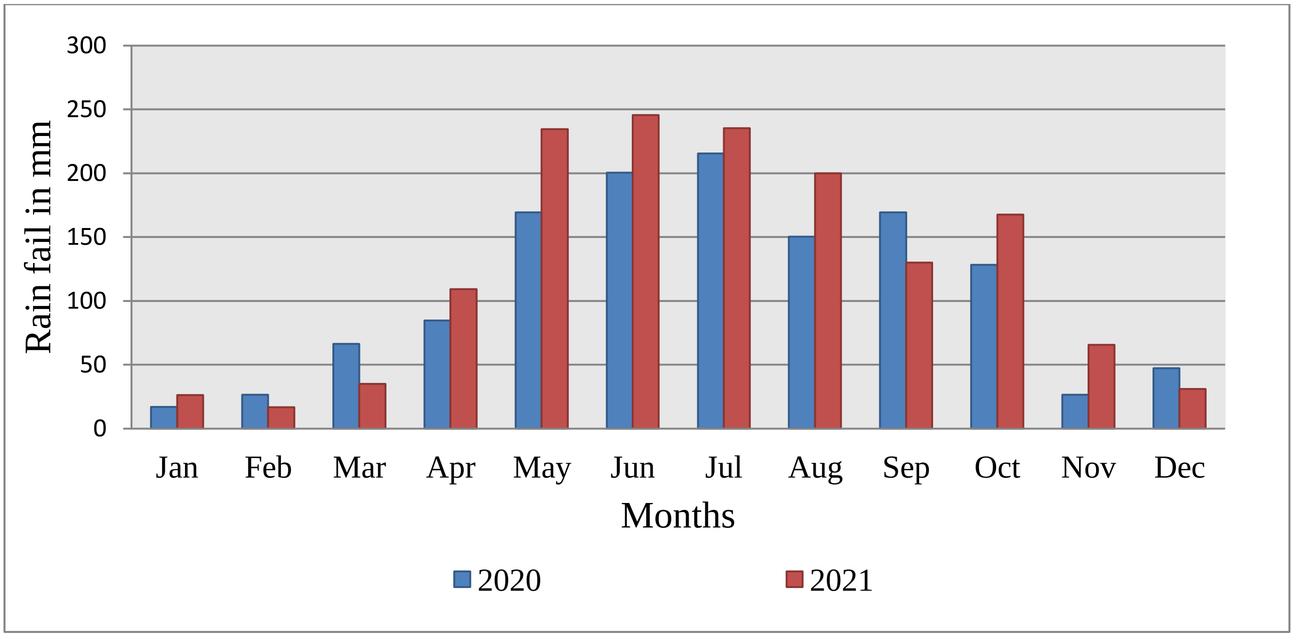
Where: PH= Plant height, NTPP= number of tiller per plant, NLPP=number of leaves per plant, LLPP= leaf length per plant, LWPP= leaf width per plant, LSR= leaf to stem ratio, DMY= dry matter yield, Frg*Frt =interaction of grass varieties and fertilizer, yr*Frg = interaction of years and grass varieties, yr*Frt = interaction of years and fertilizer, yr*Frg*Frt = interaction of years, grass varieties and fertilizers application

Appendix table 7.1.4: ANOVA on main and interaction effects on chemical composition and digestibility of grasses

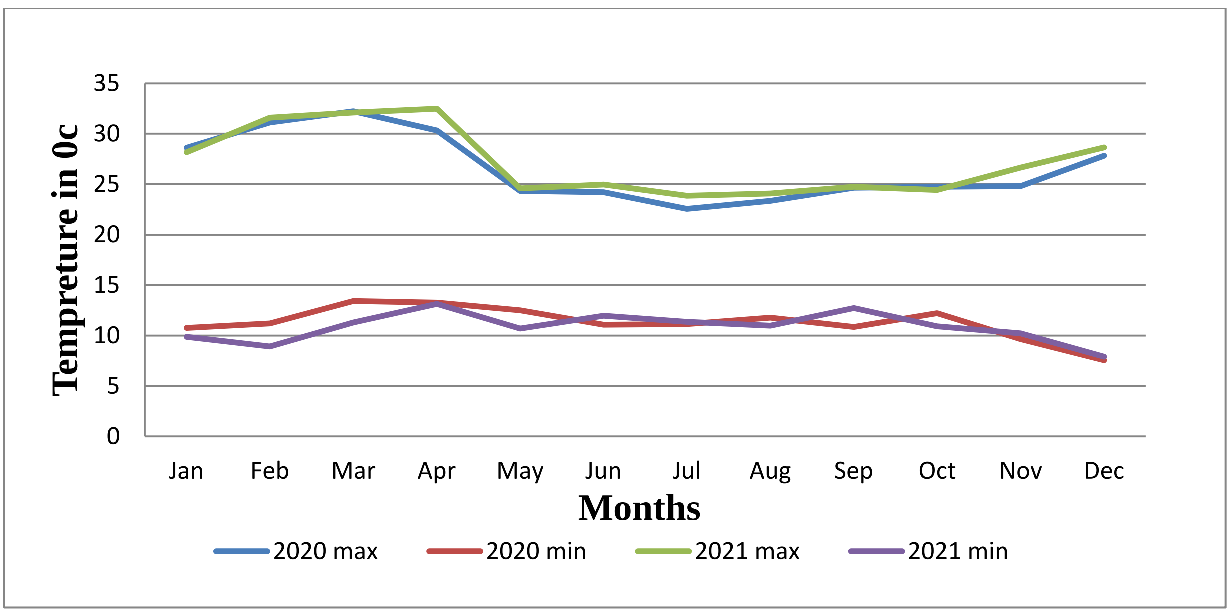
Variables	Parameters (Dry matter basis)									
	DM	ASH	OM	CP	CPY	NDF	ADF	ADL	IVOMD	$ME_{(MJ/kg)}$
Grass varieties	***	***	***	***	***	***	***	***	***	***
B.Decumbens	91.36[c]	8.69[c]	91.31[a]	11.35[c]	0.99[c]	60.26[a]	40.17[a]	5.83[a]	58.05[a]	9.96[c]
Desho grass	91.43[b]	9.73[b]	90.27[b]	11.98[b]	1.45[b]	58.47[b]	39.62[b]	5.38[b]	53.78[c]	10.02[b]
Napier grass	91.72[a]	10.06[a]	89.94[c]	12.32[a]	1.78[a]	58.34[c]	38.77[c]	4.6[c]	57.34[b]	10.16[a]
Overall mean	91.51	9.49	90.51	11.88	1.41	59.03	39.52	5.27	56.39	10.05
CV%	0.23	4.16	0.44	0.93	8.09	0.27	0.47	2.29	1.3	0.26
Fertilizer rate	***	***	***	***	***	***	***	***	***	***
Control	90.04[d]	11.52[a]	88.48[d]	9.65[d]	0.86	65.27[a]	44.86[a]	6.32[a]	51.75[d]	7.56[d]
Manure	93.79[a]	8.16[d]	91.84[a]	13.09[a]	1.81	54.55[d]	35.45[d]	4.41[d]	61.76[a]	11.94[a]
100kg N	91.01[c]	9.45[c]	90.55[b]	12.11[c]	1.41	58.32[b]	39.26[b]	5.28[b]	55.21[c]	9.11[c]
300kg N	91.18[b]	8.85[b]	91.15[c]	12.6[b]	1.55	57.96[c]	38.51[c]	5.08[c]	56.84[b]	11.58[b]
Years	***	***	***	***	***	***	**	***	***	***
2021	91.17[b]	8.41[b]	91.59[a]	11.46[b]	0.92	59.68[a]	39.45[b]	5.57[a]	54.68[b]	9.39[b]
2022	91.84[a]	10.58_a	89.42[b]	12.31[a]	1.9	58.37[b]	39.59[a]	4.98[b]	58.11[a]	10.7[a]
Interactions				***	***	***	***	***	***	***
Frg*Frt	p<.0001	p<.0001	p<.0001	p<.0001	p<.0001	p<.0001	p<.0001	p<.0001	p<.0001	p<.0001
yr*Frg	0.0002	p<.0001	p<.0001	p<.0001	p<.0001	p<.0001	p<.0001	p<.0001	p<.0001	p<.0001
yr*Frt	0.0071	0.0022	0.0022	p<.0001	p<.0001	p<.0001	p<.0001	p<.0001	0.0005	p<.0001
yr*Frg*Frt	p<.0001	0.0309	0.0309	p<.0001	p<.0001	p<.0001	p<.0001	p<.0001	p<.0001	p<.0001

Where: DM= Dry matter content,OM= organic matter, NDF=Neutral detergent fiber, ADF=Acid detergent fiber, ADL=Acid detergent lignin, CP= Crude protein, CPY= Crude protein yield, IVOMD= In vitro organic matter digestibility, ME = Metabolizable energy, Frg*Frt =interaction of forage varieties and fertilizer, yr*Frg= interaction of years and forage varieties, Yrs*Frt = interaction of years and fertilizer, Yrs*Frg*Frt = interaction of years, forage varieties and fertilizers application

Appendix figure7.2: List of figures



Appendix figure 7.2. 1: Monthly rainfall data of experimental districts in each year



Appendix figure 7.2. 2: Maximum and minimum temperature of experimental district in each year

Appendix figure 7.2. 3: Land preparation, Plot layout, and plantation of experimental grasses

Appendix figure 7.2.4: Forage at establishiment stage

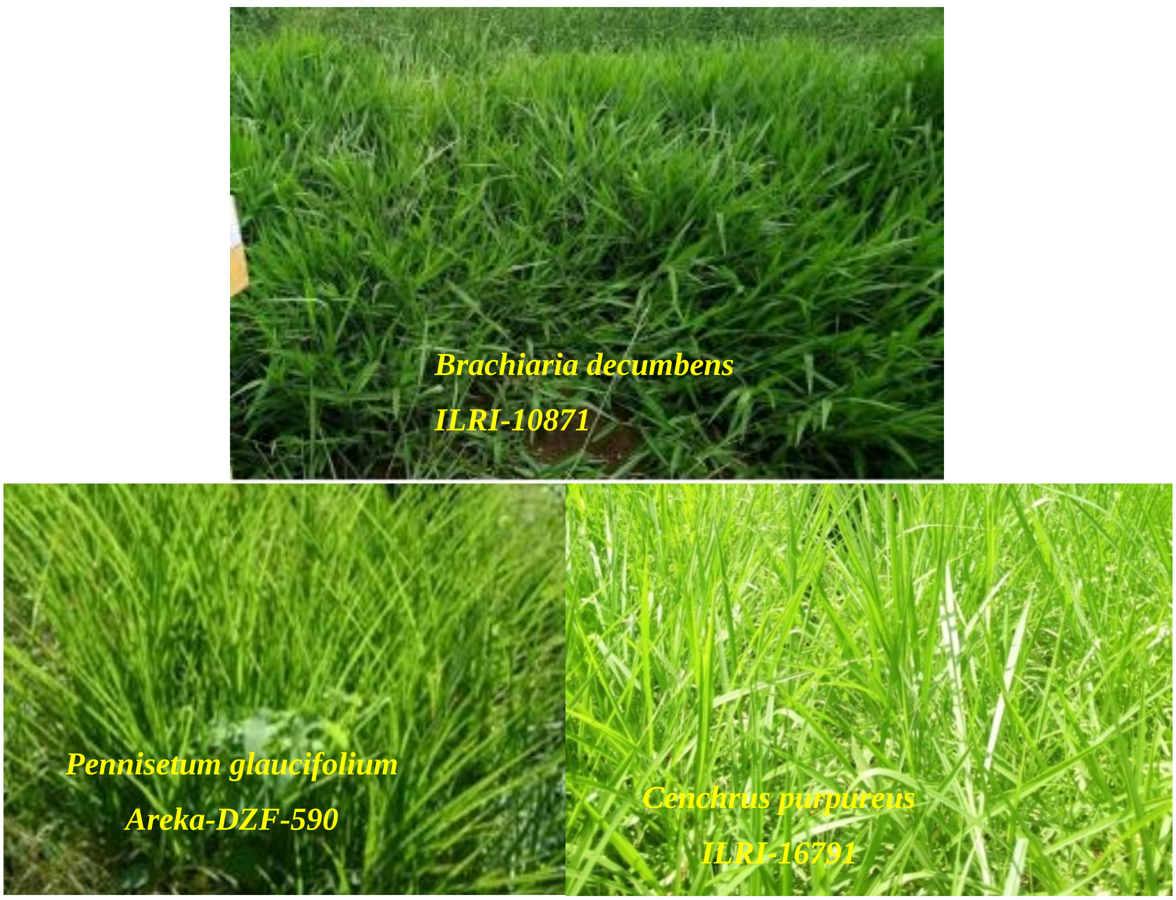
Appendix figure 7.2.5 Separation and waighting of stem and leaves

Appendix figure 7.2.7: Leaf length and width measuring

Appendix figure 7.2.6: Plant height measuring

Appendix figure 7.2.8: Fresh biomass measuring

Appendix figure 7.2.9: Labeling of samples



Appendix figure 7.2.10: Experimental grass varieties

Appendix figure 7.2. 11: Cattle manure used in this study

15m

Block-1	Plot-1 T1	Plot-2 T5	Plot -3 T4	Plot- 4 T9
	Plot-5 T6	Plot-6 T2	Plot-7 T7	Plot-8 T12
	1m			
	Plot-9 T11	1m Plot-10 T10	Plot-11 T3	Plot-12 T8
	1.5m			
Block-2	Plot-13 T4	Plot-14 T7	Plot-15 T12	Plot-16 T8
	Plot-17 T6	Plot-18 T3	Plot-19 T10	Plot-20 T2
	Plot-21 T1	Plot-22 T5	Plot-23 T9	Plot-24 T11
Block-3	Plot-25 T2	Plot-26 T10	Plot-27 T4	Plot-28 T8
	Plot-29 T5	Plot-30 T12	Plot-31 T3	Plot-32 T9
	Plot-33 T6	Plot-34 T11	Plot-35 T1	Plot-36 T7

36m

$36m \times 15m = 540m^2$

Appendix figure 7.2.12: Experimental layout of Plot and Block arrangement